Unfamiliar Territory: Teaching Children Science in the UK's First National Lockdown

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Candidate Declaration

I hereby declare that:

1. I have not been enrolled for another award of the University, or other academic or professional organisation, whilst undertaking my research degree.

2. None of the material contained in the thesis has been used in any other submission for an academic award.

3. I certify that this thesis is my own work. The use of all published or other sources of material consulted have been properly and fully acknowledged. I confirm that I have sought and obtained copyright permission for any third party materials included in this thesis.
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4. The work undertaken towards the thesis has been conducted in accordance with the SHU Principles of Integrity in Research and the SHU Research Ethics Policy, and ethics approval has been granted for all research studies in the thesis, as shown in the table below.

Ethics review reference number	Title of research study	Approval date	Date of any post-approval amendments (if applicable)
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Abstract

When UK schools were locked down in March 2020 due to the COVID-19 pandemic, most teachers had no experience of remote education, and parents were compelled to facilitate education in the home. Through the twin lenses of teachers' and parents' experiences, this thesis presents a detailed account of how science education was provided remotely for schoolchildren in the UK during the first ever national lockdown, from March to July 2020. Focusing particularly on the role of digital technology in this provision, it addresses an acknowledged shortage of UK-based subject-specific research into school teaching during this period.

Representing both primary and secondary school contexts, 139 teachers and 76 parents participated in a mixed methods study comprising surveys and semi-structured interviews. Key findings generated from quantitative and thematic analyses show that apart from effects on practical work, most aspects of remote science education reported by teachers and parents were generic rather than subject-specific. Experiences for both groups varied considerably, however, revealing a complex interplay of factors. Educational provision relied heavily on the internet, but implementation was often problematic, highlighting numerous issues such as gaps in teachers' knowledge and pupils' access to technology. Despite challenges, innovation was possible and educational benefits were reported.

This study has implications across several domains: emergency planning in schools, evolution of the mainstream science curriculum, conceptualisation of high-quality remote science education for children, post-pandemic trends in science practical work in schools, and parental involvement in children's

science education. By revealing pre-existing issues that proved challenging in a remote education context, the research raises important policy questions regarding ICT teaching in schools and equitable provision of digital devices to teachers. Given that the pandemic represented a major disruptive event that profoundly influenced educational practice and catalysed innovation, future research should examine whether and how science teaching policy and practice have been shaped in the longer term. The study makes a significant contribution to knowledge by its school-centric, subject-specific focus and rich qualitative evidence, generated using mixed methods. It thus complements a literature field predominantly characterised by quantitative data drawn from non-subject-specific and higher education contexts.

Table of Contents

List of figures

List of Tables

List of Abbreviations

‘A’ level	Advanced level
AI	Artificial Intelligence
AIDS	Acquire Immunodeficiency Syndrome
AQA	Assessment and Qualifications Alliance (exam board)
ASE	Association for Science Education (subject association)
‘AS’ level	Advanced Subsidiary level.
BBC	British Broadcasting Corporation
BESA	British Educational Suppliers Association
CIEC	Centre for Industry Education Collaboration
COSMO	COVID Social Mobility and Opportunities (study)
COVID	Coronavirus Disease
COVID-19	Coronavirus Disease 2019
CPD	Continuing Professional Development
DT	Design and Technology
EdTech	Educational Technology
ERIC	Education Resources Information Centre
ESRC	Economic and Social Research Council
GCSE	General Certificate of Secondary Education
GDPR	General Data Protection Regulation
HE	Higher Education
HNC	Higher National Certificate
HND	Higher National Diploma
ICT	Information and Communications Technology
IoP	Institute of Physics
IT	Information Technology
ITE	Initial Teacher Education
LRT	Live Remote Teaching
MOOC	Massive Open Online Courses

n.d.	No date
NFER	National Foundation for Educational Research
n.p.	No page number
NSPCC	National Society for the Prevention of Cruelty to Children
NSTA	National Science Teachers Association
NVQ	National Vocational Qualifications
‘O’ level	Ordinary level
OCR	Oxford, Cambridge and RSA (exam board)
PC	Personal Computer
PD	Professional Development
PhET	Physics Education Technology
PISA	Programme for International Student Assessment
RAAC	Reinforced Autoclaved Aerated Concrete
RSB	Royal Society of Biology
RSC	Royal Society of Chemistry
SARS	Severe Acute Respiratory Syndrome
SATs	Standard Assessment Tests
SENCO	Special Educational Needs Co-ordinator
SEND	Special Educational Needs and Disabilities
STEM	Science, Technology, Engineering and Maths
TES	Times Educational Supplement
TIMSS	Trends in International Mathematics and Science Study
TPACK	Technological Pedagogical Content Knowledge
TV	Television
UK	United Kingdom
US	United States
USA	United States of America
VLE	Virtual learning environment
WHO	World Health Organisation

Chapter 1: Introduction

This thesis explores how teachers and parents experienced science education for school-aged children during an unprecedented period in British educational history: the UK's first national lockdown from March to July 2020. The COVID-19 pandemic forced a rapid transformation of educational delivery, with previously unfamiliar practices of remote teaching and learning quickly becoming mainstream. During this four-month period, education became fundamentally dependent on internet connectivity and digital tools.

Throughout this thesis, the term 'digital technology' refers to any technology that creates, stores, processes, transmits, or displays digital information. This broad definition includes physical hardware (e.g. computers, tablets, smartphones), software applications, and the full ecosystem of internet-based technologies that enabled remote learning during lockdown. This terminology is distinct from 'Information and Communications Technology' (ICT), which is reserved specifically for the former school subject of that name.

1.1 Research origins, aims and objectives

In my former professional roles of science teacher, professional development facilitator and university lecturer I have explored and developed an interest in the use of digital technology for science teaching and learning. Before the outbreak of COVID-19 at the start of 2020, this doctoral research had been focused on teachers' uses of digital technologies in science lessons, reflecting my professional interests. National lockdown and school closures prompted a re-evaluation of this focus. With schools compelled to provide remote education, an opportunity arose to investigate the teaching of science in these completely new conditions. With digital technology central to the process, there was a strong resonance with my original research interests.

The situation was unique: schools and teachers had little or no prior experience to fall back upon, while parents, most of whom were also confined to their homes under lockdown, would potentially have a new role in their children's education. Taking place against the disruption of a global emergency affecting many aspects of daily life, these factors comprised a novel and interesting research opportunity.

The main research objective was to investigate experiences of providing school science education during conditions of lockdown, focusing on how digital technology was facilitating this provision. This objective embraced experiences of both teachers and parents and led to the following research questions:

1. How have teachers responded to requirements for teaching science remotely in lockdown conditions, and with digital technology as the predominant means of delivery?

2. How is remote science teaching being experienced, mediated or supplemented by parents/guardians?

The UK experienced three lockdowns during the pandemic, and evolution of educational practices occurred during and between these distinct phases. Data for this study were collected in summer 2020, towards the end, and shortly after, the first lockdown. Of the three, this was the longest in terms of the duration of the strictest restrictions (Yang et al., 2022). In conjunction with the newness of the experience, it was also, arguably, most disruptive to education (Cullinane et al., 2022).

1.2 The COVID-19 pandemic in context

Throughout human history, pandemics - global health crises that transcend borders and transform societies - have repeatedly reshaped civilization (Grennan, 2019; Huremović, 2019). The medieval bubonic plague decimated at least one-third of Eurasia's population, claiming over 100 million lives in the 14th century (Eastman, 2009; Huremović, 2019). The Spanish flu pandemic following World War I killed more than 40 million people (Barro et al., 2020), while the ongoing AIDS pandemic has resulted in over 32 million deaths since its emergence (Beyrer, 2021).

By December 2022, COVID-19 had claimed over 6.6 million lives worldwide (World Health Organisation, 2022). As deaths and hospitalizations declined, the World Health Organization officially ended the global health emergency status in May 2023 (World Health Organization, 2023). While widespread immunity suggests COVID-19's mortality rate will likely remain lower than that of AIDS, focusing solely on death tolls fails to capture the pandemic's true societal impact.

COVID-19 represents what researchers call a typical "wicked problem": an unforeseen crisis that challenged conventional thinking and "*pushed our societal systems over a tipping point*" (Sturmberg & Martin, 2020 p1361). The level of disruption experienced in the UK hadn't been seen since World War II (Buchanan et al., 2023).

The educational sector bore particular witness to this chaos. Scholars have struggled to find adequate metaphors for the scale of disruption: Azorin (2020) compared it to an educational supernova, while Hargreaves and Fullan described the experience as "undeniable chaos" (2020, p334). The firsthand accounts detailed in chapters 4-6 of this thesis provide compelling evidence for such dramatic characterizations.

The period between COVID-19's official recognition, in January 2020, and widespread disruption, was relatively short, as illustrated in Figure 1. By 12th March 2020, 46 countries on five continents had announced school and university closures to limit the virus's spread (Ali, 2020).

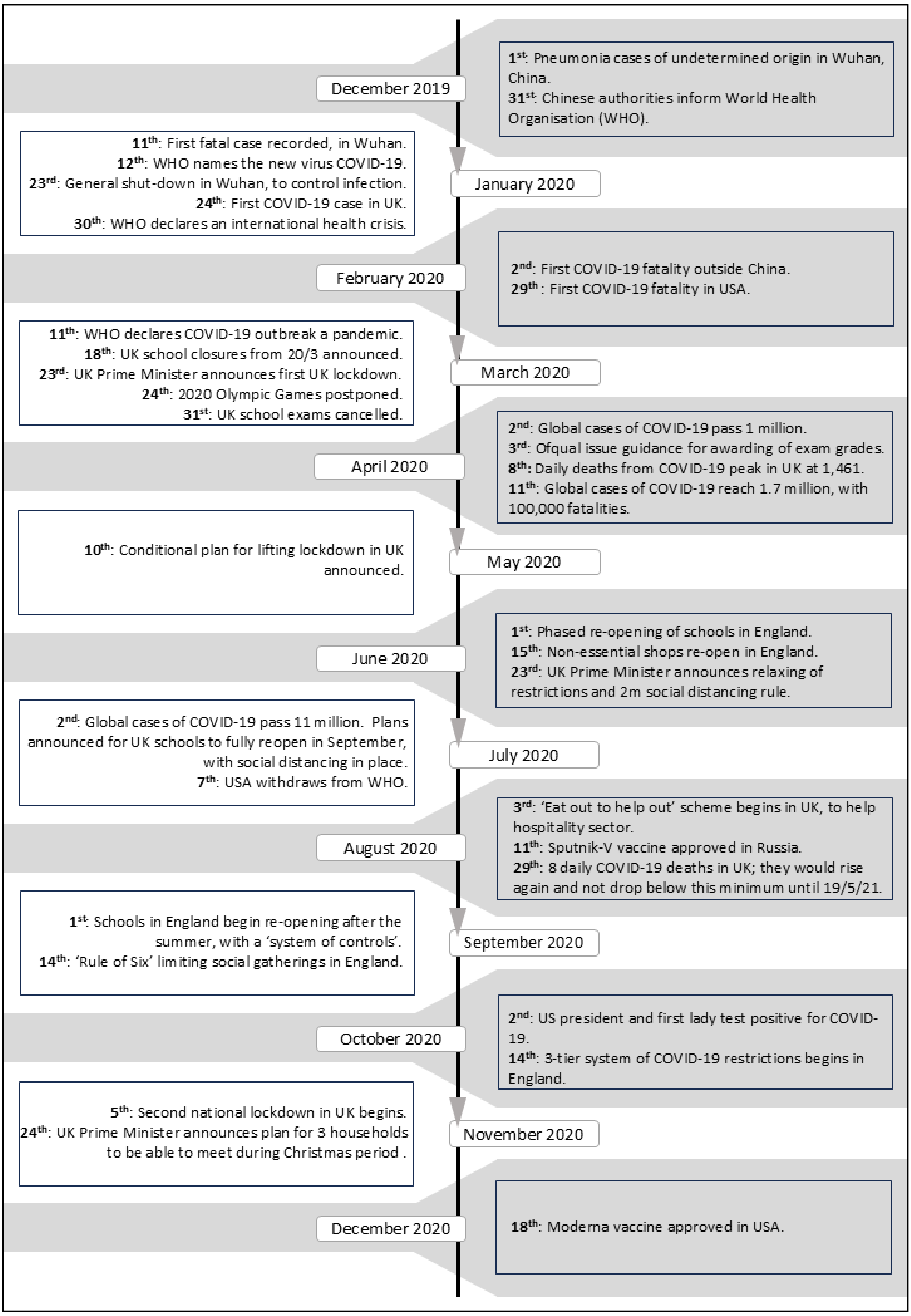


Figure 1: Timeline of selected events relating to the pandemic during the period December 2019 – December 2020. (Allam, 2020; McCarthy, 2022; Siddiqui et al., 2022; Timmins, 2021; UK Health Security Agency, 2023; Williamson, G., 2020a, 2020b).

As Williamson et al. stated, the pandemic was *“not only a serious public health emergency, but a political, economic and social emergency too”* (2020, p107). As the emergency receded, after-effects became readily observable, both trivial and serious. ‘Long-COVID’, one of over 1,000 new terms which arose from the pandemic (Thorne, 2020), is a health condition experienced by almost three million people in the UK, affecting their lives and ability to work (Reuschke & Houston, 2023). Worldwide, longer term effects of remote education are predicted to encompass far more than educational outcomes, because of various other ways that schools support children (Reuge et al., 2021). It is thus likely that COVID-19 will continue to fuel research for many years (Collins, 2023; Williamson et al., 2020).

1.3 Positioning this study within the context of science teaching with digital technology

The importance of science education, to individuals and advanced societies, is well established (Osborne & Millar, 1998; Osborne et al., 2003; Osborne & Dillon, 2008), and in recent decades further reinforced by science’s integration into the broader concept of STEM (Science, Technology, Engineering and Maths) (Sanders, 2008; Holman, 2017). Also recently, a close association between school science teaching and digital technology has developed (Walan, 2020; Webb, 2005), with the period 1997-2010 under the New Labour government witnessing *“an unprecedented focus on tooling up schools for the 21st century”* (British Educational Suppliers' Association (BESA), 2015, p4). This period was characterised by centralisation and regulation, and reflected by the obligation for ICT to be a component of successive iterations of the science National Curriculum for England (Osborne & Hennessy, 2003). This imperative remained in force until the curriculum review of 2013.

Despite educational benefits for science-specific applications of digital technology (e.g. Barton, 2005; Dixon, 2008; Smetana & Bell, 2012; Yeung et al., 2019), Ofsted evidence up to 2013 suggests most science teachers in England were not incorporating digital technology into their lessons much beyond the use of teacher-led presentations, with pupils rarely using it themselves (Ofsted, 2008, 2011, 2013). An absence of comparable evidence published since 2013, either from inspections or research, makes it difficult to determine whether this situation has changed, in any of the nations of the UK. However, research into technology integration suggests barriers may persist, with studies continuing to document obstacles that prevent teachers from effectively incorporating digital tools into their practice (E.g. Aldunate & Nussbaum, 2013; Bingimlas, 2009; Francom, 2020; Tosuntaş et al., 2019; Vrasidas, 2015). Ertmer (1999) identifies 'first-order' barriers such as technology provision, training and technical support, and 'second-order' barriers such as teachers' pedagogical beliefs and attitudes towards technology, later suggesting that the second-order barriers are most resilient to change, with first-order barriers having diminished in many contexts (Ertmer & Ottenbreit-Leftwich, 2010). However, at the start of lockdown it was hard to know with certainty how first- or second-order barriers were affecting UK science teachers specifically, or how well they would cope with changes requiring digital technology at the heart of their teaching. Coupled with stresses caused by lockdown conditions, the newness of remote education to schools and schoolteachers (Ellis-Thompson et al., 2020; World Bank, 2020) and the likely changed involvement of parents in their children's education (Villadsen et al., 2020), it was anticipated this research would reveal a variety of challenges.

1.4 Original contribution to knowledge

By focusing specifically on science as a school subject, this study addresses a significant gap in lockdown literature: most research lacks subject-specific focus (Erumit et al., 2021; Hodgen et al., 2020; Howard et al., 2021), and most concentrates on higher education rather than schools (Ellis-Thompson et al., 2020; Müller and Goldenberg, 2021). A further limitation of existing school-based literature in the UK is its reliance on large data sets, often from surveys, giving an averaged picture of remote education but not capturing the diversity of individual experiences (Howard et al., 2021). By adopting mixed methods, with in-depth interviews as well as surveys, this study presents detailed personal experiences that provide a sense of how this diversity was manifested among teachers and parents during the first lockdown. This richness is exemplified in chapter 5, which examines the practice of live remote teaching (LRT), a teaching method which was not widely used but whose significance emerged during thematic analysis owing to the amount of time teachers spent discussing it during interviews. More detailed points of originality are discussed further in critical discussions closing each of the chapters 4-6, while a detailed literature review with further critical commentary of the field comprises chapter 2.

This study does not aim to examine the application of theoretical models of educational technology integration to the lockdown context, numerous though such models are (Bower & Vlachopoulos, 2018), but it does offer a valuable resource for future development of new or existing technology integration theories, both in terms of their application to non-traditional settings such as emergencies, and for subject-specificity. König et al. (2020) suggest the use of technology during lockdown reflects Technological Pedagogical Content

Knowledge (TPACK) (Koehler & Mishra, 2009), and in emphasising the intricate relationship between content, pedagogy, and technology, evidence discussed in chapters 4-6 tends to support this. However, Bond (2021) highlights that most lockdown studies are not underpinned by a theoretical framework, and there is some justification for not doing so. While the COVID-19 pandemic marked a tangible turning point when teachers were compelled to use digital technology in new ways, previous research into technology integration is characterised by classroom, rather than remote, contexts (Jiang et al., 2022; Ratten, 2023), with teachers' involvement voluntary not mandatory (Cahyadi et al., 2022; Huang et al., 2023). Hence, the uniqueness of education in emergency conditions of lockdown renders the application of pre-existing theories problematic (Ayoub et al., 2024; Whittle et al., 2020). There are, in addition, acknowledged limitations in the application of frameworks such as TPACK to subject-specific contexts (Angeli & Valanides, 2009). While avoiding detailed theoretical deliberations, my research nevertheless makes two distinctive contributions to the field. First, it provides detailed insights into how the content-pedagogy-technology interaction functioned under the unprecedented conditions of lockdown, offering a unique perspective on educational technology integration during crisis. Second, and perhaps more importantly for the future, the findings suggest significant potential for elements of remote education to enhance conventional classroom-based teaching and learning - a possibility that could shape science education long after the pandemic's end. In Chapter 7, I examine critical imperatives for educational practice, including the necessity of developing school resilience for future emergencies, the integration of remote education into school development frameworks, the formalisation of pedagogical principles and practices for remote teaching, and the enhancement of home-based practical science activities, incorporating expanded parental engagement.

The inevitability of future pandemics (Alexander, 2023) makes it essential to learn from the COVID-19 educational experience. Should a global health crisis demand lockdown measures again, governments and policymakers will possess a wealth of evidence about how to respond to educational disruption, hopefully enabling more strategic, planned interventions, in contrast to what happened in 2020. Although the field of emergency education was conceived during the 1990s (Burde et al., 2017), before the COVID-19 pandemic its focus had mainly been within contexts of conflict, natural disasters or regional health crises, not global pandemics (Durrani & Ozawa, 2024). The COVID-19 experience has considerably expanded this field, and this study adds important insights to emergency education literature, particularly relating to pandemics.

The practical value of lessons learned during the pandemic has already been evident. During the subsequent Reinforced Autoclaved Aerated Concrete (RAAC) crisis in England, affecting public buildings including schools, remote education practices developed during COVID-19 were valuable when pupils and teachers were unable to access buildings for brief periods. The UK government's recommendation of remote learning as a contingency option, albeit as a last resort, demonstrates how quickly these emergency innovations could be mobilized for new challenges (Department for Education, 2023). However, this research’s significance extends beyond emergencies, illustrating potential for remote education practices to have benefits, especially for science education, under normal school conditions. By supplementing the range of teaching strategies at teachers’ disposal, enriching and expanding the curriculum for pupils, and improving access for pupils unable to physically attend school, remote education can be conceived in terms of educational enhancement, not just a substitute when classroom teaching is suspended. This potential is illustrated through a variety of data within this study; however, so are challenges and pitfalls resulting from a lack of preparedness and professional knowledge of how to provide remote education successfully. Hence, this study presents evidence to inform strategic planning for schools and policymakers implementing or consolidating aspects of remote education. Policymakers need to assess COVID-19's lasting impact on emergency preparedness, specifically examining how schools have incorporated their pandemic experiences into proportionate contingency plans that enable rapid transitions to remote education when needed. School leaders must develop strategies to preserve and disseminate teachers' professional knowledge of online education, particularly to new entrants to the profession.

1.5 Chapter Summary

This thesis contains the following chapters:

Chapter 2: Literature Review.

Four categories of literature identified as relevant to this study are critically discussed, elaborating the scope, strengths and limitations of each. Thematic analysis then identifies eight key themes across these sources, which are explored in detail. Concluding comments consider relevant literature published since the end of the pandemic.

Chapter 3: Methodology.

A critical examination of mixed methods, including the methods of surveys and interviews chosen for this study, is followed by a comprehensive account detailing how data collection and analysis were carried out. Ethical issues are discussed. Critical discussion elaborates how triangulation, a key tenet of mixed methods, was conceived for this study. An account of my positionality, and ontological and epistemological standpoints is included. Details of participant samples (139 teachers and 61 parents) are given.

Chapter 4: Teachers' experiences of providing science education in lockdown.

The findings from my analysis of the data are presented, focusing on teachers' experiences of providing science education in lockdown. Critical commentaries are supported by descriptive statistics and first-hand interview evidence, identifying potential causalities and limitations in data, with suggestions of contributions to the field. In a critical discussion of findings further commentary is made on how triangulation contributed to specific findings.

Significant findings relate to:

- Teachers' lack of readiness for remote education, and struggles in setting appropriate learning tasks.
- The diversity of experiences, including workload and perceptions of difficulty.
- Teachers' predominantly negative views of the quality of science education they provided.
- Mixed levels of engagement from pupils with tasks set.
- Teachers' experiences of professional development during lockdown.

- Teachers’ views of lockdown influencing their classroom practice.

Chapter 5: Live Remote Teaching (LRT) in science.

A detailed discussion and analysis of teachers’ experiences of the specific practice of live remote teaching (LRT), drawing on descriptive statistics and first-hand accounts. Critical discussion assesses the chapter’s contribution to existing literature, identifying how the research’s methodology and findings enhance the field.

Significant findings relate to:

- Occurrence of LRT and rate of adoption by schools.
- Reasons why schools did not use LRT.
- Teachers’ experiences of LRT, including challenges and innovations.
- How LRT influenced teachers’ perceptions of the quality of their teaching.
- How LRT provided a lens for understanding schools’ decisions and priorities during lockdown.

Chapter 6: Parents’ experiences of their children’s science education during lockdown.

Drawing on empirical data, parents’ experiences are presented and analysed, supported by descriptive statistics and first-hand interview evidence. A critical commentary considers how triangulation of teachers’ and parents’ data has strengthened findings from this study, and discusses how it contributes to extant literature.

Significant findings relate to:

- Parents’ daily experiences of their children’s lockdown science education, including challenges.
- Parents’ views about different types of learning activities schools provided.
- Parents’ perceptions of their children’s motivation and interests during lockdown.

Chapter 7: Conclusions

The chapter opens with a consideration of the study’s limitations. This is followed by a synthesis of key findings, distilled from chapters 4-6, with connected implications and recommendations. A closing discussion considers how the study has addressed the research questions proposed in chapter 1, and its contribution to knowledge.

Chapter 2: Literature Review

2.1 Introduction

Literature about education during the COVID-19 pandemic is varied and extensive (Betthäuser et al., 2023; Cachón-Zagalaz et al., 2020), reflecting the scale of disruption and its global reach. In keeping with this study's subject-specific focus, this literature review concentrates on sources most relevant to science education. This inevitably incorporates sources that are broader in scope, examining how remote education affected all academic subjects, but includes some sources which capture context and detail specific to science. While challenges like the loss of hands-on learning also affected subjects such as music, P.E. and design technology (Martyniv et al., 2021; Varea et al., 2022), the pandemic gave science education distinctive relevance, revealing its critical role beyond academic goals (Erduran, 2020b; Pietrocola et al., 2021). With scientific understanding an essential pre-requisite for public health responses and citizens' ability to comprehend the scientific reasoning behind policy decisions (Archila et al., 2021; Cabreja-Castillo et al., 2023), scientific literacy and science education were placed in the spotlight by the events of the pandemic (Alameh et al., 2025). Consequently, a comprehensive examination of science education during lockdown must consider both pedagogical provision and the broader societal context in which scientific literacy gained unprecedented relevance. These interconnected dimensions constituted the conditions experienced by teachers, parents and learners throughout the pandemic.

This review commences with a critical discussion, categorising sources according to four types, considering strengths and limitations in terms of their contribution to understanding both the provision of science education for schoolchildren during the pandemic, and the broader context affecting teachers and parents. The literature used is largely from the pandemic-era period 2020-2022, with a few exceptions; most of the same sources are used in a detailed thematic analysis, which forms sections 2.4-2.8.

In concluding, an overview of relevant post-pandemic literature considers how educational priorities that characterised the COVID-19 period have evolved since the World Health Organisation declared the end of the pandemic in May 2023 (United Nations, 2023), revealing which concerns have diminished, persisted, or intensified. Differentiating between pandemic-era and post-pandemic sources reflects their distinct characteristics. Literature produced during the pandemic focuses on immediate crisis responses such as remote learning transitions and lockdown pedagogy; post-pandemic literature, by contrast, benefits from the passage of time to measure actual long-term outcomes such as learning loss and persistent absenteeism. This separation reveals how research priorities evolved from crisis management to recovery and impact assessment.

2.1.1 Literature search method

Initial literature searches were conducted mainly during the period between June 2022 and July 2023; post-pandemic literature was reviewed during 2025. Searches were carried out using key word searches in Google Scholar, using the phrases 'science education' and 'science teaching' in conjunction with 'COVID', 'COVID-19' and 'pandemic'. Specific journals were also consulted, including *School Science Review*, *Primary Science* and *Science Teacher Education* (Association for Science Education, ASE), *The Science Teacher*

(National Science Teaching Association, NSTA) and *Science Education* (Wiley Online Library). Other sources were identified from reference lists on articles found through these search methods; ultimately this was a more productive search method. During 2025, the AI platform Claude.ai was also used for literature searches, which has confirmed the range and relevance of previously found sources, and highlighted new ones, particularly relevant to the post-pandemic period. This tool has facilitated rapid and highly specific literature queries, but verification has always been carried out through accessing original sources via other literature databases, such as Google Scholar and ERIC.

2.2 Critical discussion of lockdown literature

After school closures in the UK were announced on 18th March 2020 (Timmins, 2021), it did not take long before literature began to appear, with a substantial evidence base published in a relatively short period (Howard et al., 2021). Indeed, excluding the literature published since the end of the pandemic, most sources in this review have publication dates from 2020 onwards, with approximately half originating between March and October 2020. Although many educational concepts encountered during the pandemic, such as remote education and teaching with digital technology, were not new (Green, J. K. et al., 2020), education via the medium of the internet - online education - was new to many (Erumit et al., 2021), and the extensive field of pre-existing literature about online education was limited in relevance by the unprecedented context of COVID-19. Pre-COVID studies about educational effects of pandemics are rare (Sintema, 2020), as is research about moving education online at the scale and pace required during the pandemic (World Bank, 2020); additionally, much extant research on online education focuses on higher education contexts, with little relating to schools (Ellis-Thompson et al., 2020). The integration of digital technologies by schoolteachers had long been problematic (Bingimlas, 2009; Vrasidas, 2015), representing a gradual "*complex endeavour*" (Green, J. K. et al., 2020, p907) typically pursued by willing volunteers rather than mandated across the profession (Aldon et al., 2021). As Yates et al. observe, educational technology knowledge had evolved "*for another time*" (2021, p4), not a worldwide health emergency.

Bond (2021) highlights the need for critical sensitivity when considering literature published during lockdown. The dynamic, evolving context of the pandemic, meant earlier data could be superseded by later, more representative, data. For example, initial estimates suggesting children in England were spending around five hours per day on schoolwork (Andrew, Cattan, Costa-Dias et al., 2020), were revised to 2.5 hours later (Green, F., 2021). Bond (2021) further emphasises the prevalence of studies which collected data over short timescales (generally less than a month, though some less than a week), a lack of detail about analysis methods and a predominance of online survey methods. The latter point reflects several commentaries on lockdown research (e.g. Bozkurt & Sharma, 2020; Drane et al., 2021; Williamson et al., 2020), critiquing how ‘rapid response’ surveys prioritised quantifiable data over contextual understanding, produced shallow findings that missed issues such as pedagogical complexity, and tended to omit minority groups such as vulnerable learners.

Time of publication is additionally relevant considering the multiple lockdowns which occurred. Cullinane and Montacute’s research brief (2020) deals with early stages of the first lockdown, while Müller and Goldenberg’s report (2021) spans three periods of school closures and intervening periods of socially distanced schooling. This observation is relevant especially for statistical data which can obscure differences between the different educational phases of the pandemic.

Relevant literature has been categorised into four distinct groups:

- **Articles describing pedagogical approaches** offering teaching approaches and methods.
- **Large-scale quantitative and mixed methods studies** examining institutional responses.
- **Reports of other studies** by researchers investigating lockdown experiences within their own educational settings.
- **Broader commentaries** highlighting systemic issues and implications.

While these groupings vary considerably in their depth of data, and empirical foundation, no single group provides a complete picture of science education for schoolchildren during lockdown. Collectively, however, they illuminate the diverse experiences of teachers, parents and learners in terms of remote education and, to a lesser extent, science education.

The following four sub-sections critically examine each category in detail.

2.2.1 Articles describing pedagogical approaches

Featuring a relatively small number of sources compared to the other categories, this category comprises articles that are either suggestions for teaching activities or accounts of science teaching approaches and resources tried by the author(s), with some evidence of successful educational outcomes. Often authored by school or higher education teachers, (e.g. Gibbs, 2020a;

Harris, 2020; Ray & Srivastava, 2020), many sources in this category are relevant to school-based science education, with much being UK-based. Those which are accounts of remote science teaching practice are accounts of 'what worked', but only in the individual authors' experiences. These sources primarily serve to exemplify advice and ideas available, from academic literature at least, to science teachers seeking support for remote teaching during lockdown or the subsequent period of socially distanced classroom teaching. However, they offer limited insights into the broader reality of what teachers were actually experiencing; their common practices, key challenges, innovative solutions, and everyday struggles. Additionally, there is no reliable way to determine how many educators accessed this literature or successfully implemented any of the proposed strategies. More generally, some sources potentially contribute to the literature field about specific technological innovations in science education, such as the use of simulations (e.g. Mahaffey, 2020). However, the small number of sources in this category indicates that academic literature was somewhat limited when it came to supporting remote science teaching.

2.2.2 Large-scale quantitative and mixed methods studies

In contrast to the limited literature on pedagogical strategies, research reports sponsored by research organisations (examples in the UK include the Nuffield Foundation, the Education Endowment Foundation and government research councils) provide extensive data about pandemic-era education, particularly within the UK's school system. While these reports rarely adopt subject-specific perspectives, they collectively address a broad spectrum of issues, such as parental involvement (e.g. Villadsen et al., 2020), educational inequality (e.g.

Major, Lee Elliot et al., 2020) and teaching practices (e.g. Müller & Goldenberg, 2021).

While some reports are reviews of other literature (e.g. Edge Foundation, 2020; Howard et al., 2021; Sibieta & Cottell, 2020), most present original empirical research utilising substantial datasets. Many studies draw on established research programs: the UK Household Longitudinal Study is used in Green's study (2021), while data in Villadsen et al. (2020) are from over 18,000 respondents from five nationally representative longitudinal cohorts. Other research utilises Teacher Tapp, a daily survey app delivering three questions to a self-selected teacher panel throughout the pandemic (Allen et al., 2020a). Although studies using existing cohorts of participants are generally more representative, with data pre-stratified for this purpose, most reports rely on convenience samples because lockdown conditions necessitated gathering data at relatively short notice. Such reports acknowledge their sampling strategies limit representativeness (e.g. Allen et al., 2021; Champeaux et al., 2020; Müller & Goldenberg, 2021). Large numbers of respondents were nevertheless achievable without access to prior studies; the report by Brink et al. (2020) uses data from over 45,000 respondents, for example. However, it should be noted that existing cohorts of participants are not always relevant to a study's aims; Villadsen et al. (2020), looking at parental involvement in lockdown education, could only analyse data from two of their five cohorts because most respondents in the other three did not have dependent children.

The chief limitation of most literature in this category is that despite the volume of data, they are predominantly from online surveys. Consequently, detail is rich in descriptive statistics, but diversity of individual experience tends to be absent.

Howard et al. (2021) comment that statistical data give collective measures of aspects of lockdown, such as hours of online learning children engaged in, but cannot reveal experiences outside these norms.

While a clear advantage of online surveys is the number of teachers reached - over ten thousand participated in just two of the large UK studies (Brink et al., 2020; See, 2024) - a greater sense of diversity of individual experiences is apparent in the minority of reports based on mixed methods research, combining online surveys with interviews or focus groups (e.g. Cambridge Partnership for Education, 2020; Hodgen et al., 2020; Open Data Institute, 2020). However, apart from a mathematics-focused report by Hodgen et al. (2020), science or STEM subjects feature minimally. Although some of the focus groups used by Müller and Goldenberg (2021) are based on school subjects, neither science nor other STEM subjects are represented in their study. Indeed, Hodgen et al. (2020) represents the only subject-specific perspective in this category, reinforcing the existence of the gap identified by Howard et al. (2021).

2.2.3 Reports of other studies

This category comprises academic journal articles describing smaller-scale studies conducted by researchers within their own institutional contexts or specialised areas (e.g. al Darayseh, 2020; Engelbrecht et al., 2020; Yates et al., 2021). Notwithstanding the limitations of COVID-19, university academics generally have good access to conducting research within their own educational context (Shen, 2021) through established frameworks for scholarship of teaching and learning (Gansemer-Topf et al., 2024). For schoolteachers, such scholarship frequently takes the form of action research, which is rarely publicly disseminated (Manfra, 2019). Consequently, while this category contains an abundance of sources, most examine higher education contexts using mature, independent learners or university instructors. Science-specific studies, though prioritised for this review, often prove less relevant for this study's school-based focus.

Sources addressing school-based education typically come from teacher educators or academics within education faculties, but science or STEM specificity is rare, reflecting the previous category's limitations. While general, non-subject-specific studies can illuminate various aspects of remote education, the shortage of disciplinary focus makes it difficult to assess how subject specialists' experiences differed.

The diversity of literature in this category is noteworthy, spanning multiple countries, research methodologies, sample sizes, and subject areas. Through its breadth and variety this category reflects the range of influences and impacts associated with lockdown education more comprehensively than other literature categories. Hence it encompasses sources dealing with such issues as adolescent psychiatric disorders during lockdown (e.g. Guessoum et al., 2020) and stress connected with telecommunications and online learning (e.g. Mheidly et al., 2020). While these topics are peripheral to this study's central aims, they gain potential relevance given the inclusion of parental interviews in which they discuss their children's lockdown educational experiences.

Some sources in this category are purely literature research (e.g. Guessoum et al., 2020; Oswald et al., 2020), but most describe small-scale research studies using methods such as surveys, interviews and focus groups. Online interactions are predominant, reflecting both lockdown conditions and the convenience over face-to-face methods. Sample sizes vary from small to large, reflecting a range of representativeness: Sintema (2020) interviewed three teachers in Zambia, while Bubb et al. (2020) obtained 1,995 responses to their online survey in Norway. While the international spread of sources sometimes limits relevance due to contextual differences from the UK (most research studies in this category are not UK based), it nevertheless reinforces the global impact of the COVID-19 pandemic on education, emphasising similarities teachers and learners were experiencing around the globe. Hence, challenges faced by science teachers in Indonesia (Wisanti et al., 2021) resemble many of those in Estonia (Adov & Mäeots, 2021), and resonate with some of the experiences recounted in chapters 4 and 5 of this study.

2.2.4 Broader commentaries

Scholars responded rapidly to the COVID-19 crisis, expressing concerns, offering expert analysis, and proposing recommendations through editorials, articles, and blog posts. Though not comprising empirical research, this fourth category reflects other forms of scholarship that address broader concerns brought into sharp focus by the pandemic. While some issues, such as social inequality, mirror themes found in large-scale research reports (section 2.2.2), this category encompasses a broader conceptual range, including critical examinations of the public understanding of science, the fundamental purposes of science education, and the growing influence of commercial technology platforms in shaping educational practices and values - topics explored further in section 2.8.

This category has particular relevance for this study by virtue of its connections to both science and technology. Though most sources lack empirical data about lockdown events, they provide the contextual backdrop for understanding the environment in which parents and teachers provided science education.

Literature addressing public understanding of science (e.g. Bloom et al., 2020; Dillon & Avraamidou, 2020) highlights the widespread misinformation that characterised the lockdown period. These sources illuminate how 'new normal' conditions prompted critical reflection on fundamental aspects of science education, including practical work and scientific inquiry teaching (e.g. Erduran et al., 2020). This literature captures essential qualities of the educational environment that other categories miss. Furthermore, with most remote science education provided through digital technology, literature examining the complex relationship between teaching, learning, technology and the ‘edtech’ industry in the light of COVID-19 (e.g. Selwyn & Jandrić, 2020; Williamson et al., 2020) raises many questions and issues relevant to online education, and hence to this study’s objectives. It is clear from evidence in chapters 4, 5 and 6, for example, that teachers’ decisions in providing remote education were influenced by specific software, reinforcing the existence of intricate connections between pedagogy and corporate interests. Though a deeper exploration of this connection exceeds this study’s scope, evidence in later chapters has a potential contribution to the future understanding of developments in ‘edtech’ (a definition of which is given in section 2.8.2).

2.3 Thematic analysis of literature

Sections 2.4 to 2.8 provide a comprehensive thematic analysis of the literature described above. This approach follows a traditional literature review format, synthesising a narrative from relevant literature, rather than an exhaustive systematic review methodology (Jesson et al., 2011).

It is relevant to observe that before COVID-19, literature pertaining to coronaviruses was biomedical and public-health oriented (e.g. Azhar et al., 2019; Perlman & Netland, 2009). Much of the relevant pre-pandemic literature around science education and digital technology had already been identified from my earlier doctoral activities, but this excluded sources pertaining to remote education, which were found using key word searches and from other existing literature.

Sources were highlighted and coded using NVivo12 software, using initial inductive coding. This process generated categories and themes that were predominantly generic in nature, though 'science education' was designated as a specific theme to maintain the study's subject-focused emphasis.

2.3.1 Overview of themes

Eight main themes were identified within the educational literature reviewed. In no order of priority, these were:

1. Research-oriented: gaps in the field, research opportunities.
2. Online education: challenges and solutions, pedagogy, resources.
3. Educational outcomes: learning loss, widening of attainment gaps.
4. Parental support: parents' confidence, difficulties, views.
5. School-related factors: quantity and quality of provision, comparisons between phases and sectors.
6. Social factors: mental health and wellbeing, inequality and its effect on technology access.
7. 'Micro' aspects of science education: challenges and solutions, suggested activities.

8. Wider contextual aspects: public understanding of science, misinformation, the edtech industry.

The first theme, focused on research opportunities, requires no detailed elaboration here. Literature gaps, particularly the need for subject-specific research (e.g. Hodgen et al., 2020; Howard et al., 2021), have already been described. Additional research priorities emerged around lockdown-exacerbated inequalities (e.g. Bayrakdar & Guveli, 2020), longer-term effects such as increased internet use on children (Guessoum et al., 2020), and opportunities to advance understanding of technology's educational role (e.g. Adov & Mäeots, 2021; Selwyn & Jandrić, 2020; Williamson et al., 2020). In the post-pandemic era, the nature of COVID-related educational research has shifted: from crisis response during the pandemic, the focus is now more about long-term impact assessment and recovery strategies. As this shift in focus reflects the aftermath of the pandemic, not the events informing this study, it is not included as a theme here, but considered separately in section 2.9.

Of the remaining seven themes, prevalence varies. Themes of online education, school-related and social factors appear frequently, consequently generating more analytical categories than less prominent themes such as wider contextual aspects. The themes intersect considerably; categories within individual themes often overlap with others. For instance, discussions about quantity and quality of provision (classified under school-related factors) frequently connect to online education themes.

The following sections examine each theme in detail

2.4 Online Education

2.4.1 Terminology

In elaborating this theme, it is relevant to address terminology. In this study, I adopt Finch and Jacobs' definition of 'online education' (2012): teaching and learning where participants are geographically, and potentially temporally, separated, with communication mediated by internet-connected digital technology. Online education thus represents a subset of ‘distance education’, with 'remote education' serving as a synonym.

This clarification is necessary because pandemic education discourse used terms interchangeably, creating ambiguity (Dillon & Avraamidou, 2020). The confusion predated the pandemic - Singh and Thurman (2019) identified 46 definitions of online learning in the literature - but COVID-19 intensified it. Coleman (2021) provides a comprehensive overview of alternative terms and their limitations.

Terminology concerns extend beyond clarity. The well-established field of online education (Joksimović et al., 2015) faced potential reputational damage from the hasty, improvised activities launched in spring 2020, which risked creating negative associations among inexperienced practitioners (Czerniewicz, 2020; Hodges et al., 2020). Recognising that pandemic teaching and learning fundamentally differed from established online education practices, some scholars advocate for 'emergency remote teaching' as a more accurate descriptor (Bozkurt & Sharma, 2020). Others characterise education in the first lockdown as a massive experiment, with teachers, students, and institutions as unwitting subjects in an unprecedented comparison with pre-pandemic education (Cambridge Partnership for Education, 2020; Williamson et al., 2020;

Williamson, 2021; Zimmerman, 2020). This review uses the term 'online education', while acknowledging these debates about quality and legitimacy.

2.4.2 Challenges of Remote Teaching

2.4.2.1 Teachers' Lack of Experience and Preparation

Most teachers had little or no online teaching experience at the start of the pandemic. Wisanti et al. (2021) documented this in Indonesia, while Gudmundsdottir and Hathaway's (2020) medium-scale study replicated the finding across many countries. Given teachers' varying willingness to use digital technology (Adov & Mäeots, 2021), it was unclear how they would respond when compelled to teach online. Prior technology use appears to have been a significant factor: Van der Spoel et al. (2020) found that teachers reporting more positive experiences had at least moderate pre-pandemic technology integration in their teaching.

2.4.2.2 Widespread Institutional Unpreparedness

As well as difficulties reported by individual teachers, schools and education systems struggled to adapt. Many schools lacked institutional support (Bayrakdar & Guveli, 2020; Engelbrecht et al., 2020; Hodgen et al., 2020; Wisanti et al., 2021), had no historical precedents to draw upon (Howard et al., 2021; World Bank, 2020), and possessed no evidence base for effective remote pedagogy (Cambridge Partnership for Education, 2020). Questions arose about whether education systems, even in developed countries, were equipped for large-scale online education at short notice (Dillon & Avraamidou, 2020; World Bank, 2020). In the UK, most state school teachers initially lacked confidence to broadcast live online lessons, with a survey of over 1,000 teachers in England during March-April 2020 showing that 52% felt unable to do so (Cullinane & Montacute, 2020), and 25% of over 5,000 teachers surveyed in May 2020 stating they needed more training in using technology for teaching (Menzies, 2020).Limited digital literacy among teachers, pupils, and parents was "mentioned repeatedly during focus groups as a barrier to effective distance learning" (Muller & Goldenberg, 2020, p. 28).

Rodriguez et al.’s (2021) thematic review of international research, examining how COVID-19 affected science education, suggests that many schools simply replicated classroom practices online without considering pedagogical adaptations, such as feedback mechanisms or engagement strategies, and often provided no training. However, Ellis-Thompson et al.’s (2020) rapid review of literature on approaches that schools could use to support pupils’ learning while schools were closed suggests even existing computer-assisted instruction programs offered limited guidance, having been evaluated in traditional school settings rather than remote conditions.

2.4.2.3 Practical Challenges of Online Teaching

The shift to online education created numerous practical difficulties. Resources often had to be created from scratch because classroom materials did not translate well to environments where pupils worked independently (Howard et al., 2021). Over half the respondents in Müller and Goldenberg's (2020) survey of around 1,800 primary and secondary teachers in England reported increased workloads and a lack of effective consequences when pupils failed to submit work.

For teachers using live remote teaching (LRT), not seeing pupils' facial expressions when cameras were off was a significant drawback, but Moses (2020) notes that having cameras on could have presented psychological challenges for young people: spending extended time viewing a screen of faces, including their own, was unfamiliar and could increase self-consciousness. It also removed many non-verbal communications learners were accustomed to in classroom settings. Managing engagement and facilitating collaborative activities proved difficult, especially when compounded by technological issues such as transmission lags. The most demanding situations occurred when teachers taught 'hybrid' lessons, as their attention was split between physically present pupils and those online (Constantinou, 2023). This scenario arose when UK schools partially reopened in June 2020 (Muller & Goldenberg, 2020)

Pupils' lack of access to necessary technology compounded these problems (discussed further in section 2.6.1). Some schools "abandoned all pretence of moving teaching online" (Yandell, 2020, p. 263) because so few pupils could access online learning. Others used paper-based resources—posted or hand-delivered—alongside rather than replacing online teaching (Howard et al., 2021).

2.4.2.4 Pedagogical Considerations

Teaching and learning online presented fundamentally different challenges than face-to-face contexts (Wisanti et al., 2021; Yandell, 2020). Younger learners with less experience of learning with technology struggled more than older ones (Champeaux et al., 2020; World Bank, 2020). Children with special educational needs and disabilities (SEND) were particularly disadvantaged, with Müller and Goldenberg (2020) highlighting that greater learner independence was required compared to school-based education. Several authors assert that pedagogy, rather than technology, needed to be at the heart of online education (Peimani & Kamalipour, 2021; Rodríguez et al., 2021; Yates et al., 2021), reflecting theoretical models of online education such as Kearney et al. (2012) and earlier distance education models such as Moore (1993). These views underscore the value of the qualitative teacher evidence in my study. Chapters 4 and 5 reveal that while pedagogy consistently took precedence over technology in teachers' decision-making, the relationship between the two was complex and reciprocal. Teachers adapted their pedagogical approaches in response to technological constraints, particularly when comparing remote teaching tools to the affordances of face-to-face classrooms. Nonetheless, pedagogy remained the driving force: without thoughtful pedagogical direction, technology risked becoming what Cuban (2001) termed "oversold and underused" - present but inert, failing to enhance learning meaningfully.

2.4.2.5 Dominance of negative experiences

Overall, difficulties outweighed benefits across educational sectors. Literature frequently highlights the differences between online and face-to-face teaching (Bubb & Jones, 2020; Yandell, 2020; Yates et al., 2021) and the difficulties teachers experienced in both the rapid implementation and ongoing challenges (Ali, 2020; Kovacs et al., 2022; Muller & Goldenberg, 2020). Watermeyer et al. (2021, p. 623) found that in higher education, online migration was "engendering significant dysfunctionality and disturbance to their pedagogical roles and their personal lives." School-oriented literature similarly emphasizes challenges over positive experiences (e.g. Kaden, 2020; Kim & Asbury, 2020).

2.4.3 Positive perspectives

2.4.3.1 Institutional preparedness and continuity

Despite an abundance of negative perspectives in the literature, some research provides a more positive slant. Schools with established systems for online education, where pupils and parents were familiar with them, were able to adapt more effectively (Bubb & Jones, 2020; Hodgen et al., 2020). This resonates with the World Bank's (2020) position that even where quality of provision might be lower, remote education was preferable to the alternative of no education. In developed countries, while children's expected progress was lower in online lessons than in face-to-face teaching, remote learning nonetheless reduced the impact of school closures substantially (Cattan et al., 2021b). Some authors postulate a theoretical benefit of online over face-to-face education in developing countries because of the relative scarcity of teachers and resources. Ray and Srivastava (2020) justify this view by citing the increase in attendance at massive open online courses (MOOCs), though empirical evidence of these benefits remains limited. Nevertheless, the pandemic-fuelled growth in awareness of online resources, such as virtual labs, could prove valuable in the longer term for these countries, albeit with persistent concerns about widening inequalities and families' capacity to support home learning (Engelbrecht et al., 2020; Ray & Srivastava, 2020).

2.4.3.2 Micro-level advantages: flexibility and workload

Several advantages of online education at the 'micro' level emerged, notably its role in maintaining educational continuity during an exceptionally challenging period (Mheidly et al., 2020). In Yates et al.'s survey of 1,975 high school students, respondents valued the flexibility arising from being able to access content repeatedly or at times more convenient to them (2021) - affordances consistent with online education's well-established capacity to transcend temporal and spatial constraints and facilitate personalized learning pathways (e.g. Kearney et al., 2012). At least one teacher in Evans et al.'s (2020) narrative study reported being able to organize their workload more effectively during lockdown, finding time to thoughtfully prepare future schemes of work, though this positive experience contrasted with the predominantly negative accounts from other participants.

2.4.3.3 *Live remote teaching: phase-dependent effectiveness*

Of all the online education approaches, LRT was most like the approach experienced by school pupils pre-pandemic, and was probably most effective due to the teacher's presence (Howard et al., 2021). However, Müller and Goldenberg's (2021) survey of 387 UK teachers (predominantly primary and secondary, with over 10 years' experience) suggests LRT's effectiveness was phase-dependent, with older pupils better able to engage with independent aspects of remote learning. Primary-aged pupils typically required more adult support and parental engagement during LRT sessions, as corroborated by Lucas et al.'s (2020) larger-scale NFER study of approximately 1,800 teachers, which found higher parental engagement rates for primary pupils (56%) compared to secondary (48%). Pre-recorded material and LRT were seen by teachers as having implicit pros and cons, but if used in conjunction the pros tended to be maximized while the cons were minimized (Müller & Goldenberg, 2021). Demonstrations were widely used (86% of respondents) and found effective (81%), with practical subjects like science particularly affected by equipment access issues during remote learning (Howard et al., 2021; Müller & Goldenberg, 2021).

2.4.3.4 *Learner independence: contrasting national experiences*

The need to be self-motivated and well-organised typifies features of independent learning that many UK pupils reportedly struggled with during learning in lockdown (Howard et al., 2021; Ofsted, 2021). In Norway, however, where remote learning was generally well-received and better catered for, Bubb and Jones's (2020) study of over 2,000 teachers, learners and parents in one municipality reports that learners adapted to the independence better, with 63-78% of respondents agreeing that pupils became more independent, embracing flexibility and the ability to manage their own pace and routines. This reflects Reimers & Schleicher's (2020) international analysis identifying increased autonomy among pupils in managing their own learning as an unexpected benefit of home-schooling, though Bubb and Jones (2020) note this adaptation was phase-dependent, with younger pupils requiring more adult support.

2.4.4 Educational Outcomes

Two specific educational outcomes dominate literature in relation to schools: learning loss (e.g. Green, F., 2021; Hodgen et al., 2020; Howard et al., 2021), and the attainment gap between the highest and lowest attaining schoolchildren (e.g. Bayrakdar & Guveli, 2020; Brink et al., 2020; Children's Commissioner, 2020; Cullinane & Montacute, 2020).

2.4.4.1 Learning Loss

Learning loss is defined as either the decline in students' knowledge when compared to previous cohorts of students (Donnelly & Patrinos, 2021), or as the deficit between the educational progress expected to happen under normal conditions and that which actually occurred (Pier et al., 2021). Though similar, the latter definition more closely reflects events of the pandemic, in that learners' education was disrupted and their learning suffered as a result. It is arguably more accurate to describe what happened in terms of loss of opportunity – i.e. *missed* learning, rather than *lost* learning, but the term 'learning loss' is well established in literature.

Although literature recognises the pandemic would influence learning loss and attainment gaps, in the UK a consensus on the scale of effects was not clear during the periods of lockdown (Ofsted, 2020b). Subsequent research has since confirmed substantial impacts (e.g. Betthäuser et al., 2023), explored further in section 2.9. However, during the pandemic caution was expressed regarding language and narratives around educational outcomes: Engelbrecht et al. argue that terms such as "*lost generation*" (2020, p823), used in relation to learners during the pandemic, represent exaggeration. Similarly, Evans et al. (2020) quote a UK teacher questioning whether the national discourse's focus on loss came at the expense of recognising potential gains. The emotive language characteristic of media headlines cannot be taken as reliable or factual: for instance, "*Tests reveal 'dramatic' GCSE learning loss*" (Lough, 2020 n.p.) does not reflect that headteachers' views, reported under the headline, were not universal, nor that evidence for learning loss was limited.

During 2020-21, several authors acknowledge that data about learning loss were incomplete (e.g. Hodgen et al., 2020; Howard et al., 2021). This deficiency is evident in the systematic review of Donnelly and Patrinos (2021): from thousands of articles discussing predictions of learning loss, only seven documented cases where actual losses had been empirically measured. This scarcity reflected the limited assessment data available during the pandemic's first year - in the UK, standardized testing that would have occurred in summer 2020 had been cancelled (Timmins, 2021). Subsequent research, conducted once assessment data became available, confirmed substantial learning losses had occurred (e.g. Engzell et al., 2021; Rose et al., 2021). In the UK, Major et al. (2021) reach a similar conclusion after analysing various secondary and empirical data: while substantial learning losses appeared to have occurred, most literature during 2020-21 focuses on estimation or anticipation of negative educational outcomes, rather than verified measurements. Estimates themselves proved inconsistent: the Department for Education (2021) suggest that primary teachers estimated pupils to be further behind in their learning, on average, than secondary teachers did. Moreover, Howard et al. (2021), note that teachers' estimates of lost learning were slightly higher than those suggested by assessment data, arguing that such estimates "*were often subjective and could be based on the level of content a teacher had been able to teach, rather than an objective measure of content the student understands*" (Howard et al., 2021, n.p.). They also suggest that teachers' judgements could have been influenced by extreme cases of learning loss they had encountered.

While it was possible to calculate the number of school days missed - 71 for most pupils in England during the first lockdown (Major, Lee Elliot et al., 2021) - it was harder to specify the content of missed learning. Time-based calculations did not verify what pupils had actually learned or retained, as direct assessment data remained limited during school closures. Studies using pre/post assessment comparisons (Engzell et al., 2021; Rose et al., 2021) later confirmed that reduced instructional time had translated into measurable achievement gaps, though during the pandemic itself, evidence of learning loss was largely based on school closure durations, teacher estimates, and parent surveys rather than empirical testing of pupil outcomes.

Consequently, learning loss in individual subjects receives limited coverage in literature. Howard et al. (2021) describe early-years pupils having greater issues with basic fine and gross motor skills when they returned to school, struggling with things they had previously been able to do such as holding a pencil or using a knife and fork. Hodgen et al. (2020) suggest remote mathematics learning had been impeded by restricted types of learning activity offered, and Evans et al. (2020) suggest the intrinsically social nature of English learning had not transferred well to online formats. Yandell's critique (2020) of the English lessons from the Oak National website raises questions about online learning materials favouring prescriptive learning geared largely to exam preparation. Despite broad acknowledgment that remote education hindered practical work (Howard et al., 2021; Ofsted, 2020b), science-specific analyses remain scarce, with existing reviews predominantly focused on higher education (e.g. Rodríguez et al., 2021) and a lack of empirical research examining how school science teachers and pupils experienced these challenges.

Ultimately, therefore, learning losses appeared to stem not only from reduced classroom time, but from the restrictions that remote education imposed on specific types of learning. Whereas existing research demonstrates that the first lockdown was the most educationally disruptive period (Major, Lee Elliot et al., 2021), subject-specific analyses of this disruption remain limited. By examining teachers' and parents' experiences of remote science education during this critical phase, my study illuminates mechanisms through which learning losses in this subject occurred.

2.4.4.2 Attainment gaps

Literature covering attainment gaps between higher and lower attaining learners predicts the gap widening, connected to issues of social inequality and disadvantage. This reflects a worsening of a pre-existing situation (e.g. Andrew, Cattan, Costa-Dias et al., 2020; Children's Commissioner, 2020; Cullinane &

Montacute, 2020). Brink et al. report that 80% of teachers in their large-scale study stated the attainment gap had widened, with 40% stating it had done so "*a lot*" (2020, p24). While it should be emphasised that teachers' evidence was often limited, predictions about the widening attainment gap are in part justifiable by prior evidence about the unequal impact on learning of school summer holidays (Children's Commissioner, 2020). Research on 'summer learning loss' has consistently shown that disadvantaged pupils experience greater learning regression during extended periods away from school (Atteberry & McEachin, 2021), as they have less access to educational resources, enrichment activities, and learning support at home.

Issues of inequality and disadvantage affecting learners during lockdowns were multi-faceted, and are discussed in more detail in section 2.6. A significant factor was the unequal access to online provision at home (Cullinane & Montacute, 2020; Hodgen et al., 2020), often reflecting differences in access to technology in schools for the most and least privileged children and exemplifying a *"digital divide"* (Menzies, 2020, p2). Access to technology, itself a complex issue extending beyond device availability to include internet connectivity, digital literacy, and appropriate learning spaces (Williamson et al., 2020), with shared devices and varying levels of parental support creating further inequalities, (Tienken, 2020), was just one of several other factors leading already disadvantaged children to be disadvantaged even further (Edge Foundation, 2020). Where schools normally had some equalising effect, transferring education to the home would lessen or even reverse this (Andrew, Cattan, Costa Dias et al., 2020).

2.4.5 Parental support

Limited literature documents parents' experiences and coping strategies while supporting their children's remote education. Villadsen et al.'s (2020) large-scale UK survey of over 4,500 parents during the first lockdown reveals substantial variation across families and significant demographic patterns. Mothers consistently provided more home-schooling support than fathers, particularly for younger children - a gendered pattern also documented by Hupkau and Petrongolo’s (2020) survey of over 8,000 UK parents - while degree-educated parents engaged more extensively than those with lower educational qualifications. On average parents spent just over two hours daily on home-schooling activities, though mothers spent 1.5 hours longer than fathers in these educational support roles. Among parents of school-aged children, 58% reported participating in home-schooling on typical weekdays—a figure that aligns with Lucas et al.'s (2020) findings. These quantitative snapshots from the first lockdown period may not capture the evolving nature of home-schooling arrangements or the qualitative complexities of parental experiences as the pandemic progressed. Moreover, self-reported time estimates and participation rates may be subject to recall bias and social desirability effects (Juster & Stafford, 1991; Kan, 2008; Krumpal, 2013), particularly regarding gendered divisions of labour.

Some literature describes parental difficulties. Conflict between home-schooling and parents’ own work responsibilities led to concerns they were doing neither very well (Cambridge Partnership for Education, 2020). In another survey, 62% were struggling to balance these commitments (Allen et al., 2021), and were more likely to report low levels of success with their children’s home learning.

Other factors contributed to perceptions of lower success, including lower levels of confidence in supporting learning or children's behaviour or emotions, and struggling to understand the work schools were setting. Parents' perceptions of their child's attitude to independent learning also corresponded with their perception of how successful home-learning had been. Single parents and those with more than one child generally found home-schooling more difficult (Allen et al., 2021).

Parental confidence in supporting children's learning corresponded with educational background. Cullinane and Montacute (2020) report confidence levels exceeding 75% among parents with postgraduate degrees and just over 60% for those with undergraduate qualifications. However, fewer than half of parents with lower educational levels felt confident in their ability to provide support. Despite these confidence variations, the overall experience proved challenging: nearly 60% of primary school parents and almost half of secondary school parents reported finding home-schooling support hard or very hard (Andrew, Cattan, Costa-Dias et al., 2020). The experience sometimes yielded unexpected benefits, however. A Norwegian study (Bubb & Jones, 2020) reveals that two-thirds of participating parents gained valuable insights into their children's learning processes, with over half feeling better equipped to provide future educational support.

Most parents in the UK expressed positive views of what schools were doing during lockdown conditions (Brink et al., 2020; Cullinane & Montacute, 2020), with 70% finding school communication clear (Brink et al., 2020). Many appreciated personalised support or when schools took the time to understand their specific circumstances (Child Poverty Action Group, 2020). There are differences in accounts of schools providing active support through online methods. For state school pupils, a higher proportion of parents in better-off households reported this support than parents in the poorest fifth of households (Andrew, Cattan, Costa-Dias et al., 2020). The authors suggest this reflected greater difficulties experienced by poorer households due to factors such as fewer resources and quiet learning spaces.

The parental perspectives documented in the literature generally correspond with those identified in my study, which are examined comprehensively in chapter 6. However, my study contributes additional nuance and depth. For instance, it reveals that parental satisfaction could be tempered by an acknowledgment of the difficulties schools were experiencing during this period. Furthermore, my research provides concrete exemplification of key issues; specifically, it illustrates how home conditions—including physical space limitations, inadequate furniture, and unreliable internet connectivity—acted as tangible barriers to effective home-based remote education.

2.5 School-related factors

Literature examining school-related aspects of lockdown education encompasses a broad range of issues. UK-based research frequently compares independent versus state schools and primary versus secondary contexts. Significant categories include the quantity and quality of teaching and learning, difficulties of providing remote education, and, to a lesser extent, the diversity of experience for learners and teachers. Later studies expanded their scope to compare multiple lockdown periods (e.g. Howard et al., 2021; Pensiero et al., 2021), and examine school reopening under social distancing protocols (e.g. Cattan et al., 2021b; Department for Education, 2021; Howard et al., 2021).

However, consistent with this study's primary focus, the following review concentrates on first lockdown experiences wherever possible.

2.5.1 Comparisons between types of school

Differences were apparent between independent and state schools during the UK’s first lockdown. Independent school pupils across the UK experienced several educational advantages (Major, Lee Elliott & Machin, 2020), such as:

- Over half of all pupils in independent schools were participating in live online lessons, compared with 23% of state school pupils (Cullinane & Montacute, 2020).
- 30% of teachers in independent schools reported having a platform which could be used for this already in place, compared with fewer than 10% of teachers in state schools (Cullinane & Montacute, 2020).
- 60% of independent schools had an online platform for receiving pupils’ work, compared with 37% of state schools in affluent areas and 23% in the most deprived areas (Cullinane & Montacute, 2020).
- It was more likely that independent school pupils would receive a full-day’s worth of remote education (Major, Lee Elliot et al., 2020).

Andrew et al. (2020) observe that existing research indicates teachers in independent schools demonstrate greater confidence with educational technology than their state school peers, potentially attributable to lower pupil-to-teacher ratios, which increase the feasibility of technology-integrated lessons. They also suggest some differences between schools serving more and less affluent communities could reflect conscious decisions: leaders of schools in less affluent areas may have intentionally limited online education due to concerns about exacerbating inequality within their schools. This is confirmed by evidence in which state school staff described reasons for not providing live online lessons, including pupils' lack of access to technology or internet connections (Cambridge Partnership for Education, 2020). This reinforces the presence of a so-called 'digital divide' (Menzies, 2020). Furthermore, Green (2021) notes virtually all pupils attending independent school had their own computer at home, whereas state school pupils - particularly those eligible for free school meals – often lacked such resources. Differences between independent and state schools were not limited to technological provision, however. Green (2021) suggests the fee-paying nature of independent schools caused differences in parental expectations, which could explain why independent school pupils were more likely to be spending more time on remote learning than state school pupils (Cullinane & Montacute, 2020).

Numerous differences were observed between primary and secondary schools, including the following:

- Secondary schools were more likely to provide LRT than primary schools (Howard et al., 2021).
- Support for primary pupils to work remotely was less readily available, and learning tasks for younger pupils were less easily adapted for remote education (Howard et al., 2021).
- Primary schools were more likely to offer a narrower curriculum than usual, compared with secondary schools (Department for Education, 2021).
- Primary school teachers appeared more concerned about their students' progress than secondary school teachers (Müller & Goldenberg, 2021).

- Primary school teachers expected work returned by pupils more often than secondary teachers (Department for Education, 2021)

Brink et al. (2020) use a quantitative measure termed the ‘Resilience Indicator’ to investigate how well different schools had coped during the first lockdown. Their findings reveal that primary schools generally outperformed secondary schools on this measure. Schools' official inspection ratings showed minimal correlation with resilience scores, and school size had only a marginal impact. However, they point out variation between individual schools exceeded the gap between primary and secondary school averages, and suggest schools’ unique situations and leadership were important determinants in their ability to manage the disruption.

Broad similarities between the literature and my study are again evident regarding how different types of schools were impacted by COVID-19. While my survey evidence does not explore state versus independent schools, interview evidence confirms the contrast in provision between these sectors. Similarly, differences between primary and secondary schools are apparent and discussed in detail in chapters 4 and 5. Significantly, my study highlights these differences through the lens of science education, offering a subject-specific perspective that is largely absent from the existing literature.

2.5.2 Teaching and learning

Data about the amount of time UK children spent on home learning during the first lockdown vary (Sibieta & Cottell, 2020). As mentioned in the introduction to this literature review, estimates were reduced considerably from five hours per day (Andrew, Cattan, Costa-Dias et al., 2020) to 2.5 hours (Green, F., 2021). This discrepancy reflects methodological differences. Andrew et al. measured time spent in any ‘learning activity’ during one-hour timeslots, which they acknowledge would overstate actual learning time, and included broader activities such as reading alongside school-assigned work. Green, explicitly responding to this limitation, measured only time spent on school-assigned schoolwork. While Green's narrower definition provides a more accurate picture of formal schoolwork completion, these different approaches highlight how findings, and by extension their implications, were influenced by methodological choices.

Research indicates that children from more affluent families had, on average, spent more time learning than those from less well-off families, equating to up to 15 days less schooling for children from low-income families (Sibieta & Cottell, 2020). While this inequality is consistently documented across multiple studies, (e.g. Andrew, Cattan, Costa-Dias et al., 2020; Cullinane & Montacute, 2020; Green, F., 2021) most research relies on parental self-reporting, which may be subject to social desirability bias (Krumpal, 2013) or differing interpretations of what constitutes ‘learning time’ (Juster & Stafford, 1991).

Most studies found that home learning fell substantially short of typical classroom instruction time (e.g. Andrew, Cattan, Costa-Dias et al., 2020; Cattan et al., 2021b; Green, F., 2021; Sibieta & Cottell, 2020). However, Bubb and Jones’s small-scale Norwegian study (2020) presents contrasting findings, with 62% of 10–16-year-old pupils stating they had done more schoolwork at home than they would have usually done at school. This outlier finding is notable, though it must be interpreted cautiously given the small sample size and the Norwegian context, where better than EU-average educational infrastructure and support systems may have facilitated more effective remote learning.

Furthermore, the reliance on pupil self-reporting, rather than teacher or parental accounts, may explain the divergence from UK-based findings, as students may have had different perceptions of workload compared to actual learning time.

Not all pupils participated in remote education: Sibieta and Cottell's (2020) analysis of Teacher Tapp survey data (a short daily survey with typically 5,000-8,000 responses each day) reports that 20% of teachers had said most of their pupils had not. About half of the teachers said some pupils had participated; none said that all pupils had done so. Hodgen et al.'s survey of 49 UK mathematics teachers (2020) finds that disadvantaged pupils and those with lower prior attainment participated less and were less engaged when they did so. They identify three main reasons: poorer access to technology, lower levels of parental support, and the heightened challenges of lockdown which affected disadvantaged pupils. Cullinane and Montacute (2020) report that half of independent schoolteachers had received work back from most of their pupils, compared with just over a quarter of teachers in the most advantaged state schools, and only 8% in the least advantaged state schools. Pupils returning work was a way of judging whether they had engaged or not. Teacher expectations about this varied considerably (Department for Education, 2021). It is important to note, however, that these measures of participation relied on indirect indicators such as work submission rather than direct observation of learning engagement. Non-submission of work may reflect barriers to submission, such as lack of technology or parental incapacity to assist, rather than actual non-participation in learning activities. Furthermore, these studies do not differentiate between pupils who never engaged and those who engaged sporadically, potentially oversimplifying the complexity of participation patterns.

Various educational methods and materials were used by teachers during the first lockdown. Howard et al. (2021) report most schools providing third-party materials, including pre-recorded video lessons. When schools did use their own materials, mostly it was worksheets. Green (2021) reports similar findings. LRT was not widely used in state schools (Cullinane & Montacute, 2020), although it was clear that this had changed substantially by the second period of lockdown (Müller & Goldenberg, 2021), when overall provision had improved (Pensiero et al., 2021). Literature predominantly captures what materials were provided rather than how they were used or their pedagogical effectiveness. There is limited evidence about whether worksheets and pre-recorded videos were appropriately designed for independent learning or simply repurposed from classroom contexts. Furthermore, the shift toward increased LRT by the second lockdown (Müller & Goldenberg, 2021), while representing improved provision, does not indicate whether this was driven by pedagogical considerations or external pressure from parents and policymakers.

Research indicates the quality of teaching and learning were compromised by education being provided remotely, although objective measures of this were hard to obtain. Howard et al.'s review of research (2021, n.p.) states that *"pedagogy was often less effective"*, with pupils usually being set less work than normal, and with some schools prioritising assessment-related content while eliminating broader curriculum elements and enrichment opportunities. The claim about pedagogical effectiveness, however, appears to be based primarily on teachers' own subjective assessments of their teaching quality, rather than direct observation or learning outcome measures.

Though varying expectations about how often children should submit work were reported, the Department for Education (2021) suggests 85% of teachers were expecting something returned at least weekly. Andrew et al. (2020) find that most pupils were submitting work when it was expected. However, this differed substantially according to families' financial circumstances, with children from lower income families less likely to submit work than their more affluent peers.

The evidence presented in chapters 4-6 addresses some of the shortcomings in literature described above. While subjective teacher perceptions about teaching quality also feature, the qualitative data collected in my study allows examination of contextual and pedagogical factors shaping teachers' predominantly negative perceptions of their remote teaching practice.

2.5.3 Diversity of learner experiences

Statistical data give some sense of how different the experiences of remote education could be, while also emphasising that research published at different times during the pandemic was usually capturing snapshots at specific moments during an evolving, dynamic context. In the UK Green (2021) reports that a fifth of pupils, over two million children, were doing less than an hour of schoolwork per day around a month into the first lockdown. However, some did none, while only 17% did over four hours per day. These findings, based on parental estimates of time spent on schoolwork, cannot capture the quality of learning or engagement, and the online survey methodology may have systematically excluded families with the poorest digital access.

Statistical data also indicate how specific groups of learners experienced lockdown differently: the report by ImpactEd (2021) suggests year 10 and 11 pupils experienced greater challenges than younger pupils with motivation for learning, for example, both during lockdown and afterwards when back in school. Various factors seem to have contributed to this, including difficulty getting family help when they didn't understand schoolwork, and exam uncertainty. However, ImpactEd's findings rely predominantly on pupil self-reports, which may conflate genuine motivational deficits with the external pressures of exam uncertainty and the unprecedented disruption to assessment arrangements.

Bayrakdar and Guveli (2020) report that significantly less time was spent on home learning for children who normally received free school meals, those with single or less educated parents, and those with Pakistani or Bangladeshi backgrounds. However, these findings, drawn from parental reports in April 2020, measure time spent rather than learning achieved, and the online survey design raises questions about whether the most disadvantaged families, without reliable internet access, were adequately represented. The authors speculate that ethnic inequalities were related to the pre-existing issue of lower socioeconomic background, a situation potentially exacerbated by a lack of language skills and other societal inequalities.

Statistical analyses such as those mentioned above stratify experiences by using specific metrics; useful in simplifying a complex picture, but as Howard et al (2021) emphasise, they do not reflect individuals' experiences, which varied much more widely. However, while acknowledging this limitation in the existing literature, Howard et al.'s (2021) own synthesis, as a secondary review, faces the inherent constraint that it can only be as nuanced as the primary studies it draws upon. This highlights a broader issue in COVID educational literature: the tension between rapid large-scale data collection needed for urgent policy responses and the slower, more resource-intensive qualitative research needed to understand individual experiences in depth.

Experiential differences were not just between communities or schools; the educational experience could be different for pupils in the same class. The idea of *“everyone all being in this together”* was inapplicable in many cases (Selwyn & Jandrić, 2020, p991). In their theoretical analysis early in the pandemic (May-July 2020), these authors argue that "*There has not been one homogenous remote schooling experience within any individual school, let alone across a whole city*" (Selwyn & Jandrić, 2020, p992). Howard et al. (2021, n.p.) recognise that complex variations could arise because of interactions between “*macro- and micro-level influences*”. Hence, the many variables within the home were multiplied by external variables such as what schools and individual teachers were doing. These authors suggest the existing literature was unlikely to capture the full diversity of experience because it was based on large scale surveys rather than in-depth accounts of experience. The degree of complexity reinforces Ofsted’s point (2020b, n.p.) that, though children with better home support had generally fared better educationally, “*This shouldn’t be confused for a simple message about privilege versus deprivation.*”

Barriers to educational progress were not always directly related to education. Oswald et al. (2020) speculate that children from low socioeconomic backgrounds could be disproportionately affected, psychologically, by ‘screen time’ because they were less likely to experience the counteracting benefits of ‘green time’ – restorative periods spent in natural environments. The authors acknowledge limitations in existing data and suggest further research would be needed to establish causality. Moreover, applying pre-pandemic evidence about recreational screen time to COVID lockdown conditions risks conflating discretionary technology use with remote education use.

Complexity in lockdown experiences also stemmed from the way multiple disadvantages intersected and interacted. Children with limited academic support from parents faced disproportionately greater challenges when combined with poor internet access, exemplifying how educational barriers were compounded (Pensiero et al., 2021). Conversely, these effects also intensified advantages for more privileged students, magnifying existing inequalities. It is often unclear whether claims about the compounding of effects are based on formal tests of statistical interactions or simply on observations that multiply disadvantaged groups fared worse than more privileged groups.

The qualitative evidence presented in chapters 4-6 addresses some of the limitations in literature, articulated above. Personal testimonies from teachers and parents capture the diversity of remote education experiences while illuminating barriers in granular detail that large-scale surveys cannot provide.

2.6 Social Factors

This section examines two predominant social factors identified in the research literature. The first encompasses disadvantage, inequality, and technology access barriers for pupils, which became particularly pronounced given online education's technological requirements (Anders et al., 2020; Andrew, Cattan, Costa Dias et al., 2020; Children’s Commissioner, 2020; Menzies, 2020). The second factor addresses mental health and wellbeing concerns affecting both learners and teachers. Multiple studies raise concerns about the potential for declining mental health among children resulting from heightened screen-time (e.g. Brink et al., 2020; Guessoum et al., 2020; Mheidly et al., 2020), while the effects of lockdown conditions and the health impacts of the pandemic itself are also documented (e.g. Hodgen et al., 2020; Howard et al., 2021).

2.6.1 Disadvantage, inequality and its effect on technology access

Several sources emphasise that the pandemic had worsened existing inequalities (e.g. Children's Commissioner, 2020; Menzies, 2020; Selwyn & Jandrić, 2020), while others foresee a long-lasting legacy of inequality likely to be felt most acutely by groups such as the young, self-employed and those on low incomes (e.g. Blundell et al., 2020).

Statistical data illustrate that children in lower-income households usually had poorer access to educational resources at home (Green, F., 2021; ImpactEd, 2021). This could mean access to a smartphone rather than a larger screen device or having to share a device with others in the household (ImpactEd, 2021). Smartphones' smaller screens made it harder to see details, and, where bandwidth was low, videos intended to scaffold learning were harder to watch (Müller & Goldenberg, 2021; Tienken, 2020). However, participation in online education was not just about technology; it required a suitable home environment. ImpactEd's (2021) survey of over 60,000 pupils aged 6-18 across England over a seven-month period found that pupils from socially disadvantaged backgrounds gave their home learning environment a score 6% lower than their better-off peers; they had less access to a suitable workspace, and fewer opportunities for physical exercise. Their homes were likely to be more crowded and noisier, without quiet areas for learning (Children's Commissioner, 2020). These pupils spent less time on remote learning (Hodgen et al., 2020), which Andrew et al. (2020) suggest was partly due to the poorer availability of home learning resources, making learning less interesting and enjoyable. The problem was worse for younger pupils (Howard et al., 2021), probably because they needed more adult support (Müller & Goldenberg, 2021).

While technology access was essential for online education participation, the challenge proved far more complex than a simple "*dichotomous measure*" of having or lacking devices (Williamson et al., 2020, p110). Tienken (2020, p151) argues that using "*the narrow lens of access to resources*" overlooked the crucial distinction between possessing resources and having the capability to convert them into learning outcomes. Simply providing devices and internet access proved insufficient when students faced inadequate bandwidth that prevented video streaming, smartphone-only access unsuitable for sustained learning, or single devices shared among multiple family members. Moreover, students experiencing poverty lacked the "at the elbow" support - immediate help when stuck or confused - that their better-off peers could access from available parents or skilled siblings. Selwyn et al. (2020) suggest that this resource-focused perspective problematised individuals and ignored wider social inequalities. Lockdown conditions tended to disproportionately damage the employment and financial wellbeing of less well-off households (Andrew, Cattan, Costa Dias et al., 2020), exposing children to compounding stressors such as food and housing insecurity, increasing their anxiety as a result (Tienken, 2020).

By taking vulnerable children out of school, lockdown removed a source of food, and withdrew opportunities for physical activity and a 'line of sight' for monitoring welfare (Children's Commissioner, 2020). Hence, despite programmes to loan laptops to pupils lacking access, (Edge Foundation, 2020;

Howard et al., 2021; Sibieta & Cottell, 2020), multiple disadvantages continued to undermine these children's capacity to learn. As Williamson et al. observe, "*Economic realities do not go away as a result of a laptop scheme*" (2020, p111). The authors are critical that the rush to respond to the crisis had produced quick fixes with no long-term vision: no thought had been given to how families would fare when schemes were stopped, for example.

2.6.2 Wellbeing and Mental Health

The concept of wellbeing is not precisely defined in the research field (Pollard & Lee, 2003; The Children's Society, 2020). Capturing people's own views about their lives, termed 'subjective' wellbeing, is considered the best assessment, as opposed to others' views or measures (The Children's Society, 2020). Literature examining young people's wellbeing during the pandemic draws extensively on subjective data from individuals themselves, as well as from parents and teachers (e.g. Brink et al., 2020; Child Poverty Action Group, 2020; Müller & Goldenberg, 2021; NSPCC, 2020), indicating that subjective wellbeing serves as the primary construct in COVID-19 research. However, the lack of conceptual precision creates challenges when synthesising findings across studies, as researchers may measure different constructs while employing the same overarching label. A further limitation is that existing literature has concentrated heavily on psychological outcomes such as anxiety, depression and post-traumatic stress disorder (Rajkumar, 2020; Xiong et al., 2020), with physical activity often examined primarily as a predictor of mental health rather than as a wellbeing outcome in its own right (Giuntella et al., 2021). This means claims about wellbeing impacts may overlook physical aspects such as sedentary behaviour, sleep disruption, or reduced fitness; a significant omission given wellbeing's multidimensional nature.

Some literature raises concerns about anticipated rather than directly observed effects, drawing on previous research for context: in their narrative literature review, Guessoum et al. (2020) predict lockdown will cause an increase in cases of post-traumatic stress disorder in children, citing similar outcomes from quarantine measures during the 2003 SARS pandemic - though SARS quarantine measures were different, being shorter and occurring in different social conditions to COVID-19 lockdowns (Pandey et al., 2020).

Both teachers and pupils experienced wellbeing and mental health impacts from pandemic conditions and lockdown restrictions during COVID-19 (Müller & Goldenberg, 2021). These effects on each group are examined separately in the following discussions.

2.6.2.1 Effects of lockdown on learners

Research presents mixed findings regarding lockdown's impact on young people's mental health and wellbeing (Millar, R. et al., 2020). While ImpactEd (2021, p7) characterise average wellbeing as "*stable*" across their sample of over 60,000 pupils, they acknowledge this masked significant variation by demographic group. Other studies document substantial mental health challenges: Child Poverty Action Group report “*Significantly reduced wellbeing*” of many young people (2020, p7), with academic anxieties, family concerns and experiences of bereavement taking a “*considerable toll on their social, emotional and mental health*” (Howard et al., 2021, n.p.). Brink et al. (2020) report that over half the parents in their large-scale survey stated their children had been more stressed or anxious than normal. Death and dying dominated primary school children's questions about the pandemic in McCrory and Gatt's small-scale study (2020), while Childline counselling sessions related to the pandemic raised numerous concerns, including some young people having suicidal thoughts, and the withdrawal of support for existing mental health conditions because of lockdown (NSPCC, 2020).

Various reasons for the issues described above are suggested, with confinement and lack of opportunities for socialising significant (Child Poverty Action Group, 2020; Howard et al., 2021). For some young people, being in constant, close proximity with members of their household was stressful (NSPCC, 2020). For others the absence of peers was beneficial, particularly if the environment at home was calm (Müller & Goldenberg, 2021). Although social withdrawal might otherwise be considered a psychiatric symptom (Guessoum et al., 2020), during lockdown online spaces could compensate for this, though the additional screen-time involved was a concern expressed by teachers (Müller & Goldenberg, 2021). Prolonged time using screens is associated with increased depression, stress and anxiety (Madhav et al., 2017; Mheidly et al., 2020), but this evidence is currently limited (Khouja et al., 2019; The Children's Society, 2020). Research by Oswald et al. (2020), largely reviewing pre-pandemic studies, suggests both neurobiological and social hypotheses for detrimental effects; screen-time could displace behaviours important for mental health such as physical exercise and sufficient sleep, for example. This is somewhat limited by the pre-lockdown context of the review, which risks conflating discretionary technology use (such as choosing to play games) with mandated online education. Mheidly et al. (2020) suggest that young people were more prone to exhaustion and burnout during the pandemic because of the combination of screen-time effects with other lockdown related stressors.

2.6.2.2 Effects of lockdown on teachers

Effects on teachers' wellbeing and mental health reported in literature (e.g. Allen et al., 2020b; Müller & Goldenberg, 2021) are often comparable to those affecting pupils. For example, teachers were concerned about their own screen-time, especially if they were teaching their normal timetable using LRT (Müller & Goldenberg, 2021); a factor likely to have caused higher anxiety levels among teachers from independent schools during lockdown (Allen et al., 2020b). The inference of causality here is not substantiated by data.

The situation was variable; levels of work-related anxiety reportedly spiked in the first week of lockdown, but decreased quite quickly and were slightly lower than normal during the second month: some state school teachers reported being able to find more time for their own families (Open Data Institute, 2020), which could explain this observation. This temporal pattern is based on aggregated data from different respondents at different time points rather than tracking the same teachers over time, making it difficult to distinguish between genuine population-level changes and sampling variation. Although many teachers experienced degrees of anxiety, related to factors such as uncertainty about the pandemic (McCrory & Gatt, 2020) headteachers were much more likely to experience higher anxiety than classroom teachers (Allen et al., 2020b). At its worst a quarter of headteachers were feeling either "*completely overwhelmed by my work challenges*" or "*very anxious and stressed because of my work*" (Open Data Institute, 2020, p34). However, the absence of pre-pandemic baseline data for headteacher stress makes it difficult to determine how much of this situation was attributable to COVID-19, and how much reflected longstanding pressures in senior leadership roles.

Lack of social interaction affected teachers less than pupils, but was still significant: in focus groups teachers said they missed collaboration with colleagues and the social culture of school (Müller & Goldenberg, 2021). The lack of collaboration increased a sense of isolation, often accompanied by increased workload associated with remote education. The direction of causality remains unclear: whether isolation increased perceptions of greater workload, or whether increased workload reduced opportunities for collegial interaction. Being unable to tell how well pupils were doing was also stressful, especially when pupils were known to be at risk at home. For many teachers, particularly in schools serving socially disadvantaged areas, concerns about the wellbeing of pupils took priority over those about academic progress (Hodgen et al., 2020; Open Data Institute, 2020).

Overall, social factors were a highly significant determinant of how well children could learn during remote education. Though superficially related to technology access, structural inequalities were often at the root of disadvantages, and revealed how these factors had been "*hiding in plain sight*" for years (Menzies, 2020, p2). While my study does not explicitly examine social factors, they spontaneously arose during interviews with teachers and parents, highlighting how lockdown experiences embodied the intersection of multiple influences. The issues raised in this section therefore provide relevant context for interpreting evidence discussed in chapters 4-6. Teachers' accounts illustrate this complexity: their reports of declining physical health from prolonged sedentary screen-time, contrasting with their normally active classroom roles, reveal how the educational literature's focus on mental wellbeing has obscured other consequential aspects of lockdown. This omission is particularly striking given the interdependence of physical and mental health (Giuntella et al., 2021).

2.7 'Micro' aspects of Science Education

Evidence about science education during the pandemic is limited. Consequently, the available articles constitute a limited field, included as a distinct theme due to this research's focus. Since these studies concentrate on the operational aspects of instruction, this theme is termed 'micro'; the literature examines how educators addressed specific teaching challenges or delivered particular content knowledge. Research on science education from a policy or 'macro' perspective has been classified as a separate thematic category (see section 2.8).

The accuracy of observations about the shortage of subject-specific perspectives in literature (e.g. Hodgen et al., 2020; Howard et al., 2021) is apparent from the absence of sources documenting science teachers' remote education experiences during the pandemic. Where science teachers' viewpoints are examined, they primarily emphasise the difficulties in teaching practical aspects of the subject remotely (e.g. Erumit et al., 2021; Howard et al., 2021; Rodríguez et al., 2021), a difficulty shared by teachers in schools and higher education.

In the UK, the Association for Science Education's main journal, 'School Science Review', featured articles predominantly falling into two categories: those containing suggestions for remote education activities and resources, and those examining how the pandemic could stimulate science teaching or curriculum re-evaluation. In the former category, Gibbs (2020a) describes some home-made physics videos freely available to use during lockdown teaching, while Taylor (2020) documents a ‘science at home’ practical handbook for year 7 and 8 pupils. In the latter category, Harris (2020) uses local health authority data to demonstrate how graph-based modelling could help pupils examine pandemic trajectories, and Khishfe (2022) proposes an activity for teaching pupils about infectious disease transmission. Auty (2020) draws on the 2-metre distancing rule to explore diffusion in air, and Borrows (2023) links lateral flow tests to simple ink chromatography performed in science lessons. Loughlin (2022) suggests COVID-19 provides a valuable context for teaching students to identify misinformation, arguing for science education to address this to prevent problems after pupils leave school. Turning to curriculum change, Reiss (2020) cautions against ‘knee-jerk’ responses, but acknowledges that COVID-19 does offer sufficient justification for curriculum reform. Chadwick and McLoughlin (2022) contend that, as the ‘ultimate’ socio-scientific issue, the pandemic provides an unparalleled opportunity to develop scientific literacy; something discussed further in section 2.8. Notably, the contributors to this professional journal during the pandemic appear to be academics and former practitioners rather than teachers actively navigating lockdown teaching in real-time. These practical suggestions therefore represent theoretical proposals about what could be implemented, rather than reflections on lived classroom experience during the crisis. Considering the accounts in chapters 4 and 5, it is perhaps understandable why many practising teachers would have been unable to devote time to contributing journal articles, but in any case, the challenges teachers face in engaging with research practices are well established in the literature (e.g. Borg, 2010; Coldwell et al., 2017).

Several other sources describe remote school science activities which had been carried out by pupils. Bubb and Jones (2020) specify migratory bird photography in their Norwegian study, and the New Zealand based article of Yates et al. (2021) documents both hands-on practical activities at home and tasks using digital technology, such as virtual frog dissection and making stop-motion movies of the human digestive system. Such approaches were far from universal: in the United Arab Emirates for example, science teachers focused more on teaching science knowledge rather than disciplinary methods (al Darayseh, 2020).

Several opportunities and advantages for teaching science remotely are suggested, though positive framing warrants scrutiny, as some claims redefine losses or constraints as gains. Erumit et al. (2021) report that some pre-service teachers in Turkey thought online science education was advantageous because the absence of practical experimentation increased safety. This perspective may reflect context-specific attitudes toward practical work, which differ markedly across international educational settings (Holman, 2017), but fundamentally contradicts the well-established understanding that practical work is central to authentic science learning (Hodson, 1990; Millar, 2004). Others suggest professional benefits from using technology in teaching: some teachers reported that remote demonstrations were easier (Müller & Goldenberg, 2021), and Taylor (2020) suggests the experience had shown ample scope for pupils to perform simple and safe practical work at home. Describing a primary teacher's experience, Spring (2023) reports several improvements following the pandemic: integration of digital platforms had been maintained to support pupils' learning, and the amount of teaching time for science had increased, with more focus on practical enquiry.

The limited scope of 'micro' aspects of science education during lockdown suggests that teachers' experiences may have been defined less by subject characteristics than more generic aspects of remote education. Beyond the disruption to practical work, which similarly affected other subjects in England (Ofsted, 2020a), literature reveals few distinctive features to differentiate science education from other subjects during this period. This does not imply that other differences did not exist; merely that literature does not reveal what they were. Details of teachers' and parents' experiences of providing remote science education, contained in chapters 4-6 of my study, highlight its valuable contribution to a field in which there is a demonstrable and acknowledged lack of subject-specific perspectives (Macias et al., 2022; Howard et al., 2021).

2.8 Wider contextual aspects

Dillon and Avaraamidou argue that the pandemic presented "*previously unthinkable challenges*" for education, and science education especially (2020, p2). They pose fundamental questions such as "*How well has the science curriculum prepared the world's public for COVID-19?*" and "*Is science education research producing knowledge that protects society from catastrophic events?*" (Dillon & Avraamidou, 2020, p1). These questions exemplify this thematic category, which, though less directly relevant to the research questions of this study, provides essential broader context. It differs from the previous science education theme through its macro-level focus, and its scope extending beyond science education itself. The most frequently identified category concerns public understanding of science, alongside related issues of trust in science and scientists, and online misinformation dissemination. Another significant category examines the educational technology ('EdTech') industry, exploring its role and influence throughout the pandemic period.

2.8.1 Public Understanding of Science, Trust in Science, and Misinformation

The COVID-19 pandemic provided “*a special opportunity to get a pulse on how well our society understands science and mathematics processes*” (Bloom et al., 2020, p1). With politicians regularly calling on science and scientists in their frequent televised briefings, the public arguably needed the ability to understand how science was ‘done’ more than ever before (Erduran et al., 2020). What was revealed, however, was not just a poor understanding of the nature of science (Bloom et al., 2020), but a “*deliberate mistrust of the science and scientists*” from the public and politicians alike (Dillon & Avraamidou, 2020, p1).

Limited scientific understanding and mistrust of scientists represent interconnected problems primarily attributed to deficiencies in science education, especially at the school level. Borrows (2023) links the increased prominence of the ‘anti-vaxxer’ movement during the pandemic directly to science education failures. However, Fotou and Constantinou (2020), question how the average individual, equipped only with basic knowledge of school biology, could reasonably be expected to comprehend policies and guidance. They argue that forming rational and informed views on aspects of epidemiology is difficult for people with such basic, limited science knowledge. Dillon and Avraamidou emphasise that to understand the situation required understanding of “*viruses, transmission, incubation and vaccination*”, stressing that, in the circumstances, such knowledge constituted "*life and death issues*" (2020, p1).

Shortcomings of science education predate the COVID-19 crisis; however, the pandemic probably represented a more compelling exemplification of their consequences than any previous phenomena. Decades-old appeals to address 'scientific illiteracy' do not reflect a lack of education per se; poor scientific knowledge during the pandemic was exhibited by "*politicians, policymakers and business leaders*," (Dillon & Avraamidou, 2020, p4). In light of COVID-19's complex, interdisciplinary challenges, it is issues such as the compartmentalisation of school science which face scrutiny (e.g. Erduran, 2020a), reflecting persistent debates that can be traced back to the last century, notably the tension between prioritising scientific content knowledge versus developing process skills and scientific literacy (e.g. Billingsley & Ramos Arias, 2017; Osborne & Millar, 1998; Osborne & Dillon, 2008).

Equally problematic was widespread misunderstanding of scientific processes. Dillon and Avraamidou reflect that school science emphasises factual content, while "*What scientists do, what kinds of data they collect and how they analyse those data to form conclusions, remain a mystery for most young people*," (2020, p2); moreover, they suggest, the subject is presented as "*a straight-forward, logical, empirical and reliable enterprise*" (2020, p2). Similarly, Bloom et al. contend that textbooks and websites omit the "*messy side*" of science, failing to convey the tentative nature of scientific knowledge (2020, p2). They suggest public awareness of this uncertainty might have reduced scepticism toward evolving medical recommendations and expert uncertainty. Erduran et al. (2020, n.p.) draw attention to the limitations of GCSE assessment: "*Despite decades of* *reform in the assessment of practical science in England at GCSE…these assessments tend to promote a narrow view of the scientific method whereby students carry out practical work that is formulaic and more of a hoop-jumping exercise – very far from the ways in which scientists are currently working to address key challenges such as the COVID-19 emergency*".

Loughlin (2022) contends that unclear official guidance fuelled public scepticism regarding the pandemic, noting that false narratives frequently spread through social media platforms, sometimes promoted by public figures whose statements contradicted available scientific evidence. Supporting evidence shows that immediately prior to UK lockdown, 42% of the population relied on social media for COVID-19 information—a figure lower than traditional news outlets but substantially exceeding usage of official health guidance sources (Boyd, 2020). With social media a major source of 'fake news', conspiracy theories and misinformation, ranging from the virus's origins to unproven cures, this highlights the need for "*meaningful and functional science education, and in particular biology and health literacy*" (Fotou & Constantinou, 2020, p14). Subsequent research has established a strong correlation between belief in COVID-19 conspiracy theories - specifically that the pandemic was orchestrated to mandate global vaccination - and reliance on 'alternative media' information sources (Duffy & Dacombe, 2023).

Overall, COVID-19 sharpened the focus on some of the limitations of current practice in science education and revealed, through various phenomena, that science education did not prepare many people well for such a crisis. Dillon and Avraamidou suggest "*As a global society, or as a group of interlinked societies, this has not been our finest hour*" (2020, p2).

2.8.2 The EdTech Industry and the Pandemic

'Edtech' (Educational technology) is a complex and multifaceted concept (Mirrlees & Alvi, 2019) that resists straightforward definition. Selwyn and Jandrić argue that the edtech community has failed to define itself, and is "*a constant churn of labels, movements and cliques*" (2020, p996). For this section's discussion the following short definition suffices: "*An industry and commercially available digital technologies used by teachers and learners for the means and ends of something called 'education'*" (Mirrlees & Alvi, 2019, p16).

Despite edtech having developed over many years (Corcoran, 2013), with technology "*deeply interwoven*" in the education and skills sector (Menzies, 2020, p4) the industry has never encountered an opportunity like that presented by COVID-19. As Williamson et al. state, "*Many edtech businesses have in fact been seeking to finesse the model of 'distance' education for years*" (2020, p109). With online education at the heart of educational provision, it was predicted a bright future could be expected for edtech companies in the UK (Cambridge Partnership for Education, 2020). However, literature discussing the unprecedented conjunction of business, education and a global pandemic often adopts a critical stance. Concerns emerge regarding edtech's commercial orientation and its influence on public education (e.g. Selwyn & Jandrić, 2020; Williamson et al., 2020), and fears about the erosion of individuals' privacy rights (e.g. Paris et al., 2022; Privacy International, 2020).

Williamson et al. direct criticism at "*certain actors in the edtech industry*" (2020, p108) for treating the pandemic as a business opportunity for changing how education is perceived and practised in the long term. Rather than an emergency response to a global health crisis, they suggest some companies would use ‘pandemic pedagogy’ as “*a rapid prototype of education as a private service*” (Williamson et al., 2020, p109). Though acknowledging many companies provided useful tools and content, they suggest the marketing of these products represented a chance for the edtech industry “*to prove its benefits, to extend its reach, and to grow market share*” (Williamson et al., 2020, p109). Providing free access to services in the crisis might not have been entirely charitable either, with the use of user-generated data as an established route to profit (Teräs et al., 2020). Views like these were recognised by the World Bank (2020), who suggest policymakers and parents were not adequately informed to understand what was needed from edtech vendors, nor what was being offered. Selwyn criticises organisations such as the World Bank, however, suggesting that the pandemic was helping them establish a “*digitally driven ‘new normal’*” (Selwyn & Jandrić, 2020, p991). Other authors’ views resonate with Selwyn’s prediction: Williamson suggests an acceleration of an “*algorithmic worldview*” into education systems had occurred (2021, p15), while Koenig (2020) notes that market trends indicate a growth of direct-to-consumer edtech in which the audience is not teachers, but parents. Teräs et al. urge educational leaders to consider whether decisions being made around edtech during the pandemic were “*the best way to proceed for the future*” (2020, p874).

The public understanding of science and the role of the edtech industry are important features in the contextual background of this study, relevant to its dual focus on science education and digital technology. The pandemic provided an unprecedented opportunity for teachers and parents to witness scientific understanding, process, and communication unfolding in real time through everyday life and media coverage (Erduran, 2020). Simultaneously, the imperative to continue science education remotely produced the most widespread convergence of education and digital technology ever seen, with the edtech industry positioned as both essential solution-provider and, potentially, opportunistic profiteer (Williamson, 2020; Teräs, 2020).

2.9 Educational literature since the end of the pandemic

To reiterate, the pandemic officially ended in May 2023 (United Nations, 2023). Using comparable literature search methods to those in 2022-23 (see section 2.1.1), a further review conducted in 2025 reveals that scholarship connecting education and COVID-19 has evolved, reflecting the cessation of the global health emergency and the return to pre-pandemic conditions. Post-COVID educational research has shifted from crisis management to long-term impact assessment and recovery, with several interconnected concerns now dominating the literature.

This shift renders the four-category literature classification system applied earlier (section 2.2) less appropriate for publications appearing since approximately late 2022. Practitioner-focused resources for remote science teaching have ceased: examination of article titles in the Association for Science Education's primary journal, *School Science Review*, a key source of such materials for schoolteachers during the pandemic, shows the final explicit pandemic reference occurred in June 2022. Academic commentaries reflecting expert concerns and raising urgent questions, which proliferated during 2020-2021, have largely subsided. Large-scale organisational research has shifted from documenting the immediate events and impacts of remote education toward tracking persistent effects such as learning loss, chronic absenteeism and mental health deterioration, which now characterise post-pandemic school-level research concerns. Meanwhile, academic journal articles have become noticeably focused on higher education contexts, particularly assessing lasting changes to pedagogical practices.

The shift in literature focus, away from remote education practices and pedagogies, does not necessarily indicate that pandemic experiences have faded from teachers' practice, though Talagala and Talagala's (2024) large-scale analysis of global internet search trends between 2019 and 2024 suggests many teachers may have abandoned online education tools, at least temporarily. Searches for digital content creation tools and collaborative platforms such as Zoom spiked during 2020-2021 but subsequently returned to pre-pandemic levels. Nevertheless, these data cannot capture more subtle lasting pedagogical effects, such as continued use of online resources discovered during lockdown or shifts in the nature of homework tasks assigned to pupils.

Several longitudinal studies now track cohorts affected by COVID school closures. In the UK, the National Foundation for Educational Research is tracking pupils who were in Key Stage 1 during the first school closure (2020/21) through to Years 4 and 5 in 2023/24 (Rose et al., 2024), examining both overall attainment recovery and persistent disadvantage gaps. At secondary level, the COVID Social Mobility and Opportunities (COSMO) study (Yarde et al., 2023) has recruited over 13,000 young people who were in Year 11 in 2020/21, following them through post-16 transitions and into higher education and employment to examine how the pandemic affected socio-economic inequalities in life chances. However, neither study tracks subject-specific learning trajectories or pedagogical changes within individual disciplines such as science, humanities, or creative subjects. Hence, though the following sub-sections capture key areas of post-pandemic concern in education, significant gaps in research and knowledge remain.

2.9.1 Learning loss

Where it is oriented towards schools, recent academic literature about COVID-19's educational legacy is predominantly focused on learning loss. With more attainment data now available, several studies reveal actual impacts of pupils learning under lockdown conditions, in contrast to earlier literature in which impacts were usually predicted but not confirmable (see section 2.4.4.1). UK children lost around a third of expected learning during the pandemic, with pupils requiring approximately 60-65 additional days of schooling (Major et al., 2021), while a global meta-analysis including UK data found losses equivalent to 35% of a typical school year's progress (Betthäuser et al., 2023). Gajderowicz et al. (2025), analysing data from all countries in the 2023 TIMSS assessment, concluded that attainment in science and mathematics across all countries involved was significantly lower than would have been expected normally. These findings align with Storey and Zhang's (2024) meta-analysis of 30 studies into global post-COVID learning losses, which identified particularly severe impacts on reading and mathematics.

In their large-scale study in the United States, Kowalski and Peters (2024) suggest smaller learning losses for science than for mathematics or reading, speculating that lower curriculum time for science and variations in how effectively different subjects' assessments captured remote learning outcomes may explain the discrepancy. Blackwell et al.'s (2024) smaller scale US study confirms learning losses in reading and mathematics, and suggests children of parents with lower levels of education were disadvantaged most. This complements findings suggesting learning losses were greater for pupils who were already lower attainers (Gajderowicz et al., 2025). These intersecting dimensions of disadvantage - parental education, prior attainment, and socioeconomic status - align with the differential recovery patterns observed in both the NFER longitudinal study (Rose et al., 2024) and COSMO's analysis of GCSE outcomes (Anders et al., 2023), confirming that pandemic impacts systematically widened pre-existing educational inequalities. Such patterns were predicted early in the pandemic: Engzell et al.'s (2021) analysis of Dutch primary schools found learning losses were up to 60% larger among students from less educated parents, establishing that parental education operated as a key determinant of pandemic resilience even in the initial school closure period.

Notwithstanding widespread learning losses, it is notable that England's science performance remained robust: the most recent round of TIMSS assessments in 2023 found performance of year 5 and year 9 pupils was significantly higher than in the previous round before the pandemic (Golding et al., 2024), while England's 2022 PISA performance in science showed little difference from the previous assessment in 2018 (Ingram et al., 2023). Together, these outcomes suggest pupils in England learning science in the immediate aftermath of COVID-19 disruption coped no less well than previous cohorts who had not experienced disruption. Nevertheless, while effect sizes vary slightly across studies - probably attributable to differences in samples, year groups, methods of assessment and countries of origin - literature consistently demonstrates that the disruption caused by COVID-19 caused measurably significant learning losses.

2.9.2 Achievement gaps

Beyond absolute learning losses, the pandemic has systematically widened pre-existing achievement gaps. The NFER longitudinal study (Rose et al., 2024) tracking Key Stage 1 pupils found that while the overall 'COVID-19 gap' had largely closed by 2024, with average attainment recovering to pre-pandemic expectations, the 'disadvantage gap' between pupils eligible for free school meals and their peers remained persistently wide at around 6-7 months' progress in both reading and mathematics. This differential recovery - where disadvantaged pupils experienced both greater initial losses and slower catch-up - reflects what Major et al. (2024) characterize as a 'double whammy': both overall declines in achievement and unprecedented widening of socioeconomic gaps. The COSMO study's analysis of GCSE Teacher Assessed Grades (Anders et al., 2023) similarly revealed significant gaps by socioeconomic background even after controlling for prior attainment, with compounding effects for pupils who experienced financial hardship or health vulnerabilities during the pandemic. These patterns extend beyond academic attainment to encompass differential impacts on mental health, school attendance, and access to recovery support, suggesting the pandemic has not simply delayed education but fundamentally reshaped educational inequalities for affected cohorts.

2.9.3 Mental Health

Mental health challenges represent one of the pandemic's most profound impacts: the prevalence of probable mental disorder in children aged 8-16 years rose from 12.5% in 2017 to 17.1% in 2020, with rates remaining elevated through 2023 at 20.3% (Newlove-Delgado et al., 2023). For young people aged 17-19 years, rates increased from 10.1% in 2017 to 25.7% in 2022, stabilising at 23.3% in 2023 (Newlove-Delgado et al., 2023). The specific mental health manifestation of eating disorders increased dramatically: among 17-19 year olds, rates rose from 0.8% in 2017 to 12.5% in 2023, with incidence four times higher in young women than young men (Newlove-Delgado et al., 2023). Research identifies vulnerability among certain groups: shared risk factors for anxiety, depression and loneliness included being female, being older (18-19 years versus 13-17 years), experiencing financial difficulties, and having pre-existing mental health issues (Rouquette et al., 2024). A large-scale comparative study found that depression cases were 8.5 percentage points higher among young people assessed during the pandemic than among a comparable cohort assessed before 2020 (Montero-Marin et al., 2023).

In all the studies referenced above, attributing causality remains complex: pre-pandemic data already showed worsening child mental health trends throughout the 2010s (Pitchforth et al., 2019), making it difficult to isolate pandemic-specific effects from longer-term societal changes.

2.9.4 Chronic absenteeism

Chronic absenteeism, which doubled to 22.3% during 2022/2023 (Eyles, 2023) remains far above pre-pandemic levels of 10.9% despite recent improvements (Department for Education, 2024), while achievement gaps have widened, with disadvantaged pupils now 5-6 months behind their peers (Major et al., 2024). Projections suggest educational damage will impact GCSE results well into the 2030s (Major et al., 2024). Secondary school absenteeism has proven particularly resistant to improvement, with 87% of secondary teachers reporting increased absenteeism compared to 62% of primary teachers (Save the Children, 2024). Pupils with social, emotional and mental health needs have been disproportionately affected, experiencing over twice the absence rates of their peers by autumn 2022, with this group also growing by 37% between autumn 2019 and autumn 2023 (Hunt et al., 2024). Disadvantaged pupils now miss an additional 3.2 days per term compared to their peers, up from 2.1 days pre-pandemic, representing a 'double widening' of the absence gap (Hunt et al., 2024). Research increasingly links persistent absenteeism to emotionally-based school avoidance, driven by anxiety and mental health difficulties that intensified during the pandemic (Lester and Michelson, 2024).

2.10 Concluding comments

This literature review has examined the extensive but uneven scholarship on education during COVID-19, revealing both its breadth and limitations. Through the lens of science education, literature generated during the pandemic has been analysed across four distinct categories: pedagogical resources, large-scale quantitative studies, smaller-scale institutional research, and broader academic commentaries. While these collectively illuminate the disruption to education systems globally, they reveal a persistent and acknowledged gap: the shortage of subject-specific perspectives, particularly for science education at school level.

Using thematic analysis has identified several interconnected challenges, spanning online education delivery, educational outcomes, parental support, school-related factors, social issues, and wider contextual aspects. Science education faced distinctive challenges - most notably the disruption to practical work - yet remained conspicuously absent from or tangential to most research.

Where science appears, it typically features in higher education contexts or as brief mentions within broader studies. The few subject-specific sources predominantly offer pedagogical suggestions rather than documenting lived experiences of science teachers navigating remote education.

Large-scale quantitative studies, while providing valuable statistical overviews of provision, engagement levels, and inequality patterns, cannot capture the diversity of individual experience or reveal pedagogical decision-making processes underlying remote education. Post-pandemic literature has shifted toward measuring long-term impacts – predominantly learning losses, achievement gaps, mental health deterioration, and chronic absenteeism - but largely maintains the same limitation of a lack of subject-specific, qualitative depth.

This study addresses these gaps directly. By combining survey data with in-depth interviews with science teachers and parents, it provides the first detailed, subject-specific examination of how science education was experienced and delivered during the UK's first lockdown. The qualitative evidence in Chapters 4-6 illuminates not just what happened, but why particular pedagogical decisions were made, how technology and pedagogy intersected in practice, and how the distinctive characteristics of science as a discipline shaped remote education experiences. In doing so, it contributes essential understanding to a field where, as the literature consistently acknowledges, subject-specific perspectives remain critically underrepresented.

Chapter 3: Methodology

3.1 Introduction

This chapter details and justifies my methodological approach. I explore my positionality as a researcher and discuss how the choice of mixed methods aligns with my ontological and epistemological beliefs. The chapter then outlines the research design, sequence of research activities, recruitment of participants, methods used, ethical considerations, data collection and analysis.

As explained in the introductory chapter, this research was not anticipated: COVID-19 jeopardised my original research because of school closures. Following discussions with supervisors, the research proposal was amended, and ethical approval was obtained on June 8th 2020.

Mixed methods were a compelling choice because, as Greene et al. (2001) argue, complex social phenomena cannot be adequately researched using a single method. Combining methods was not an attempt to produce the 'full picture'; as Silverman (2017) suggests, such an endeavour is illusory. It would be as logically unattainable as metaphysical concepts of 'truth' or 'reality'. My goal in obtaining different types of data was to provide a *fuller* picture than either method could achieve independently, reflecting Shannon-Baker's point: "*The purpose of a mixed methods research is to provide a more complex understanding of a phenomenon that would otherwise not have been accessible by using one approach alone.*" (2016, p321).

Given the constraints of conducting research during lockdown, surveys and interviews were chosen as the most suitable instruments for gathering data, and drawing meaningful inferences from them. Survey questions were considered unlikely to elicit widely differing interpretations that might compromise data quality, though they have acknowledged limitations for revealing meanings research subjects attach to named concepts. Interviews can compensate for this, however, as they involve probing for meaning. Nevertheless, the extent to which data collected represent an externally verifiable ‘reality’ remains minimal. Within this research, context of this is regarded as immaterial: the reality which matters is what the research participants themselves perceive; essentially their own individual experience. A fuller discussion of these methods is given in section 3.3.

Alternative research methods were deemed less suitable: ethnography was rejected as unsuitable for addressing the research questions since it would not have enabled examination of personal experiences. It would also have been technically problematic given the conditions of lockdown. An in-depth case study was more feasible, but was not adopted because of the inherent uncertainty about data quality when selecting cases; an uncertainty heightened by the unpredictability of lockdown conditions and the anticipated limited window of opportunity for data collection.

In selecting methods for analysis, my experience steered me towards established techniques that would promote the confirmability described by Bryman (2015) as one of the tenets of trustworthiness. Performing basic statistical analyses on quantitative data was a process I had abundant prior experience of, and the online survey platform provided data in the form of a spreadsheet, making it straightforward to employ automated features of spreadsheet software. Quantitative analyses would hence be grounded in raw data; researcher influence would be limited to choosing which analyses to pursue. For qualitative interview data, the established method of thematic analysis (Clarke & Braun, 2013) also provided the means to keep analysis closely grounded in data. Using relatively simple, and as far as possible unambiguous, categories and themes during the analysis, the process also reflects the confirmability being sought.

3.2 Positionality

I am a white, heterosexual, middle-aged male from a conventional middle-class background: both parents pursued professional careers, and I progressed directly from school and sixth-form college to a 'red-brick' university. After graduating with a chemistry degree, I entered science teaching and have remained within science education as a professional development facilitator and initial teacher education lecturer. These experiences shape my positionality, influencing my ontological and epistemological beliefs and research preferences.

My natural sciences background and subsequent science education work predispose me toward a pragmatist perspective. As a critical realist (Archer et al., 2013; Fleetwood, 2014), I believe in a reality external to observers, but acknowledge its logical unknowability, since transcending individual viewpoints remains impossible. Despite the logic, I view this philosophical conundrum as effectively circumvented by pragmatism, which seeks practically useful knowledge generation methods. This reflects Tashakkori and Teddlie (1998), who suggest ‘what works’ should take precedence over metaphysical concepts such as ‘truth’ and ‘reality’. This perspective matches my understanding of scientific knowledge creation processes: scientists develop provisional explanations based on available data without claiming ultimate, unchanging 'truth'. Though I recognise positivism in natural sciences, I see it more as a pragmatic enterprise; hence my natural science background influences my preference for approaches like mixed methods that embody pragmatism in social science research. This philosophical standpoint therefore permits the embracing of interpretivism, aligning with the predominant paradigm of social science research (Yanow & Schwartz-Shea, 2015).

Punch and Oancea (2014) suggest it is impossible for researchers to avoid some position in relation to their research; essentially, genuine objectivity cannot be attained. This does not necessarily reduce the quality of research; indeed, the authors question the ethics of researching communities with whom one could not empathise. The challenge is demonstrating a suitable degree of neutrality, avoiding bias and subjectivity as far as possible (Denscombe, 2002). Hence my own positionality, stemming from my background, biases and potential for vested interests, had to be considered throughout the research process. This included a reflexive awareness of my beliefs about the importance of children's science education, and my own concerns about the impact of lockdown on this, for example through the likely cessation of practical work. Similarly, convictions about the importance of my own study, for contributing to an understanding of children's lockdown science education, required tempering to distance myself suitably from the research process. I considered it beneficial that my positionality encompasses both 'insider' and 'outsider' perspectives (Gair, 2012). As a parent, former science teacher and confident digital technology user, these 'insider' perspectives contributed significantly to my capacity for empathy with research participants. However, having left school teaching, and with less involvement with educational technology, I also possess ‘outsider’ perspectives. These contrasting viewpoints promoted both a capacity for gaining insights and a degree of neutrality.

Some limits on objectivity were relatively obvious: most interviewees were female, for example. Since interviews did not intentionally explore gender-specific issues (unless raised by interviewees), this was considered unproblematic. Nevertheless, being reflexively aware of my own subjectiveness was important for bracketing during interviews (Kvale & Brinkmann, 2009) and subsequently during analysis of transcripts, because one’s own preconceptions, assumptions and experiences can contaminate data collection and analysis. This is discussed further in section 3.3.4.

Conversely, other aspects of my positionality benefited this research. As a former science teacher, I could relate to teachers' contexts, maintaining tight alignment between data collection and research aims while avoiding tangential issues. This also facilitated empathetic probing during interviews. Similarly, prior knowledge of educational digital technology provided technical understanding and empathy for teachers' technological experiences. Additionally, I was experiencing lockdown as an educator myself, albeit in higher education. Empathising with parents was more difficult due to potential diversity within the parent sample. However, having two daughters, one of whom was still in education during the research period, enabled empathetic understanding through my own parenting experience.

3.3 Choice of methods

3.3.1 Overview

As established in Chapter 1, the objectives of this research were to explore teachers’ and parents’ experiences during remote science education provision under conditions of lockdown, with a focus on digital technology's facilitating role. The data were expected to demonstrate breadth due to anticipated variation across teacher and parent samples, and depth reflecting individual experiential differences. Via a mixed methods approach, surveys were selected to capture the breadth across samples, and interviews the depth in selected participants' accounts. These methods offered the additional benefit of online implementation, avoiding person-to-person contact and travel, both of which were restricted at the time due to infection control. Preceding interviews with surveys offered other practical advantages: surveys were a convenient vehicle for recruiting interview participants, and survey data obtained in advance helped identify lines of enquiry for interviews.

The following section briefly summarises the principles and debates surrounding mixed methods, with commentary on my research in relation to these.

3.3.2 Background and critical perspectives on Mixed Methods

3.3.2.1 Origins and characteristics

'Mixed methods' is the term used when methods generating both quantitative and qualitative data are combined (Clark & Creswell, 2008; Silverman, 2017; Tashakkori & Teddlie, 2009). In this research, quantitative data were expected mostly from surveys, with qualitative data generated mainly from interviews. Although it was not apparent at the time of data collection, later analysis of lockdown literature revealed that a large majority of research studies had generated only quantitative data, as discussed in chapter 2. The small number of studies which combine quantitative and qualitative data through mixed methods (e.g. Cambridge Partnership for Education, 2020; Hodgen et al., 2020;

Müller & Goldenberg, 2021) are distinctive for supplementing statistical representations of lockdown education with vivid accounts of personal experiences, revealing the diversity which many, often larger, studies cannot adequately convey. At the time of planning this research, the prospect of obtaining richer, more immersive data through interviewing made mixed methods preferable to using a survey alone. Surveys were considered necessary, however, for providing contextual breadth and background to interviews. Hence, if only by its chosen methodological approach, my study adds to the field for which comparable studies are demonstrably few.

Creswell (1994), Tashakkori and Teddlie (1998) and others trace origins of mixed methods to work by Campbell and Fiske (1959), who sought 'methodological triangulation' to eliminate the possibility that variation in data resulted from undetected and inadvertent variance in their method. Jick (1979) relates the term 'triangulation' to its navigational use, where an object's exact position is obtained by viewing it from two known positions (hence there are three positions, including the object's, forming a triangle). Denzin identified four forms of triangulation in social research:

1. **Data triangulation**, gathering data through several sampling strategies, so data are gathered at different times, in different social situations.
2. **Investigator triangulation**, where more than one researcher gathers and interprets data.
3. **Theoretical triangulation**, using more than one theoretical framework in interpreting data.

4. **Methodological triangulation**, where more than one method is used for gathering data.

(Denzin, 1970, as cited in Bryman, 2004).

Thurmond (2001) suggests two further types of methodological triangulation: within-method or across-method. In the former, researchers use at least two data-collection methods within the same research strategy or design, but do not mix quantitative and qualitative methods. In the latter, both methods are employed, reflecting Bryman's description of mixed methods as constituting an approach that "*integrates quantitative and qualitative research within a single project*," (2016, p628). By this principle, methods should be used not just in tandem, but in support of each other. Essentially, benefits of methodological triangulation are in using strengths of one method to compensate for weaknesses in another.

3.3.2.2 Debates about research paradigms

Challenges arising from applying triangulation to qualitative research reflect broader mixed methods debates. These arguments became known as the 'incompatibility thesis' (Tashakkori & Teddlie, 2009), following Lincoln and Guba's characterization of fundamental irreconcilability between paradigms underlying quantitative and qualitative research (1985). The debate centres on attempts to reconcile quantitative research concepts of researcher impartiality and objectivity with qualitative research emphases on researcher positionality and subjectivity. Plano-Clark and Creswell summarise the logic of this irreconcilability by stating, "*Any one research study, no matter what the methods or techniques used, cannot simultaneously or sequentially be informed by, for example, a belief that valid results are enhanced by a dualist and detached* *relationship between researcher and participant and by the opposing belief that valid results are obtained only when a fully participative relationship exists*" (2008, p307).

House (1994, p16) surmises that different positions adopted by opponents in the debate are manifested as "*dichotomies of objectivity versus subjectivity, fixed versus emergent categories, outsider versus insider perspectives, facts versus values, explanation versus understanding, and single versus multiple realities*", and argues subject matter should take priority over methodology debates. Varpio et al (2017) suggest the debate is rooted in the history of qualitative research itself and the way researchers have had to develop strategies to make their research acceptable to the prevailing hegemony – that is, to researchers from positivist or post-positivist traditions.

Despite incompatibility arguments, many authors view mixing of methods as unproblematic, provided researchers remain alert to potential pitfalls. Gobo and Molle suggest rigid distinctions between qualitative and quantitative methods in contemporary research are overly-simplistic, and that "*constant osmosis between the two*" occurs (2017, p21). Biesta (2010) emphasises that mixed method problems arise not because of mixing types of data, but when knowledge claims are derived from methods with incompatible epistemological underpinnings. Sensitivity to such incompatibility was maintained in this research, particularly during data analysis.

3.3.2.3 Triangulation and Trustworthiness

Through its intrinsic connections to measurement, triangulation has positivist connotations (Guba & Lincoln, 1989), posing a conundrum for qualitative research into social phenomena, through an interpretivist paradigm. However, it is possible to circumvent this problem by adopting a suitably adapted conception of triangulation. Hence, for this research the purpose of using two data sources and combining survey and interview methods was not to achieve mutual *confirmation,* which a more literal interpretation of triangulation might imply; it was so data would be "*mutually illuminating*" (Bryman, 2016, p628). Although a positivist application of triangulation, providing degrees of mutual confirmation, can be loosely applied to some data in this study (for example in specific cases of comparing teacher and parent data), opportunities are generally limited because sampling was not controlled to be able to achieve this. Additionally, rigorous confirmation between survey and interview data is not possible because interview data from individuals are not guaranteed to confirm survey data, especially from a large sample, or vice versa; the opposite might happen, depending on survey samples and individuals being interviewed. Rather, interview data enabled a 'zooming in' on specific individual cases from survey samples, contributing to deeper understanding of issues. Hence, in this research, qualitative data comprising subjective interpretations are not processed with quantitative data to converge on 'truth' or generate 'proof' of objective reality. The process is not analogous to ways quantitative data are triangulated to confirm measurable entities (such as an object's physical position). Instead, different data types are analogous to 'macro' and 'micro' perspectives, generating richness of understanding by highlighting similarities and differences, for instance. This dual perspective reflects the 'bird's eye view' and the 'worm's eye view' suggested by Covey and Yunus (2016).

To address the ambiguity of different connotations of triangulation, and acknowledge difficulties of subjectiveness in social research, Bryman (2015) suggests the concept of trustworthiness is preferable over triangulation for discussing data and conclusions, using four elements:

- Credibility - the degree to which a researcher presents an account of realities that is acceptable to others.
- Transferability – the degree to which a researcher's account quality makes it applicable to other situations.
- Dependability – an assessment of the extent to which a researcher's data, notes and associated materials, when viewed by others, are seen as consistent.
- Confirmability – the degree to which research findings are logical and grounded in data, free of the researcher's personal biases.

These criteria for trustworthiness acknowledge the absence of a single 'reality' at the heart of social research, recognising that within an interpretivist paradigm there are multiple 'realities', including those of researchers as well as research subjects. Similarly, they encompass a recognition of contextual uniqueness often associated with social research, in which events are non-replicable, requiring 'thick' description to capture data with rich detail. In the context of my research, detail is captured particularly through interviews, in which teachers and parents were facilitated, through careful questioning, in describing their experiences. As these varied considerably, it was important to allow them to speak freely and at length; an outcome achieved particularly through open questioning. Hence, most scripted questions were open and exploratory, using question stems such as "Why...?" or "How…?", while unscripted probing phrases such as, "Tell me more about…" were used to encourage candid elaboration. An example interview script can be seen in Appendix 7.

3.3.3 Applying triangulation in this research

This sub-section gives specific details of how triangulation was applied, identifying two variants:

- Triangulation between data types (survey and interview data).
- Triangulation between participant groups (teachers and parents).

With lockdown requiring most people to remain at home, it was anticipated that teachers would be able to provide valuable perspectives on how science education was being provided, but their evidence would be somewhat limited because they would probably have little direct contact with their pupils. (Data in my study confirm most teachers rarely knew how children were coping with the work they were setting, for example). By contrast, direct contact with their own children meant parents could give the sort of evidence teachers were unable to. They could describe effects of learning materials being sent home, and observe how their children were responding to lockdown conditions. Additionally, many parents were providing some form of educational support to mitigate difficulties inherent in emergency remote education.

Exploring educational provision during lockdown solely through the lens of what teachers were doing would therefore yield a limited picture: a fuller understanding required input from both teachers and parents. Although using data from these two stakeholder groups does not by itself constitute mixed methods, it reflects a primary justification of triangulation, which is to increase "*the validity, strength, and interpretative potential of a study… and provide multiple perspectives*" (Thurmond, 2001, p253). Multiple perspectives could be used to aid comparison between teachers' and parents' data which, though conceivable in terms of positivist confirmation, was mainly valuable for giving cues to further interrogation of data or opening new lines of enquiry.

Survey question design was a primary means of achieving this triangulation. Although questions in each of the teacher and parent surveys reflected anticipated differences in experience between these two groups, in several instances they were asked about similar things. Hence, questions explored common areas to reveal the extent to which teacher and parent perspectives on the same issue aligned or diverged. An example is the exploration of types of science learning activity - teachers were asked about the type of activities they were setting; parents were asked about the types of activities they thought their children were being given. In this specific case (see chapter 6, section 6.3.2) there is broad similarity between what each group reported, providing some reassurance that parents perceptions about activities matched teachers' intentions. In another example, comparison of findings from the two participant groups reveals divergence between teachers' opinions of the quality of the science education they had provided, and parents' reports of their children's views of science work (see chapter 6, section 6.3.4). This strengthens a tentative conclusion that teachers' opinions were being influenced by the presence or absence of feedback about what they were doing.

As well as employing evidence from two stakeholder groups, this study enacts triangulation by using the two data collection methods of surveys and interviews; this enables triangulation largely within each specific group. The research design (see section 3.3) intended surveys to be used both to collect data and to recruit interview volunteers. Interviews, which happened after participants had completed the survey, were a convenient vehicle for triangulating their survey data. Individuals' survey responses were the basis of interview questions, enabling those responses to be explored in more detail. On the one hand this permitted the checking of data collected through the survey; on the other it meant individuals could be asked to elaborate. By elaborating, detail that would have been virtually impossible to obtain through the survey would be revealed, reflecting the justifications for mixed methods cited previously (e.g. Greene et al., 2001; Shannon-Baker, 2016). This made it possible to gauge degrees of similarity and variation between different individuals' experiences; it was helpful, for example, in revealing how practices in live remote teaching (LRT) differed widely. While survey responses gave a broad impression of how widespread the practice had been; interviews revealed detail that enabled a deeper understanding of remote education experiences.

In summary, triangulation in this study is a concept not applied in a positivist sense. Its main purpose is to achieve fuller and more complex understanding; the 'mutual illumination' referred to earlier (Bryman, 2015). It was planned for at the research design stage, and enacted both during data collection and afterwards during data analysis.

3.3.4 Background to surveys and interviews

Surveys were chosen as the first of the two data collection methods, to enable the description of trends (Creswell, 2012) and to enable the generation of graphic displays for illustrative purposes, without complex statistical processing (Tashakkori & Teddlie, 1998). Following up surveys with semi-structured interviews, which are a well-established qualitative research method (Bryman, 2015) was to generate in-depth data to complement the breadth, but expected shallowness, of the survey data. Quantitative 'discoveries', such as demonstrable relationships between different variables, were not being sought through this research. Survey questions are intended to shed light on patterns that might be noticeable, but it is recognised that scope for deriving meaning, such as explanations for a teacher’s actions, would mostly be limited to raising further questions and proposing tentative similarities to other findings. The interviews would better facilitate the exploration of questions of ‘why’ or ‘how’ (Tenny et al., 2017; Yin, 2009) contributing to a deeper understanding of lockdown experiences.

The survey design is cross-sectional, collecting data at a particular point in time to examine attitudes and practices (Creswell, 2012). The approach follows Nardi’s description of self-administered questionnaires (2014), which have several advantages:

- They measure variables where the number of response categories makes them unsuitable for reading out in interviews.
- They investigate things that are not usually observable.
- They can be applied to a large sample.
- They can be anonymous, favouring more candid responses.

Hosting surveys online adds further advantages, including convenience, more streamlined user experience and presentation of one question at a time, avoiding split attention and errors in responses (Bryman, 2015). Compared to paper surveys there are no postage costs and no data transfer from paper to digital formats for analysis, avoiding clerical errors (Evans & Mathur, 2005). They are far less time-consuming for researchers than phone or face-to-face surveys. Nardi (2014) and Creswell (2012) both suggest lower response rates compared to face-to-face or phone surveys, although this is not regarded as problematic for this research as aims are not to generalise from data (discussed further in section 3.4.3). The need for an internet connection is a limitation (Nardi, 2014), but teachers were thought likely to have school email addresses and to be online during lockdown, so was a minor concern for the teacher sample. It was potentially more significant for the parent sample, the composition of which is discussed in section 3.4.3.

The interviews are described as 'semi-structured' because, though each followed a detailed pre-prepared script, strict adherence to this was not necessary, and spontaneous probing could occur to invite interviewees to elaborate (Jamshed, 2014). Interviews offer flexibility and an apparent simplicity, but the resemblance to conversations is illusory, obscuring features such as skills which experienced interviewers have developed through practice. Unlike most conversations, the roles of interviewer and interviewee are different, and can reflect power asymmetry (Anyan, 2013). Irrespective of the interviewer's intentions, steps are usually necessary in interview preparation if its impact is to be minimised. Kvale and Brinkmann describe "*setting of the interview stage*" (2009, p128) so that interviewees are suitably briefed and comfortable to describe their perspectives and experiences openly. However, favourable conditions need maintaining throughout, highlighting the extent to which interviewing relies heavily on social awareness in interviewers.

Interviewing, rather than *gathering* data, is deliberate engineering of dialogue to *generate* data for understanding another person's perspective. It attempts to identify meanings that people attach to phenomena, and Kvale and Brinkmann emphasise "*the important reality is what people perceive it to be*" (2009, p26).

The aim is to *describe* another person's social reality, not to *explain* it. Doing this successfully can require suspension of interviewers' own conceptual structures, a process referred to as "*bracketing*" or "*reduction*" (Kvale & Brinkmann, 2009, p27). Interviewers' own conceptions can contaminate descriptions of phenomena and prevent their essence being adequately revealed. It was important during interviews with teachers, for example, to ensure my own science teaching experiences did not intrude into the dialogue, as they might have done during a more informal discussion about the subject matter. Though they were a valuable component of my positionality, as outlined earlier, they might also have inhibited interviewees' candid disclosures, and coloured how I discerned what was being described. Hence, bracketing was a deliberate act throughout the interviewing process; a conscious 'parking' of my own pre-conceptions and experiences, while still accessing sufficient prior knowledge to be able to conduct the proceedings meaningfully, without recourse to time-consuming clarification of technicalities.

Conducting interviews online, using the Zoom platform, helped set the interview stage for this study. Its convenience was advantageous: up to three interviews could be carried out per day, with interviewees who were geographically widely dispersed. Interviewees chose the location from which they were interviewed, and the date and time most convenient to them. By exercising choice over their own comfort and convenience, power asymmetry was reduced. Archibald et al (2019) suggest interviewees preferred video conference interviews (and Zoom especially) to in-person or telephone interviews. Jenner and Myers (2019) also suggest that private settings of interviewees in videoconferences were key to the quality of information they shared. Discussing positive outcomes of interviewees being in their own homes, Oliffe et al. noted that, “*For the most part, we sensed a naturalness, and spontaneity with participants talking frankly and freely about their experiences and feelings*” (2021, p3)

To obtain rich interview data, techniques to encourage interviewees to speak candidly and at length were used. The number of ‘closed’ questions requiring short and simple responses such as ‘yes’ or ‘no’ were limited. As mentioned previously, open questions were prioritised.

3.3.5 Research Ethics

Ethical approval was obtained prior to research activities taking place. For surveys, piloting represented a further monitoring of ethical standards, as did subsequent discussions with supervisors. As Bryman (2015) comments in relation to the Framework for Research Ethics from the Economic and Social Research Council (ESRC), poorly designed studies are inherently unethical. Not least they risk wasting participants’ time, but at worst might cause physical or emotional harm. Ethical practice was a primary reason for maintaining researcher reflexivity throughout this study. Such reflexivity is not confined to procedural steps involved in executing methods, however. It extends to awareness of inherent limitations in methods used, ensuring knowledge claims would be well-founded rather than spurious.

Bryman (2015) identifies four main areas for ethical considerations in social research:

1. Whether there is harm to participants;
2. Whether there is a lack of informed consent;
3. Whether there is an invasion of privacy;

4. Whether deception is involved.

These areas overlap. Although physical harm arising from this research was deemed unlikely, research participants could experience personal suffering if researchers breach confidence or privacy, for instance by publishing sensitive data. Similarly, degrees of harm can result without full understanding of implications of involvement, when consent is not 'informed'. If deception is required, which might be justifiable for achieving research aims, then consent cannot be fully informed.

Addressing the four areas above involved careful deliberation. Fowler (2013) suggests most surveys do not require signed consent in advance, and this was impractical for the online surveys. Instead, each survey was prefaced by a short summary of the research aims and a statement about ethical integrity, including relevant contact details (see Appendix 13). Hence informed consent was assumed by submission of surveys – had recipients thought the research was unethical they could choose not to participate. For those volunteering for interviews, however, consent forms were sent in advance, along with detailed information about the research and interview process, and an offer to clarify matters of concern (see Appendix 14). Forms were returned, signed, by email. This was considered satisfactory for informed consent, although interviewees were also allowed to withdraw their data later, should they change their mind about involvement.

Obtaining data for this research did not require, nor intentionally involve, deception. Careful design of surveys, and subsequent piloting, enabled an expected completion time to be included in the information provided for participants. Calculated from metadata, average completion times were within the expected times stated, confirming that this was consistent with expectations. Though superficially minor, such points relate to transparency and are tenets of informed consent: encouraging participation by deliberately understating time commitments would be unethical; omitting to give an estimated time requirement could mislead.

Survey participants' privacy was preserved by making surveys anonymous, apart from for those who volunteered to be interviewed. There was limited ability to withdraw most individuals' data, therefore, although in practice no requests were received. Restricting requirements for personal data avoided risk of repercussions from data being attributable to named individuals. Hence survey participants were not asked for names, addresses or names of schools. Partial school or home postcodes were requested simply to establish geographical distribution of survey responses. Questions inviting respondents to criticise people or organisations were avoided.

For interview volunteers, contact details were necessary; their data were not, therefore, anonymous. Pseudonyms were used in interview transcripts, with the key to real names held on an encrypted file. All electronic data were encrypted and stored securely.

For transparency, interviewees were advised of likely durations of interviews and given an idea of questions in advance, to avoid deviating from their expectations. However, fully informed consent is not possible for exploratory semi-structured interviewing: interviewees are consenting to questions they do not know precisely, and might object if enquiries differ significantly from their expectations. To navigate this potential pitfall, researchers require constant ethical vigilance, termed 'judging thickly' which involves using practical wisdom to read contextualised situations, rather than applying ethical rules blindly (Kvale & Brinkmann, 2015). Active listening and interpreting non-verbal cues are important, and hence interviewing by videoconference was preferable to telephone interviews. In practice there were no instances of interviewees objecting to questions.

Differences between written and oral modes of language raise further ethical issues. Without temporal features such as pauses, no vocal expression or non-verbal communication, and the disjointed nature of spontaneous oral narrative, transcripts can appear as "*impoverished, decontextualized renderings of live interview conversations*" (Kvale & Brinkmann, 2015, p204). Modifying verbatim speech to improve fluidity for reading is an ethical dilemma that risks changing the intended meaning of what was said. Remaining faithful to accurate transcribing of verbal utterances does not remove potential to affect meaning, however, as this can be determined by choices transcribers make in inserting punctuation. Such dilemmas reflect wider problems of representation in qualitative research. As Riessman suggests, "*Investigators do not have direct access to another's experience*" (Huberman & Miles, 2002, p. 221). Rather, during research direct experience is filtered through multiple processes such as telling, transcribing and analysing. Researchers have an ethical imperative to recognise this, minimising misrepresentation.

3.4 Research Design

3.4.1 Timescale of data collection

Figure 2 outlines data collection activities spanning approximately four months during summer 2020. Teacher interviews were conducted over an extended period because interviewing during school summer holidays was avoided; these interviews thus straddled the holiday period, occupying a longer timeframe than parent interviews. Dataset sizes and interview durations are indicated here; more detailed discussion appears in section 4.

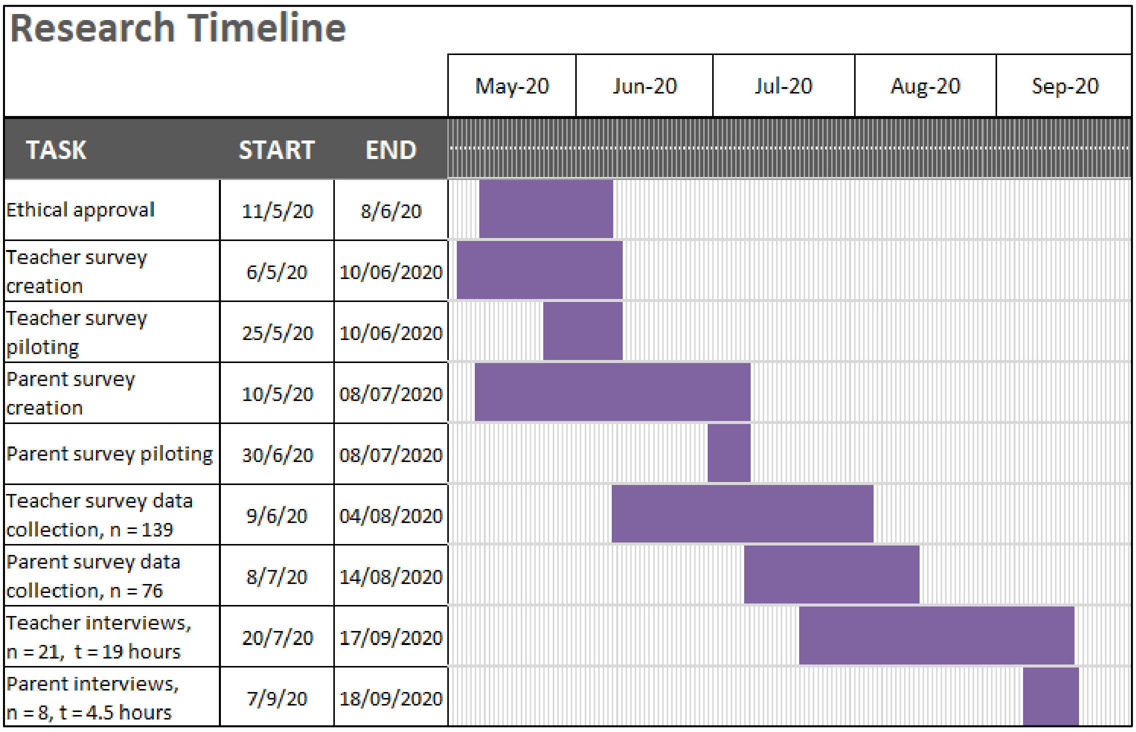


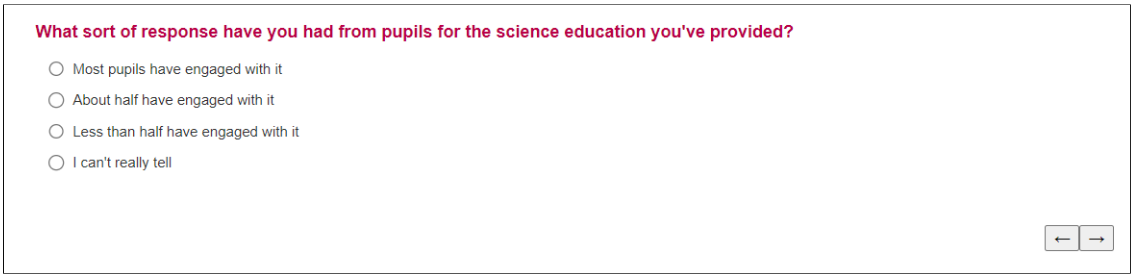
Figure 2: Gantt chart showing timeline of data collection activities.

3.4.2 Survey creation, structure and circulation

This sub-section details key factors about the surveys. As research questions focused on experiences of both teachers and parents - distinct groups whose backgrounds and lockdown experiences were likely to be different - separate surveys were created for each group.

3.4.2.1 Online platform

The ‘Qualtrics’ platform was used for authoring and hosting online surveys. Several additional advantages emerged through this method, and are discussed below. Data were easily accessible through the online interface, including metadata such as completion duration, which would have been harder to capture through paper surveys. The platform enabled survey optimisation across multiple electronic devices including mobile phones, potentially increasing completion rates. The difference between computer and mobile screen versions is illustrated below.



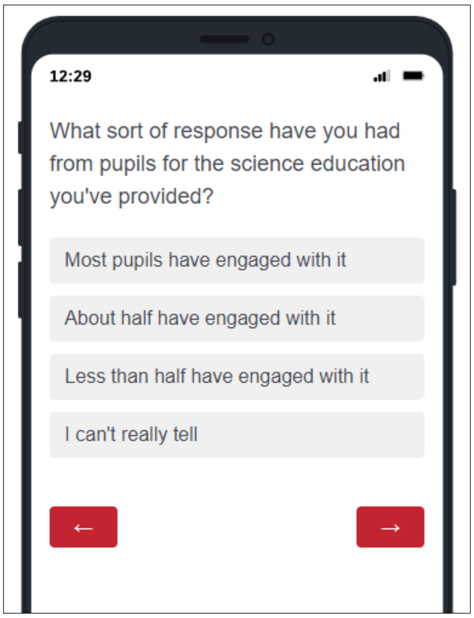


Figure 3: Illustration of how the same question would appear on a laptop or PC screen (above) and a mobile phone or tablet (left).

3.4.2.2 Question formats

To streamline user experiences and optimise data analysis, most questions were multiple choice, requiring either one or multiple options to be chosen. Option choices aimed to encompass all likely responses, but a ‘catch-all’ using a text entry box was occasionally required, when the option of ‘Other’ was selected. Similarly, ‘Don’t know’ or ‘No opinion’ response options were provided where appropriate. Where elaboration was desirable, some questions invited longer text entry responses. Other questions required respondents to rank lists of items. Examples of question types are shown below for illustration.

1

If you know your school's last Ofsted rating, please indicate it below:

- ○ Outstanding
- ○ Good
- ○ Requires improvement
- ○ Inadequate: serious weaknesses
- ○ Inadequate: requires special measures
- ○ Don't know

2

Before lock-down which of the following things did you do frequently in your science teaching? (Please select all that apply)

- ☐ Showed pupils things from the internet (eg. YouTube videos)
- ☐ Showed pupils presentations (eg. PowerPoint)
- ☐ Set tasks which required pupils to use the internet in lessons
- ☐ Set homework that required pupils to use the internet (eg. for research or to access tasks you'd set)
- ☐ Set tasks in which pupils used technology in lessons to make digital content (eg. presentations, videos etc)
- ☐ Set tasks in which pupils used digital technology for experiments (eg. data-loggers, digital microscopes etc)
- ☐ None of the above

3

Please indicate briefly what changes to your teaching you are thinking about as a result of the lock-down.

4

How important do you think these things have been for helping your child/children learn science during lockdown? Drag them into a rank order. 1 is most important.

• Looking up information on the internet	1
• Written tasks such as worksheets	2
• Watching videos online (eg. on Youtube)	3
• Online 'lessons', such as BBC Bitesize	4
• Home experiments or observations (eg. the weather, astronomy, living things etc)	5

Figure 4: Illustrative examples of question types from the teacher survey. (1) Single response multiple choice. (2) Multiple response. (3) Text entry (question shown was dependent on a previous response). (4) Ranking (options presented according to previous response).

The online format enabled ‘piping’, where users only saw questions relevant to them based on their responses. This optimised experience by avoiding the need to skip irrelevant questions. For ranking-type questions, only items chosen in a previous question would be shown, so that respondents were not asked to rank items they did not think were relevant. This represented another practical advantage of the online format over paper-based surveys.

3.4.2.3 Survey structure

Each survey comprised information and questions in category blocks, shown below:

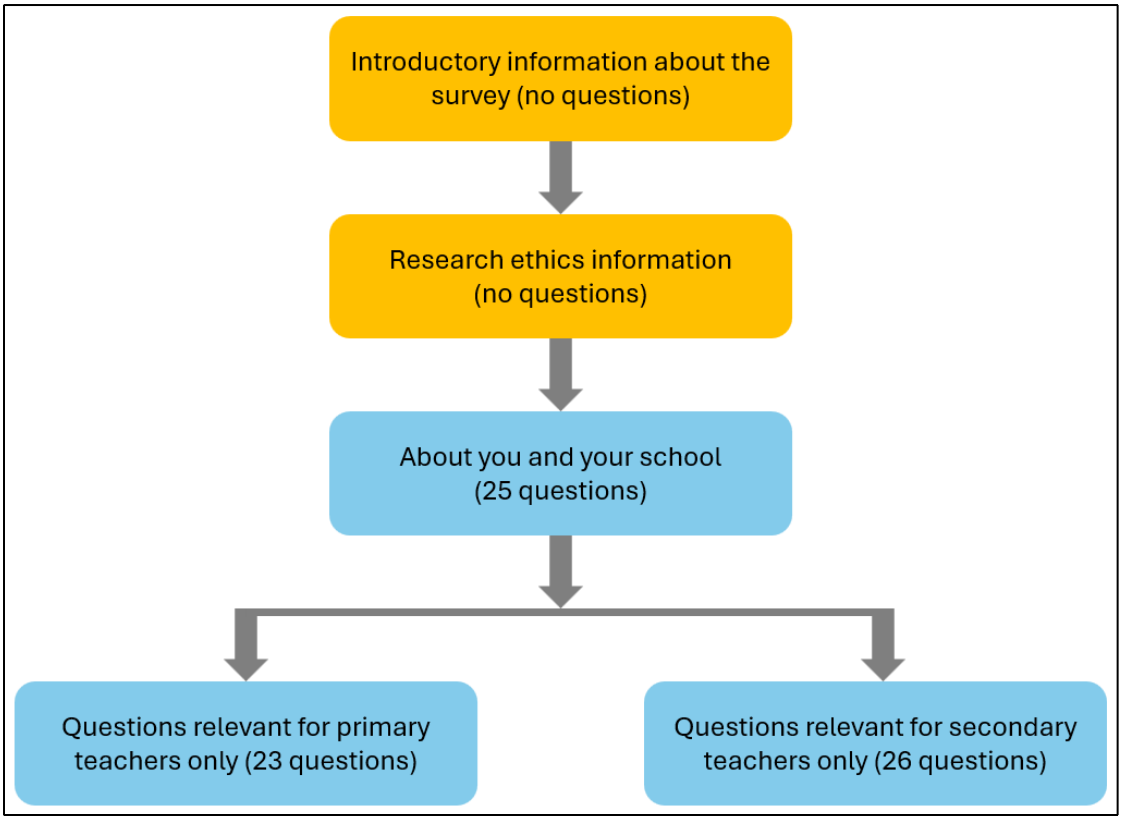


Figure 5: Basic structure of teachers' survey. (Sections with questions in blue).

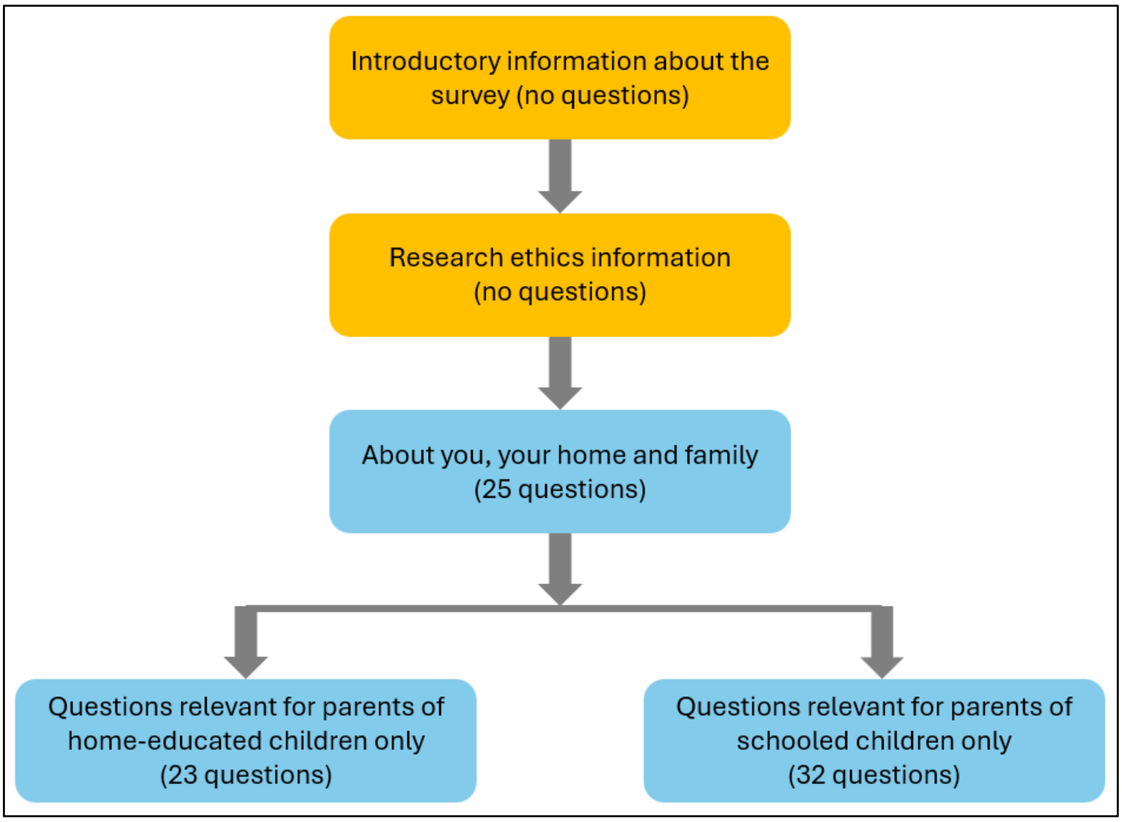


Figure 6: Basic structure of parents' survey. (Sections with questions in blue).

Figures 5 and 6 show basic structures; the piping within each question block meant many different routes through the surveys were possible and consequently respondents did not all answer the same questions, or the same number of questions. More detail, of questions and survey structures, are in Appendices 4-7. The mean number of questions answered was 37 and 44 on the teacher and parent surveys, respectively. This reduction of reading and scrolling is an acknowledged advantage of online formats called ‘Go to capabilities’ (Evans, J. R. & Mathur, 2005).

The smoothly functioning survey which users experienced masked underlying complexity in the authoring process, reflected in the creation time for the surveys (see Figure 2). Category blocks, shown in Figures 5 and 6, helped to allocate question identification codes for monitoring logical flow to ensure piping directed respondents correctly: in practice, piping was often complex with ‘layers’ of nested questions, for which correct logical flow was necessary.

To reduce complexity in survey structures some compromises were made, particularly in the parent survey. So that parents of multiple children could avoid answering questions about science provision for each child, they were asked to nominate one child to answer questions about. This reduced the number of questions they had to answer, and hence time spent on the survey, and was considered unlikely to compromise data quality significantly.

3.4.2.4 Piloting

Surveys were piloted over several days using colleagues at university and one of my research supervisors. Feedback related mainly to the clarity and conciseness of question wording; survey logic and flow worked as intended. Unlike interviews in which clarification can be provided on request, surveys have no explanatory narrative and no facility for seeking clarification. Questions needed to be clear, simple, and free from bias. Where ambiguity was a risk, examples were provided in question wording. An example was the phrase ‘science teaching’, which, in the context of lockdown, could have been interpreted numerous ways. Connotations of direct interaction with children which ‘teaching’ might provoke could have excluded activities the question was aiming to capture, such as putting learning materials on virtual learning environments, emailing work, or other things teachers were doing as substitutes for classroom teaching. The relevant question was therefore worded as ‘Have you provided any science education for pupils during lock-down? (E.g. remote science teaching, providing materials or instructions for pupils etc).’

Avoiding bias involved omitting value-laden language wherever possible and ensuring consistency and accessibility of language. The more socially acceptable 'home-education' was used instead of 'home-schooling' for parents who normally chose not to send their children to school. 'Pupils' rather than 'students' was chosen for the teacher survey, to avoid the risk of favouring a secondary school perspective. Similarly, it was recognised that primary teachers would probably not be science specialists, so subject-specialist terminology was avoided. Issues of technical vocabulary around the use of digital technology, and the terminology which arose during lockdown itself, were also considered and avoided where possible. Thus, words such as 'synchronous' and 'asynchronous', which became more familiar during the pandemic, were not used.

Piloting also helped gauge whether the time intended for survey completion (roughly 10 minutes) reflected user experiences. No significant amendments were needed, and as previously mentioned, metadata indicated average completion times of around nine minutes for each survey.

3.4.2.5 Survey questions

Full lists of survey questions, and diagrams showing survey flow and piping, are in Appendices 4-7. Below are tabulated summaries, omitting exact question wording but giving an overview. As explained in section 3.2.3, respondents would see some questions according to their prior responses; this detail is not shown.

Teacher survey:

Survey section	Summary of questions asked
About you and your school	Teachers were asked about: • Their gender. • Their use of technology at home. • Their social media use. • Their teaching role. • Their current method of working. • Number of pupils on school roll. • Ages of pupils they taught. • Their teaching experience. • Technology provided for them by school. • Their school location. • Last school inspection rating. • Teaching and learning responsibilities. • Their awareness of pupils' home internet access. • Curricular importance of science during lockdown in their school. • Using technology in science teaching prior to lockdown. • Any predicted influence of lockdown on future teaching practice.

Primary and Secondary teachers	Primary and secondary teachers were asked mainly about the same things. Questions about the following differed occasionally in terms of wording: • Whether science work had been supplied for pupils. • Proportions of their pupils responding to science work. • How pupil response varied over time. • How pupil response varied for different ages. • Whether work required pupils to use the internet. • How work required internet use. • What sort of work requiring the internet was set. • Whether a virtual learning environment was used (secondary only). • The quality of lockdown science compared to normal lessons. • Whether pupils or parents had been in touch about science. • Whether there had been requests for extra work. • Which websites had been used. • Any activities not requiring the internet which had been set. • The experience of continuing to provide science education remotely. • Monitoring pupils' science learning. • Things that would have improved their science teaching during lockdown.

Table 1: Summary of questions used in the teacher survey.

Parent survey:

Survey section	Summary of questions asked
Basic questions	Parents were asked about: • Their age. • Whether they were a single parent. • Their gender. • Their home location. • About their home broadband connection, including during lockdown. • Their highest level of educational qualification, including in science-related subjects. • How many school-aged children they had. • The kinds of schools attended. • Whether any children were due to sit exams. • Whether anyone in the household worked in a school or was a teacher. • How their children accessed the internet at home. • Whether they thought their child's interest in science had been affected by lockdown. • Whether their child's mental health had been affected.
Questions for parents of schooled children	Parents were asked about: • Their child's motivation for schoolwork over lockdown. • Whether their child had been looking forward to returning to school. • Children's opinions about science work. • Things besides schoolwork that have helped children learn science.

	• Whether school provided any work during lockdown. • Whether the work included science. • How science work was communicated to children. • What kind of science work was set. • How important parents thought different activities had been for helping their child learn science. • What, if any, websites schools have used for science work.	• Whether parents had had to learn anything to help their child learn science. • Parents' views on science work schools supplied. • Whether they had contacted school about science work. • How confident they felt about helping their child learn science in future.
Questions for parents of home-educated children	Parents were asked about: • Number and ages of home-educated children. • Any changes they had experienced in home education due to lockdown. • Their child's motivation for educational work over lockdown. • Communication with other home-educating parents. • How the internet supported science home education.	• Whether science was included in their child's education, and how this had been affected by lockdown. • Public services used to supplement home education, and how lockdown had affected this. • Any significant actions they had taken to help their child learn science during lockdown.

Table 2: Summary of questions used in the parent survey.

3.4.2.6 *Survey circulation and completion*

Being online, engaging survey respondents required circulating survey links as widely as possible. Beyond publicising via Twitter, the teacher survey link was also distributed through my professional networks, with requests that recipients either complete it themselves if appropriate or forward it to their own science teaching contacts. The main contacts within this network were from the following organisations:

- Sheffield Hallam University (including Triple Science Network and Wipro teachers).
- The Association for Science Education (including ASE Futures group).
- The Royal Society of Chemistry.
- Teach First (including Teach First employees, trainees, early career and experienced teachers, and national tutors).
- STEM Learning.
- Techniquest (Science discovery centre in Wales who provide teacher professional development).

For parents, circulation was harder as comparable networks did not exist, or were less accessible. A considerably larger population than science teachers, the parent population is also more diverse. Although some of the teacher respondents were themselves parents and could have completed the parent survey, this option was not pursued as it was felt it might produce data similar to the teacher survey. Surveying parents was therefore focused on non-teachers where possible. Exploratory emails were sent to a small number of online networks for parents, including Mumsnet and Education Otherwise, a platform for parents/guardians of home educated children. The survey was also tweeted, and emails sent to personal and professional contacts who were not intimately connected with science education, including staff at Sheffield Hallam University.

3.4.3 Interviews

This sub-section details the preparation, protocols and questions for the interviews.

3.4.3.1 Interview preparation

Via the surveys, 51 teachers and 20 parents indicated their willingness to be interviewed, providing contact details. All were sent an information sheet and consent form to be signed and returned (see Appendix 14). Mutually convenient dates and times for interviews were arranged for those returning the consent form. Interviews were subsequently conducted with 21 teachers and eight parents.

Before interviews, notes were made from each interviewee's survey responses. This ensured contextual information was available should it be needed during the interview, avoided repeating information already given in the survey, and occasionally prompted interviewees who had forgotten their survey responses. The notes were written in a grid alongside relevant scripted questions for ease of access during interviews. This grid constituted the script used to guide the interview, and was printed for convenience. Sample scripts for teacher and parent interviews are in Appendices 7 and 8.

3.4.3.2 Interview protocols

All interviews followed the same format. After initial greetings, each participant was thanked for their participation and time. To further set the interview 'stage' they were verbally informed about the anticipated interview duration and details of the audio recording. They were invited to say as much or as little as they liked in response to questions, and to interpose if they changed their mind about anything, or wished to ask a question. They were also reassured about dealing with any domestic issues arising at their ‘end’. They were advised when recording began, and asked an initial question to put them at ease and encourage them to talk freely, before getting into more focused questions.

Each interviewee’s script of structured questions differed according to the individual’s survey responses. Scripts accommodated the verbal responses given, allowing issues to be discussed as interviewees raised them, not necessarily as scheduled. Prior awareness of scripts was important, therefore, to maintain continuity and avoid asking questions already addressed. This required active listening, monitoring the script as the interview progressed, and alertness for opportunities to probe for more information when relevant.

Interviewees were informed when audio recording finished at the end of the interview. An extra digital recorder was used as backup.

3.4.3.3 Interview questions

A sense of the scripted questions is provided by part of a script, for a teacher called Julia (a pseudonym). This does not show additional unscripted questions used for probing responses further. The left-hand column contains notes from Julia’s survey, while the right-hand column contains questions devised from these. Exact question wording was not necessarily observed rigidly to preserve a more natural conversational tone.

Notes from survey responses	**Interview questions**
	I'd like to start with a pretty general question about the role of digital technology in your life generally, either in your personal life or for work. So, I mean things like computers and everything you might use them for, the internet, social media and so on. This is just to help me get a sense of the kind of relationship you have with technology; so for example, whether you really like technology or if you just see it as a useful tool; if you've used technology for a long time, perhaps getting into it as a child or whether you were an adult before you really started using it, and so on - just feel free to tell me about things like that.
<u>Personal + School</u> Julia is a secondary school science teacher with 5-10 years' experience. She teaches KS3 and 4 in a school of 500-1000 pupils in the SO45 postcode district (Fawley area of Southampton). The last inspection rating for the school was 'Good'.	Tell me about how the 'working in school occasionally' worked. Do you think it was the same for other science teachers and other teachers?

During lockdown she was teaching in school occasionally.	
<u>Use of technology</u> Julia uses a laptop at home. She does not use social media for personal use, but does use Twitter for work purposes, (she uses it to communicate with a group of colleagues in school about work issues, and looks at what other people are saying, following specific individuals whose work or views she is interested in). Julia has a laptop provided by school.	How do you think your classes benefit from what you do on Twitter?

Lockdown experience Most pupils have a smartphone, but suggests there is a lack of computers at home. She feels science has not maintained its importance in the school curriculum during lockdown.	Is the lack of computers at home something you've picked up? Why do you think science hasn't maintained its curriculum importance at school?

Table 3: Example of part of an interview script used for a teacher interview.

3.5 Survey Samples

This section presents contextual data about teacher and parent survey samples in the form of tables, charts and descriptive statistics, with a brief discussion of the non-generalisability of the data.

3.5.1 Teacher sample

From 178 teacher respondents, 134 fully completed the survey. An additional five completed over half the survey, giving a sample size of 139 whose data have been analysed. This is 78% of the total number of respondents.

3.5.1.1 Geographical distribution

The 139 teachers represented schools around the UK, including from each devolved nation of Scotland, Wales and Northern Ireland. A greater concentration in the north of England reflects my professional networks. Figure 7 shows geographical spread of schools by postcode. One teacher worked in Belgium; their ‘pin’ is omitted for convenience. Postcode analysis reveals most completions were from Sheffield (19), Wakefield (14), Leeds (12) and Cardiff (10). Other towns or cities were sometimes represented by one teacher.

Figure 7: Map of UK showing location of school postcodes for teacher survey respondents.

3.5.1.2 Data about teachers and their schools

Three-quarters of survey respondents were female, and a quarter male. This is comparable with the teaching workforce generally, in which 69.5% of UK teachers are female, and 30.5% male (British Educational Suppliers Association, 2021).

Secondary teachers (n = 109), outnumbered primary teachers (n = 30). This split potentially stems from distribution networks, though fewer responses from primary teachers may also reflect the lack of science specialism in the sector (Denholm, 2019; Henry, 2014) or lower willingness to complete the survey.

Most primary teachers (18) taught exclusively in key stage 2. For secondary teachers most (68) taught in key stages 3 and 4; 32 also taught pupils in key stage 5, although only two taught this age group exclusively. It was commonest for teachers to hold no additional paid responsibility. A third of secondary teachers and around a quarter of primary teachers did have a paid responsibility, usually related to science.

A range of teaching experience was represented, as shown in Figure 8. Most primary respondents had over 10 years of experience, whereas most secondary teachers had fewer than ten years, with a large number having fewer than two years.

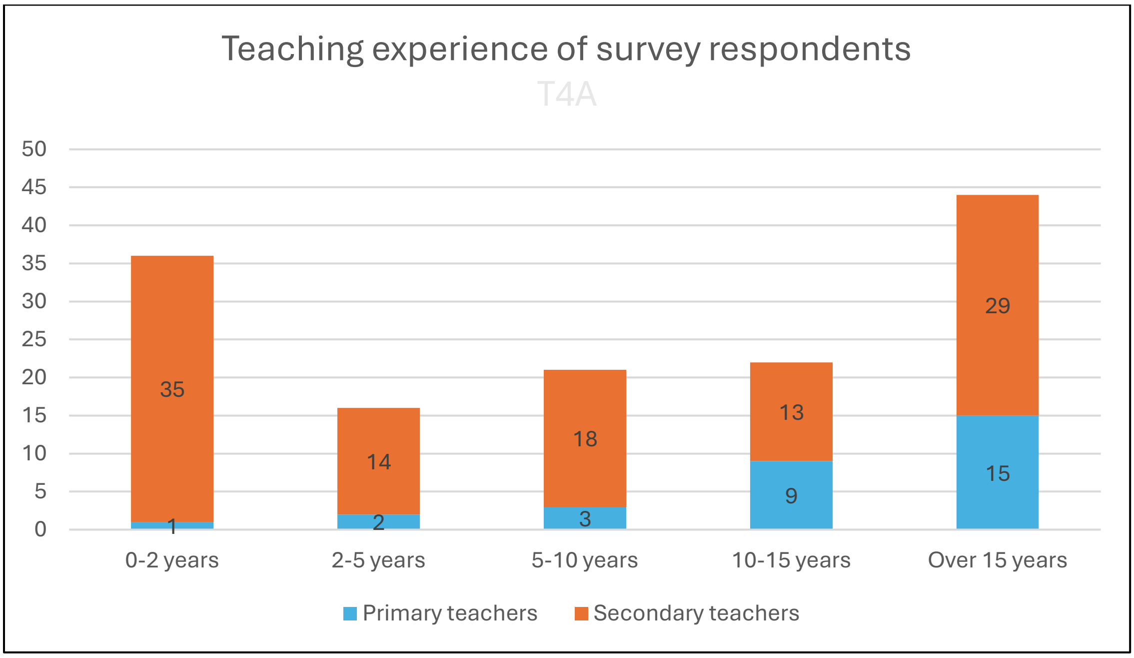


Figure 8: Teaching experience of survey respondents. Columns are labelled with raw numbers of respondents. N = 139.

Teachers worked in schools of varying sizes, according to the numbers of pupils on the school roll, as Figure 9 shows:

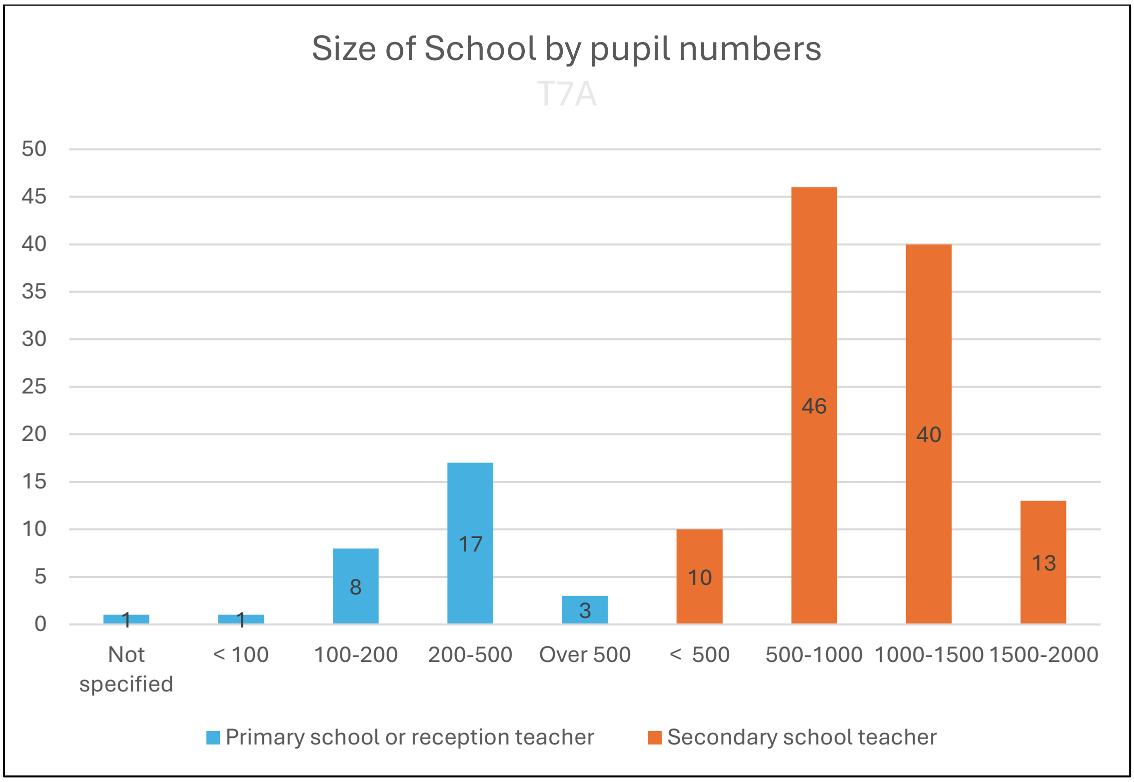


Figure 9: Size of school by pupil numbers. Columns are labelled with the raw numbers of responses given. N = 139.

3.5.2 Parent sample

From 99 respondents, 71 fully completed the survey, with eight partial completions. From these 79 respondents, data from 18 home-educators were not subsequently analysed (see section 3.6.1.1), leaving a sample of 61 whose data form the basis of the analyses in chapter 6. This is 62% of the total number of respondents.

3.5.2.1 Geographical distribution

Figure 10 shows a comparable distribution to the teacher survey, with a similar concentration in the north of England.

Figure 10: Map of UK showing locations of survey completion for the parent survey.

3.5.2.2 Data about parents and their children

Most parents were in their forties. A large majority (68) were female; 13 were male, and two preferred not to say. Most parents (68) did not class themselves as single parents.

Nineteen of the parents interviewed home-educated at least one child, which is a higher proportion than across the population generally, where, in England, approximately one in 78 children is home educated (Gov.uk, 2022; Weale, 2021). Higher representation of this group is probably due to survey circulation.

Data on school-aged children and their education circumstances are quite complex. Table 4 shows it was commonest for parents to have two or more school-aged children; these children might have been attending the same school, different schools, or in some cases a child might have been home-educated while their sibling(s) attended school.

Number of school-aged children	Number of parents reporting this number of school-aged children
1	27
2	34
3	12
More than 3	3

Table 4: Number of school-aged children of parents.

Most families were dealing with a single school for their children’s education – primary or secondary. In most cases of home-education, all school-aged children in the family were home educated. Twelve parents were dealing with more than one school. Sixteen had children who would have had public examinations in 2020, such as GCSEs or Key Stage 2 SATs.

For insights into parents’ capacity to help children with science learning, parents were asked about their highest level of educational qualification, and their highest level of qualification specifically in a science, science-related or technical subject. Figure 11 shows these data.

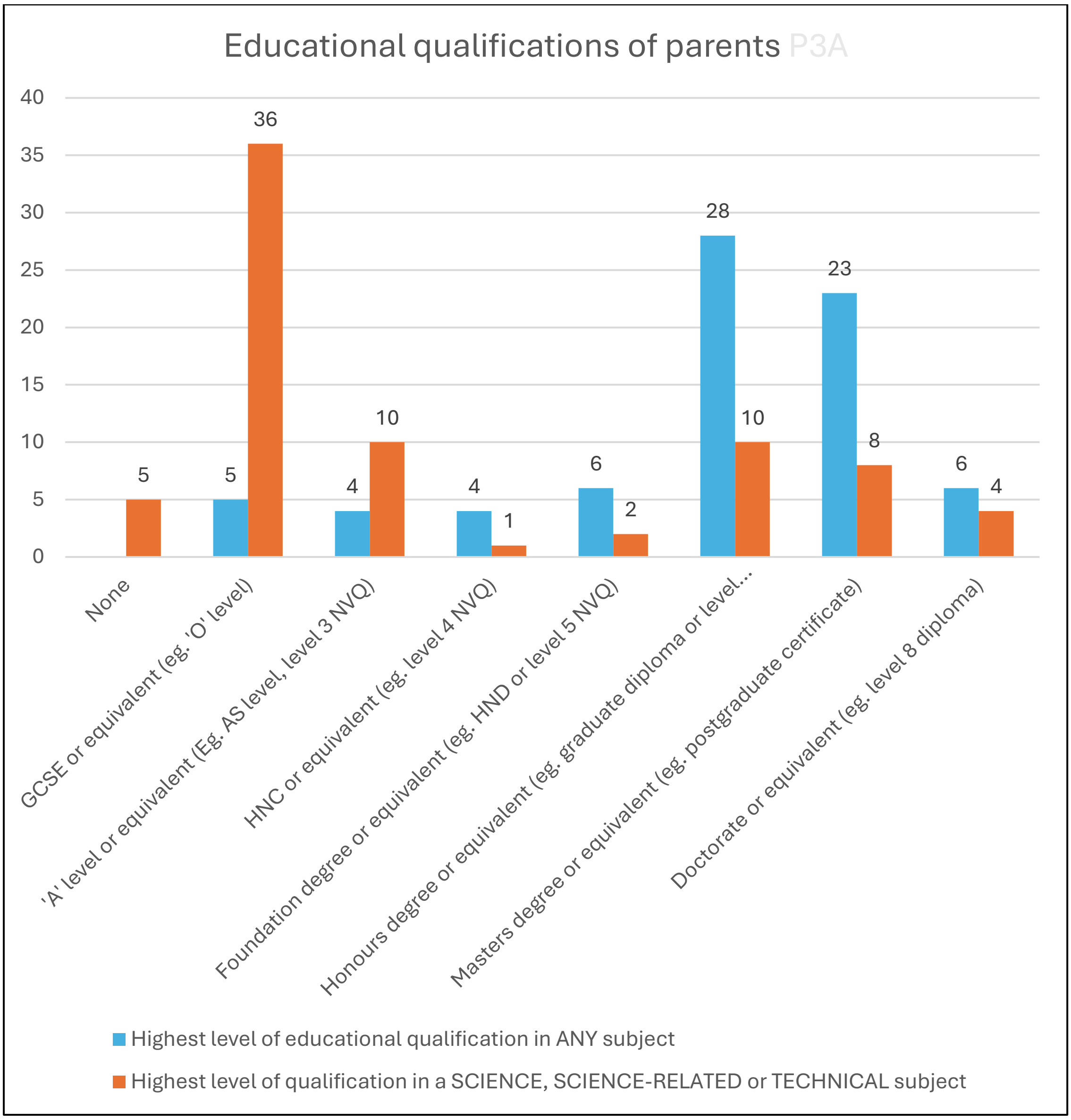


Figure 11: Educational qualifications of parents, in any subject and in science, science-related or technical subjects. Columns are labelled with the raw numbers of responses given. N = 76.

Figure 11 suggests the parent sample was generally well-educated, with the majority (75%) educated to at least honours degree level (level 6 of the National Qualifications Framework), reflecting recruitment concentrated among specific demographics. The picture for science, science-related or technical subjects, however, was slightly different, with just over half having GCSE or equivalent as their highest qualification. Parents' educational level is relevant for considering the extent to which their evidence can be regarded as a proxy for children's experiences. While data collected for this study frequently investigates parents' direct experiences, in some cases parents were asked to express views about their children’s experiences. It is recognised that such proxy data has the potential to be skewed (Rotsika et al., 2011; Varni et al., 2007), but in terms of proxy reporting in education surveys, agreement between proxies and subjects is found to be a function of parents’ education level (Wittrock et al., 2017). With higher than average levels of education, the parent sample here is expected to provide proxy data giving better than average agreement with children’s experiences.

An additional question for gauging parents’ capacity to help children with lockdown learning asked whether anyone in their household was a teacher or teaching assistant, or had been in the past. Responses indicate a sample skewed towards adults working in education, and hence more familiar with the intricacies of school life. Again, this can plausibly be attributed to recruitment, suggesting these parents may have been better able to help their children than average. These data are shown in Figure 12:

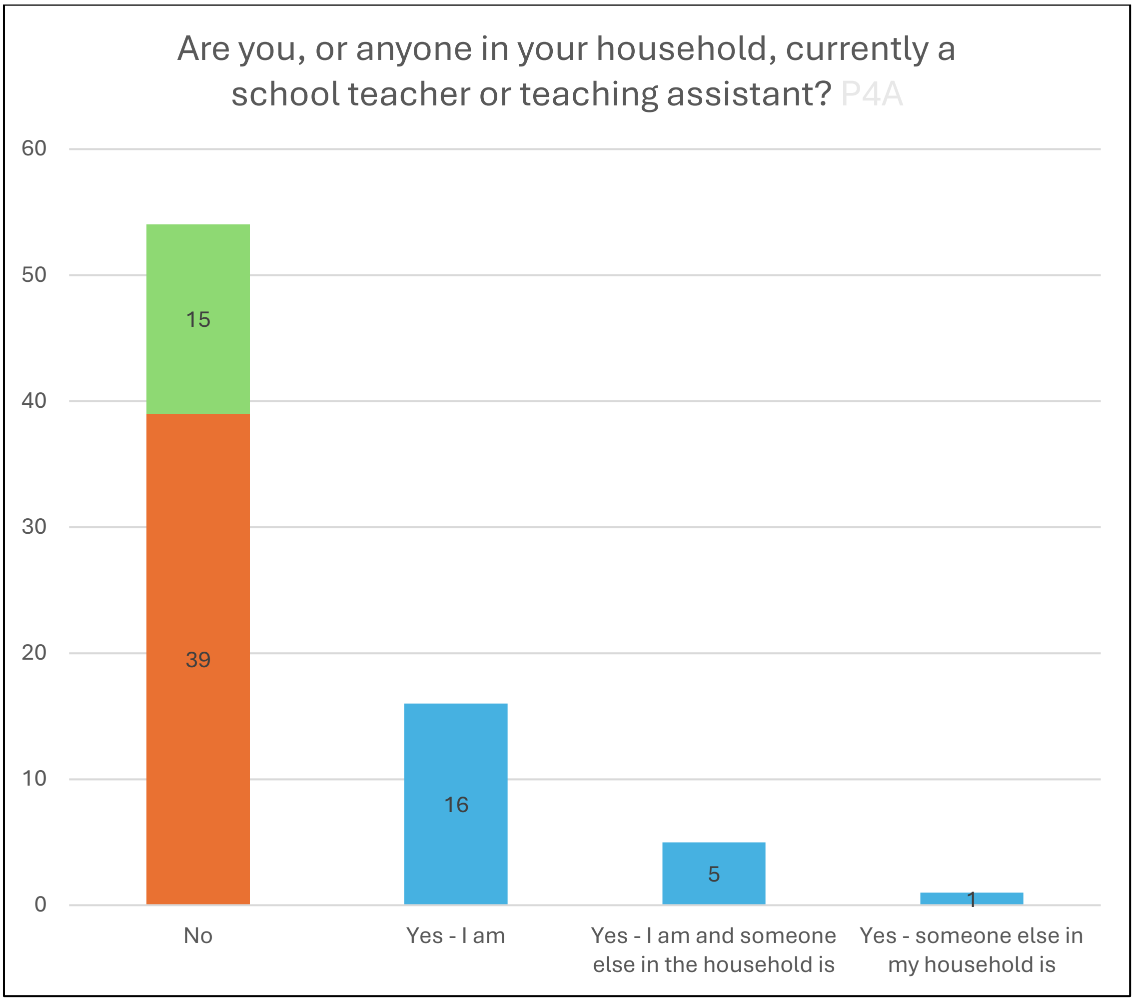


Figure 12: Parents' current or previous employment as either teachers or teaching assistants. The green portion of the 'No' column indicates parents who had been a teacher or teaching assistant in the past. Columns are labelled with the raw numbers of responses. N = 75.

Figure 12 shows 37 responses, just under half the sample, indicated households with adults working currently or previously as teachers or teaching assistants. Five households had two teachers, presumably both parents. Those who were currently teachers, or had previously been, were also asked whether they were, or had been, science teachers. Two were current science teachers and one had been previously. Among interviewees, three were teachers or teaching assistants, and one had been previously.

3.5.3 Non-generalisability of the survey samples

The strategy employed for surveys and interviews was convenience sampling. This approach proved most suitable given speed and cost imperatives (Tracy, 2013), considering lockdown's finite duration and the fact that some schools were already relaxing restrictions when data collection commenced. The data are inherently non-generalisable; their value lies in knowledge contribution, offering potential pathways for further research or establishing connections with existing scholarship (Bryman, 2015).

Within the chosen methodological framework, this research's aims were not to generalise but to generate knowledge about experiences of teachers and parents. It is acknowledged that despite breadth and depth of data, they cannot capture all science education experiences during lockdown. Equally, it would be inappropriate to imply an 'average' experience derived from data.

3.6 Data analysis

As the methods used generated two types of data, quantitative and qualitative, there were two principal methods of data analysis, discussed below.

3.6.1 Analysis of Quantitative data

The main aim of quantitative analysis was to use descriptive statistical methods to communicate understanding of the data, identifying patterns and relationships (Tashakkori & Teddlie, 2009). Relatively small sample sizes meant inferential statistical methods were not appropriate. Where inferences have been suggested from the descriptive methods, these are speculative and would require further data for confirmation.

Quantitative data were obtained from the Qualtrics platform as Microsoft Excel spreadsheets. Consequently, all analysis was performed within Excel, except geographical distributions, for which Google Maps was used.

3.6.1.1 Data management strategies

Although raw data were always available from the Qualtrics platform, the original downloaded spreadsheet was copied in case of data loss. Raw data and processed data were then kept separate.

Data quantity necessitated data management strategies. Unnecessary data for analysis were eliminated, including records from survey previews (generated during my periodic checks), some metadata, and records from participants completing less than a threshold survey proportion. For the teacher survey, 39 respondents completed 22% or less and were excluded from analysis as these data were primarily demographic. All remaining teachers completed at least 61% of the survey, with over three-quarters achieving full completion; these data were retained for analysis.

In the parent survey, 20 partial completions contained no question responses, registered by Qualtrics merely through survey opening. Three additional participants completed 32%, 46% and 50% of the survey, respectively, all of whom were home-educators. Although home-educators were initially included in data collection, their data were not subsequently analysed. This enabled a tight focus on school-based education to be maintained, facilitating triangulation against teachers' data. Of the remaining 61 respondents, whose children attended school, the lowest completion level was 76%, and 93% fully completed the survey.

The resulting spreadsheet for each survey became the foundation for subsequent analyses, with column headings color-coded according to simple categories including metadata, school information, and teacher details.

Survey questions naturally suggested analytical categorization. Some questions formed individual categories where initial analysis involved simple response tabulation. For instance, a category examining teachers' opinions of the quality of education they had provided began with basic counting of multiple-choice option selections. Other data explorations then developed from these initial analyses, combining responses from different questions to investigate potential associations. For example, quality responses were cross-referenced with activity types, revealing correspondence between teachers' quality assessments and their use of live remote teaching (LRT) (see chapter 5, section 5.4.4).

Analyses were assigned unique label codes and catalogued, streamlining location and retrieval, auditing their completion and avoiding unnecessary repetition. The teacher survey, for example, produced 29 categories of analysis, and a total of 125 individual analyses. Each analysis label code linked to any charts produced; 59 charts were produced from the teacher survey, each of which was traceable to its original data via a code. In addition to being a clerical necessity, cataloguing also enabled a judgement to be made about when to stop analysing. Bar charts were usually chosen over other chart formats, reflecting the discrete nature of variables being displayed. This also provided a consistent approach to visual presentation of data. Label codes are visible next to titles of charts (for example, in section 3.4 above). Appendices 11 and 13 show categories of quantitative analysis for the teacher and parent surveys, respectively.

3.6.1.2 Data processing

Apart from the geographical mapping mentioned above, all analyses could be performed using functions and formulas in Excel. While this did not eliminate all errors, it removed human clerical errors, and streamlined the analysis process. Most analyses involved the creation of frequency tables (counting the spread of specific responses to each question), with some converted into percentages for proportional comparisons where relevant.

Questions permitting multiple responses required additional processing, analysing both the number of responses each person selected and their specific choices. Similarly, questions asking respondents to rank lists of their choices required more complex processing. Ultimately, however, the number of spreadsheet functions used was relatively small. Filters for separating columns of data into individual values were used often, often followed by the 'countif' function to extract frequencies of each value. Where questions required respondents to select several items, the 'Text to columns' function was necessary for separating list items and assigning each its own cell to facilitate further analysis. Though essential, using this function almost doubled the number of data-containing cells in the teacher spreadsheet.

For more complex analyses pivot tables were used, enabling frequency data to be quickly extracted and tabulated when investigating hypotheses. Choices for investigations followed an inductive process of hypothesising which variables might be expected to be connected. Associations were sometimes demonstrated, as described above in section 3.5.1.1, but in many cases none were found. Hence some analyses were of limited value and are not discussed in the chapters that follow. (For example, social media use by teachers, whether for personal or work purposes, shows no correspondence with anything else that was asked about in the surveys). The scope for conducting these investigations was theoretically huge and was not, therefore, exhausted. However, those completed were considered sufficient.

3.6.1.3 *Limitations of quantitative survey data*

Multiple-choice questions invariably imposed limits on data analysis, and consequently interpretation. For example, in the teacher survey, a question asking about pupil engagement included options like ‘Most’, ‘About half’ and ‘Less than half’ which, while representing gradation in a phenomenon, were numerically limited for simplicity. Consequently, respondents could only approximate their actual experience, appearing identical to others choosing the same option, with genuine differences remaining undetected.

Question options were frequently simplified because they addressed topics where respondents could not be expected to supply precise numerical data. Such questions sought judgements, so besides being limited by options supplied in the question, responses have degrees of subjectivity. Data granularity from these questions remains limited, therefore, and has limited objective ‘truth’. Though not preventing interpretations, such issues underscore that awareness of limitations was essential to ensure data were not conflated into inappropriate or dubious findings. This further exemplifies researcher reflexivity.

3.6.2 Analysis of Qualitative Data

The purpose of qualitative analysis is to generate categorisations through which a *“particular story”* reflecting the data could be constructed (Clarke & Braun, 2013, p230). Hence thematic analysis (Bryman, 2015; Clarke & Braun, 2013; Tashakkori & Teddlie, 2009) was considered most appropriate for analysing the 23.5 hours of interviews, reflecting the method of choice for many other qualitative studies on lockdown education (Bond, 2021). I transcribed the interviews myself and manually error-checked them. Each interview was therefore listened to at least three times: once during recording, once during transcription, and once during checking. This aided immersion in the data (Clarke & Braun, 2013), allowing initial impressions to be formed and items of significance noticed, before the formal processes of thematic analysis commenced.

3.6.2.1 Transcription

Orthographic transcription, focusing mainly on words spoken, was considered adequate for the purposes of analysis, although it is acknowledged that, as a transformation of oral to written communication, all transcription has inherent limitations (Kvale & Brinkmann, 2015). An effective and efficient transcription process was developed, using speech-to-text capabilities of Microsoft Word. Due to variations in spoken language, and the recordings themselves, the software could not satisfactorily process audio files straight into text. However, it performed better if 'live' speech was enunciated clearly into a microphone. Hence, listening to each audio file through headphones while simultaneously re-speaking dialogue into a microphone was a viable method. Slowing dialogue down to two-thirds original speed facilitated this successfully, producing satisfactory first draft transcripts.

Checking transcripts involved several processes. Transcription errors, where the software had inserted incorrect words, were corrected. Names or other identifiers were changed or redacted. My own initial and that of pseudonymised interviewees were inserted at the start of our respective utterances, as were start times of each from the audio file. Start times were helpful when raw audio data needed revisiting during analysis, for example when quotes from interviewees were selected for inclusion in data chapters. Punctuation was mostly omitted from transcripts to save time, but has been added in quotes used in data chapters to convey the sense inferred from spoken dialogue. An example of an interview transcript can be found in Appendix 8.

3.6.2.2 Thematic analysis

Given COVID-19's unprecedented context, thematic analysis was deemed suitable for interview analysis. Allowing code, category, and theme generation through inductive reasoning, it was considered preferable to deductive approaches employing *a priori* themes.

Bryman (2015) suggests thematic analysis lacks distinctive techniques, unlike other analytical approaches. However, Braun and Clarke suggest that good qualitative analysis is about *"analytical sensibility"* rather than rule-following (2013, p201), and cite flexibility as a strength of the approach, a quality that was considered desirable for this study.

Analysis was undertaken using NVivo software. Teacher and parent interviews were analysed separately, but the process was the same for each. This involved coding transcripts, then grouping these codes into categories and themes, following Saldaña's method of analysis *("first cycle coding")* followed by synthesis *("second cycle coding")* (2021, p6). The first step required complete coding of all transcripts, assigning short phrases to capture the essence of selected items of dialogue. Teacher interviews generated around 665 individual codes; parent interviews 326. The second cycle involved iterative reading of codes to identify patterns or similarities representing identifiable categories. This process was repeated for categories, bringing these together into themes -

broad organising concepts (Clarke & Braun, 2013) reflecting more significant areas of experience that teachers and parents recounted.

Generating categories and themes was not a straightforward process of natural emergence. It required critical reflection about interviewees' statements, and constant comparison to test whether categories and themes were adequately described and justified. Some codes and categories were ultimately not subsumed into themes, typically because they did not fit easily or contained few codes. However, they sometimes proved useful to inform discussions in data chapters.

This thematic analysis produced the following themes from the teacher survey:

- Science work - set or submitted
- Lockdown outcomes
- Pupils learning away from school and teachers
- Experience of live remote teaching
- Teaching during lockdown (other than LRT)
- Communication
- Technology provision and tools
- Skills, confidence, attitudes, views
- Wellbeing
- Whole-school aspects

Each of these themes comprised numerous categories within which coded data were located. The richest theme was about teaching experiences during lockdown. Within this were categories such as live remote teaching, which itself comprised six further categories containing 85 codes – the richness of these specific data, and the significance of the practice of LRT to those teachers who experienced it, influenced the decision to devote a chapter of my thesis to this theme.

For the parent survey, containing substantially less data, the following themes were generated:

- Parental factors and actions.
- School provision – content, quality, or quantity.
- Children's emotions or wellbeing.

Full codebooks for each set of interviews are in Appendices 10 and 12.

Chapter 4: Teachers’ experiences of providing science education in lockdown

4.1 Introduction

This chapter analyses and discusses data from teachers’ surveys and interviews. Section headings provide a narrative framework that reflects both significant findings from survey data and themes generated by thematic analysis of interview data, as listed at the end of the previous chapter. Although this framework does not reflect a strict chronology of lockdown, it attempts to construct a meaningful story, beginning with the early challenges faced by teachers and their schools, moving on to the core experiences that teachers described, and finishing with their predictions about how their future practice might change because of lockdown. The chapter closes with a summary of key findings and a critical examination of how they connect to existing research. The role of triangulation is also examined through a critical discussion.

As thematic analysis identified LRT as a significant and novel area of experience, this has been allocated its own chapter (Chapter 5), with limited discussion within this chapter.

As outlined in the methodology chapter, it is recognised that all data are ultimately teachers’ perceptions rather than objective accounts of events. However, their significance lies in capturing teachers' lived experiences, regardless of their objective accuracy. Where relevant, verbatim quotes from interviewees have been used to exemplify or illustrate specific points, and quantitative survey data are represented through tables and charts to support analysis and discussion. As stated previously, the dataset was 139 survey respondents, from which 20 interviewees' data have been analysed (one teacher's data was omitted due to poor recording quality). Short descriptions of teacher interviewees are provided in Appendix 1.

4.2 Preparedness for lockdown

This section discusses six principal areas which emerged from analysis of surveys and interviews, all connected with issues of preparedness for remote education:

- The suddenness of lockdown.
- Teachers' access to suitable technology during lockdown.
- Schools' knowledge about pupils' access to technology.
- Provision for pupils with no internet access.
- Pupils' IT skills.
- Teachers' retrospective views of what would have helped them.

4.2.1 The suddenness of lockdown

Evidence collected in this research suggests that teachers were not well prepared for the transition to working in lockdown conditions. On March 18th, 2020, the Prime Minister's announcement that schools would be included in national lockdown conditions (Johnson, 2020), left schools two working days in which to finalise plans for continuing the education of their pupils, remotely, over an indefinite period. Although media coverage of the pandemic was high profile, and several European countries, including Denmark, Ireland and Italy, had already instigated national lockdowns, UK teachers nevertheless experienced a profound, sudden change. Some teachers in this study described it using words such as “*panic*” and “*scramble*”. The abruptness with which normal school working ceased meant there was very little time for detailed planning of what would follow.

The inability to plan adequately was compounded by several factors, not least the unprecedented nature of lockdown itself. Teachers’ evidence suggests schools had no pre-existing contingencies for providing full-scale remote education; an understandable situation, having never had to do it before. Although most schools already had online platforms to supplement teaching, many teachers reported that pupils were not sufficiently familiar with these, and the rapid onset of lockdown meant little time to rectify this. Additionally, such platforms were designed to support face-to-face teaching, not replace it entirely. To make matters harder, at a time when coherent planning was essential, physical isolation of teachers and the move to entirely electronic communication exacerbated difficulties.

Teachers’ interview evidence suggests school leaders experienced difficulties making informed decisions due to uncertainties. Not knowing how long the lockdown would last made it hard to gauge whether to plan for long- or short-term disruption. Equally uncertain was what pupils were experiencing at home, and whether teaching staff could effectively provide remote education. Some teachers had young children to look after, some lacked adequate internet access at home, and some were dealing with COVID infections in their own households.

Teachers had little knowledge of what high quality remote education for schoolchildren looked like, or indeed whether they could realistically provide it.

Interview evidence suggests that some adapted quickly, learning what worked and what did not. However, factors relating to preparedness and preparation represented barriers affecting the quality and consistency of what they were able to do.

4.2.2 Teachers' access to suitable technology during lockdown

A large majority (93%) of the survey sample indicated they had provided some form of science education during lockdown 1, and 92% of these teachers stated that this had required pupils or their parents to use the internet (for example because instructions had been emailed). Hence, most teachers were using digital technology for providing science education from home.

Evidence from interviews adds richer detail to these statistics, showing a more complex picture. Technological requirements for providing remote online science education sometimes exceeded what teachers might be expected to have in their homes. Live Remote Teaching (LRT), discussed in more detail in chapter 5, could require simultaneous use of multiple devices; some teachers mentioned using two screens for example. Moreover, teachers with furloughed partners (i.e. not working but being paid a retaining salary until lockdown ended) or their own school-aged children could have internet access compromised by the need to share devices, bandwidth issues or even just find a suitable space to work.

Survey responses reveal that most teachers had a school-supplied device, but approximately a third of primary and secondary teachers reported having neither a laptop nor tablet supplied by school. These individuals stated that they used a personal device at home to do schoolwork. These data are shown in figure 13.

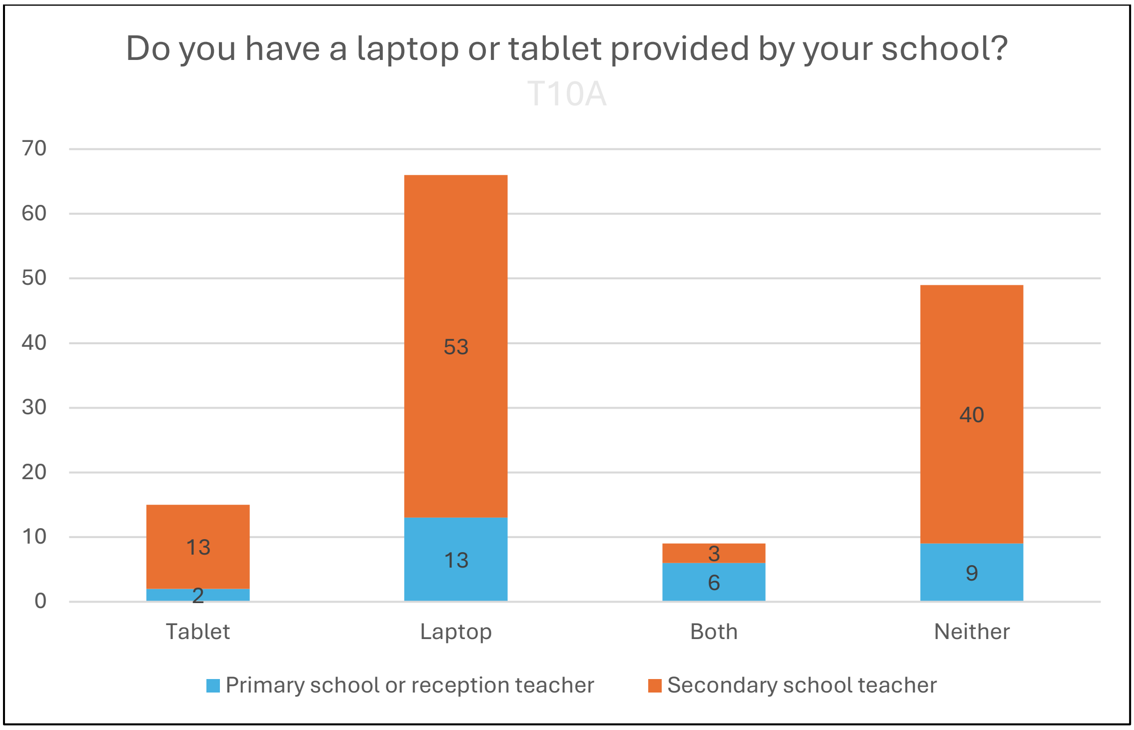


Figure 13: Responses to the question, "Do you have a laptop or tablet provided by your school?" Columns are labelled with raw numbers of responses for each category. N = 139.

Teachers' views about having to use their own device for work varied. Nigel, an early career secondary teacher, had plenty of his own technology at home so did not feel disadvantaged. June, a more experienced secondary teacher, reported that although she had a personal laptop, she only used it for schoolwork, a situation she regarded as *"an insult"*. However, most teachers who had a school device reported that they *also* used a personal device at home for carrying out schoolwork.

Celia, a primary teacher, reported that before lockdown some of her colleagues had neither a school device *nor* their own. Her school had had to supply laptops, previously used solely in school, to these teachers. Such provision was not always an effective solution: Elspeth, another primary teacher, was offered a school laptop, but it was so old that she found it more convenient to use her own. Lisa, a secondary teacher, had a similar experience. She was allocated two laptops successively during lockdown, neither of which was adequate for what she needed to do. This resulted in her feeling compelled to buy her own, which she regarded as an unwelcome expense. She stated:

"In the end you just give up. You just get so frustrated…I felt a failure because I couldn't do what they were asking me to, so I just ended up having to buy one."

4.2.3 Schools' knowledge about pupils' access to technology

Interview and survey evidence suggest that at the start of lockdown teachers, and their schools, lacked sufficient knowledge about how easily pupils could access the internet at home. Hence, as well as a lack of experience, teachers' initial planning for remote education was hindered because they could not precisely tailor the work they set to pupils' capacities for completing it. When asked in the survey about what things would have improved the quality of science education they'd provided, the most frequent option selected (by 83 teachers), was 'If pupils had had better access to technology'. Considering that most surveys were completed near the end of the first lockdown, in June-July 2020, it is possible this view was gained retrospectively from the experience of lockdown teaching, rather than from prior knowledge. Interviews tended to confirm that teachers did not know with certainty, in advance, how easily pupils could access the internet at home. They did not know what technology pupils would be using, implying assumptions had been made about pupils' abilities to complete work online. Hilda, a secondary teacher whose school served an area of socio-economic disadvantage, specifically stated that she had not realised until lockdown just how poor internet access at home was for some:

"I personally didn't realise this until lockdown that we have quite a significant number of students that don't have access to the internet at home at all. They

don't have wi-fi and they don't have devices to access the wi-fi except normally a phone… it wasn't just like a couple of students; it was a significant number of students where it was going to be an issue throughout school.”

Ella, who taught in a secondary school in similar circumstances, described the issue of families who had internet access, but not enough devices:

“We know from some cases that some kids might have access to a smartphone but there might be three siblings in the same house, so they've got access to a smartphone but it's not going to be at a suitable time for them to take part in a ‘live’ lesson. Again it's similar with laptops. There might be a laptop in the house, but mum and dad are using it so it's not available till 6 o clock.”

Other teachers reported families with insufficient devices for the combined requirements of parents’ work and children’s online learning. Beatrice, a secondary teacher, had a pupil whose family had a tablet, but an older sibling who was at university needed to use this to learn from home. Anne, who taught physics at an independent school, and whose pupils came from more affluent families, described how having enough devices was not always problem-free, especially for larger families. With additional internet-connected devices in use, home wi-fi networks faced potential strain from increased traffic generated by parents working remotely and multiple children participating in video-based lessons simultaneously.

Sharon, who worked in a state secondary school in an area of high socio-economic disadvantage, had concluded that her pupils were not just relatively ill-equipped, but did not want to reveal this for fear of being stigmatised. The short lead-in time to lockdown had meant pupils had been asked to respond to a question about home internet access by raising their hands during form-time. Subsequent poor levels of engagement with online work led Sharon to conclude pupils' responses about their access had been exaggerated because of peer influence. She also thought this was unfortunate because they would have received some support had they said they lacked a device or internet access. While Sharon's hypothesis cannot be verified, it highlights difficulties caused by the suddenness of the lockdown; more time would have permitted collection of more accurate information.

Andrea, a secondary teacher, thought that one of the problems for economically disadvantaged families was that they did not have any digital device with a large screen:

"It is a financial reason that they can't gain access to the internet…they would buy themselves a mobile phone, but they won't buy themselves a laptop … they've invested in mobile technology and they haven't actually invested in a computer as such…we've also had instances where we've got four children trying to share a mobile phone."

Other teachers described families whose internet access was only possible through a smartphone. For them, the small screen was not the only problem when trying to do online learning. Hilda had discovered that the pupils who did not have wi-fi at home could only access the internet using their phone's mobile data allowance, paid for in their monthly tariff. Once this had been used up, further internet use would incur an extra charge. This was an additional disadvantage for pupils whose parents who could not afford either wi-fi or a large screen device.

The consequence of insufficient prior knowledge about students' home internet access meant that some schools invested time and effort creating teaching materials that many pupils either had difficulty using or never accessed. Had teachers known in advance that many pupils would find this difficult, efforts could have been channelled more productively. However, the picture is complicated by teachers' lack of experience of remote education and the lack of time to prepare before the lockdown. Therefore, while pupils' internet access clearly represented one barrier to effective lockdown learning, it was not the only obstacle.

4.2.4 Provision for pupils with no internet access

Once they had identified which pupils lacked internet access, schools typically adopted one of two main contingencies. One approach involved lending laptops to households without them, though this was constrained by the limited availability of devices, which were usually computers normally used on school premises. This option sometimes required additional support: homes without wi-fi needed routers, and students might need assistance if they were unfamiliar with the borrowed laptops. The more widely used approach was to send paper packs of learning materials to pupils' homes, either by post or by teachers delivering them in person.

Not all interviewees disclosed or knew how long it was before these contingencies were implemented. In view of general uncertainties about how long lockdown would last, and teachers learning as they went along, delays can be appreciated. Nigel was not involved in providing paper packs, but said the school had got on with this *"fairly quickly."* Hilda thought her science department began providing paper packs halfway through the lockdown, implying that, in her school, some pupils had little or no science education for several weeks.

The number of paper packs sent home varied considerably between schools. Ella worked in a school of 1000-1500 pupils and estimated there were 80 families by mid-June who had received paper packs in science. However, this did not constitute the total number who could not participate in online learning; it was just the families with whom contact had been made and who needed an alternative to online provision. She was concerned that her school had been unable to contact some families at all during lockdown. In Julia's secondary school, which was about half the size, a higher proportion of paper packs was sent out, but similarly these were just for families who requested them. This suggests, again, that there could have been families whose children had little or no science education.

The type of work included in the paper packs often reflected the online tasks that were being set for those pupils with internet access. For example, if pupils accessing materials online were being sent a PowerPoint presentation, or taught using one via videoconference, the paper equivalent was a printed version. Such paper materials highlight how lockdown learning was invariably not time-dependent; most approaches were based on the assumption that pupils would undertake the learning at a time convenient to them.

Not all schools sent paper packs out to pupils, even if the need existed. Elspeth recounted how one of her colleagues, a year 3 teacher, had printed materials but was told *not* to send them because school leaders did not want one year group to have these while others did not. This, and the use of paper packs in general, illustrates the piecemeal nature of lockdown provision. The reliance on parental requests additionally highlights that some children potentially did not receive any schoolwork at all.

4.2.5 Pupils' IT skills

A commonly mentioned problem teachers reported in interviews was pupils struggling with IT-related aspects of completing science work. Most learning tasks set during lockdown required pupils to use the internet, if only because it was the medium of communication. They also often required familiarity with software packages such as Microsoft Office, something many teachers were unaware that their pupils lacked skills in. Anne put it bluntly:

"I've massively seen how much the kids need to be better educated in using tech, and they're rubbish at it."

Josh, another secondary teacher, contrasted what he saw as popular views about young people's flair for technology with his own experiences:

"People often say, "Well, this is the generation, they understand technology so much," and I don't think that's true. I don't think kids, teenagers, necessarily understand…they have grown up as consumers of the things. So when I say to someone "I want you to download this app, and I want you to send me it in this format," it took three months to really get some of the students using it, even though I sent them step by step instructions or I sent them videos on how to do it."

Several teachers cited examples of pupils being unable to perform tasks which they'd considered routine, and thought would be straightforward. Such aspects of remote education were invariably peripheral to learning science, and had possibly been overlooked as relatively trivial. Sending completed work to teachers, for example, frequently ended up being fraught as pupils struggled with email or attaching files. Hilda described how the task of ‘copy and paste’ gave her pupils difficulties. Sharon, whose departmental approach was based on pupils being sent an electronic self-study work booklet, recognised that she and her colleagues had made assumptions about what pupils would be able to do:

“I just assumed they could open up the student booklet, type on it, save it under their name and send it back to me, and they really couldn't do that… maybe I just assumed that, you know, there was someone at home that could show them how to do that.”

These examples illustrate that teachers were encountering a basic mismatch between their assumptions and students' actual capabilities. Joelle, a primary teacher, explained that while her pupils could confidently perform specific digital tasks like creating videos or blogging, they struggled with office-style documents that comprised much of the lockdown learning activities. She discovered that students responded more effectively to assignments where they could photograph their problem-solving work to share with her. Their skill set, therefore, differed significantly from her expectations.

Email, which schools relied on for communication with pupils and homes, was clearly difficult for many pupils. Alina, a secondary teacher, reported that one of the main reasons her pupils struggled was because they had lost their passwords to log on to their email accounts, and hadn’t realised this was important. Although the school had put a ‘how to’ video on their website for pupils having this problem, this was then communicated to pupils by sending out an email; inevitably those who needed the help were unlikely to view the video unless they looked at the website by chance. This example typifies how lockdown conditions could amplify minor difficulties by disrupting the normal chains of communication that pupils and teachers were accustomed to. Alina explained that her school had had to resort to resetting all pupils' passwords to '12345678' to make it easier for them to use their school IT accounts. She though that, in hindsight, it would have been better to have done this at the start of the lockdown.

Eleanor, who taught in an independent secondary school, described how her pupils could use email but did not know about its conventions or etiquette. She received emails from pupils written in the style and language more appropriate for their peers, rather than a teacher. She speculated that this knowledge was not in the school's curriculum; pupils' formal computer-based tuition tended to be more about coding rather than office software. Hilda expressed similar views. She'd received emails from pupils in which the whole message had been typed in the subject box. She stated:

"It's not just the younger ones that were doing that: it's from all year groups. We've not prepared them to use technology properly."

To supplement or host the tasks pupils were set, schools frequently made use of online platforms. For secondary schools this often involved a Virtual Learning Environment (VLE). Forty-six secondary teachers indicated that they had used the school's VLE to provide work during lockdown. Of these most stated that the VLE had required varying degrees of updating for it to be ready; only eight teachers stated that it was completely ready before lockdown. Hilda was one of the teachers whose survey response stated that the VLE required 'a little additional preparation', but her interview suggested that this was immaterial:

pupils were simply not familiar enough with it. She described pupils still asking her how to access the VLE eleven weeks into lockdown. Jack, another secondary teacher, identified a similar issue:

“I must have had close to 500 messages with either year seven and year eight or their parents, and I would say the vast majority of them - 90% - come from not knowing how to access online portals that we are using.”

In contrast to the number of messages about logging into online systems, Jack stated he’d had fewer than one query per week related to the science he was teaching. Rachel, a secondary teacher, expressed the view that pupils needed more exposure to using computers, and that more investment was required:

“I think education would benefit from proper investment in IT - making sure that students are able to use systems. We do have computer science on the curriculum … but you know that's one lesson a fortnight… when I take a class and get them to make an account on Seneca for example, I mean they’re literally asking you, “What do I type in this box?” when it's asking them for their name…it's just the lack of familiarity.”

The evidence discussed in this section highlights that teachers were mainly unaware what pupils’ repertoires of digital skills were. Secondary teachers, in particular, were setting work that required specific office-type skills, yet were unaware that pupils were unfamiliar with them. As Rachel’s comment indicates, this is an issue for schools to address if pupils are to benefit from digital learning resources, and if remote education is needed again.

4.2.6 Teachers' retrospective views of what would have helped them

The results of a question about what teachers thought would have improved the quality of the science education they had provided are shown in Figure 14.

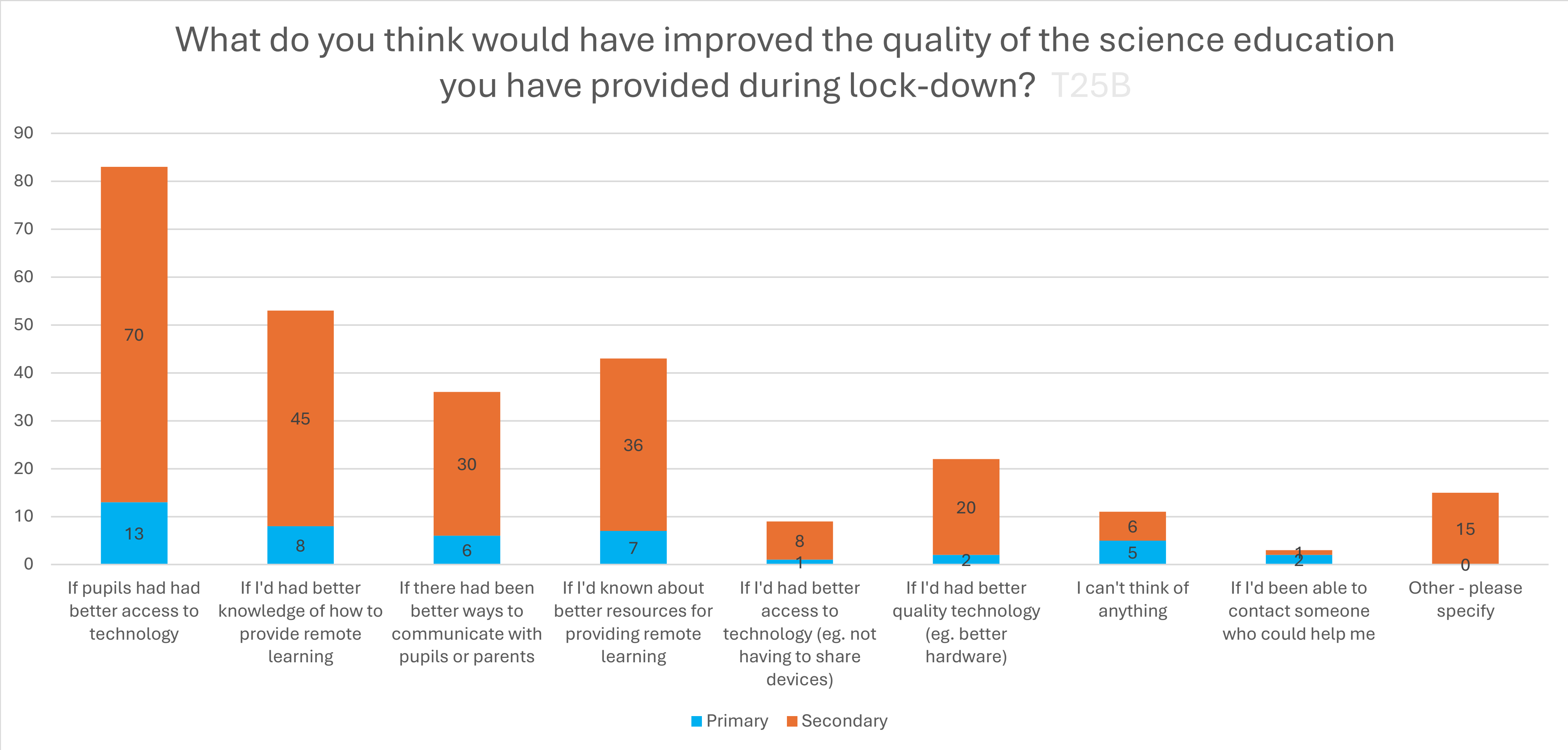


Figure 14: Responses to the question, "What do you think would have improved the quality of the science education you have provided during lock-down?" Respondents could choose multiple options, as well a free-text option. Columns are labelled with raw numbers of responses. N = 123.

As noted previously, pupils' access to technology was the most frequently cited factor that would have improved the quality of teachers' remote science education. Teachers' lack of knowledge of remote education methods, and suitable resources, were also frequently selected; a total of 96 responses being received for these two factors. A smaller, but still significant, number of responses (31) related to teachers' own access to technology, and its adequacy, reinforcing some of the points made in section 4.2.2.

The 15 free-text responses were in the main elaborations of the other options, but occasionally raised different points. For example, one teacher suggested that parents also needed help and training in the use of one of the online platforms used by their school, an interesting proposition which resonates with some of the parental experiences that are discussed further in Chapter 6.

4.3 Teachers' working arrangements, workload and wellbeing during lockdown

This section examines issues relating to how teachers worked during lockdown, including their workload and wellbeing. Reflecting the lack of preparedness discussed in previous sections, surveys and interviews reveal considerable variation.

4.3.1 Teachers' working arrangements

Roughly a third of teachers were working from home full time when they completed the survey. Interview evidence suggests this was usually because of COVID vulnerability or family commitments such as having children at home. Approximately 60% were teaching at school occasionally, usually to provide staffing for children of key workers or those deemed vulnerable, who were still required to come into school during lockdown. This is another area in which some schools lacked accurate information, however. Hilda reported being rostered twice at the start of lockdown to cover for the children of key workers, before it became apparent that there were only four pupils who would be attending, in a school of approximately 900 pupils. Staffing was subsequently scaled back, and she did not go into school for the remainder of lockdown. Sharon reported a similar situation in her school. The remaining small number of teachers, about 10% of the sample, stated that they were teaching in school on most or all their usual working days. This group was dominated by primary teachers.

For secondary teachers going into school to cover for key worker children, this mainly involved supervision rather than teaching science specifically, although some managed this occasionally. For most pupils it was a case of getting on with online work which had been set by their subject teachers who were working at home. For both primary and secondary teachers, going into school to supervise these pupils usually had to be done on a voluntary basis because of their own care commitments. Consequently, the frequency with which they attended school varied. Sharon, for instance, chose to go into school every Thursday and Friday primarily for her own mental wellbeing, while her colleagues covered just one day per week. The time in school was helpful to enable her to do her own planning, when she was not helping the group of eight children. Anne also chose to physically attend school to get on with work. She described instances of teachers who did this because their ability to work at home was affected by poor internet connectivity, or by other family members who needed to use the internet for work or school. As schools began to partially reopen from July 2020, inevitably more teachers were spending more time in school, teaching year 6 or year 10 pupils in ‘bubbles’, isolated groups kept apart for infection control.

4.3.2 Teachers’ workload during lockdown

Most teachers’ working days, and indeed work, were substantially different to their normal school routine before lockdown. Of the 20 teachers interviewed, only the three who worked in independent schools taught their regular timetables from home, using LRT, for virtually the whole of lockdown. As such their working day had a superficial similarity to pre-lockdown conditions. However, as Anne explained, teaching using the unfamiliar medium of a videoconference initially increased her workload:

“At the beginning it was horrendous because it was double planning everything. It wasn't just thinking, “Oh I'll photocopy this worksheet,” it was: find a worksheet, and make sure it was in a format they could access, and edit, and do.”

As well as the requirement for materials to be in a suitable electronic format, Anne’s workload was increased by the school’s monitoring of attendance:

“We had to follow up after every lesson if any student hadn't been there, or if you'd called on them and they hadn't responded… it was called a ‘distance learning concern’. So as a tutor I got a load of those in, for example saying, “Violet’s internet dropped out three times during the lesson - I'm concerned she's going to fall behind.””

Much of Anne's account emphasises issues that would have been trivial concerns or non-existent in traditional face-to-face working conditions. She described how things which could be resolved by quick conversations in school became protracted electronic processes when conducted remotely. Absent pupils, who would have simply missed the lesson under normal circumstances, could email her afterwards to request a recording of the videoconference lesson to watch. Although this provided an educational advantage over face-to-face lessons, it contributed to Anne's increased workload.

Judy, an experienced teacher who taught in an independent school in Belgium, also reported that LRT was more tiring, and her workload was higher than usual:

"I teach 24 lessons a week, of 50 minutes, and to be prepared and constantly watching that clock to be prepared, to be on time, I found exhausting, I will admit… I had to be more prepared when I was doing it online, to have everything ready, and so therefore I felt my workload was higher."

New ways of working caused by lockdown meant that Judy's substantial experience, normally a tremendous advantage enabling her to perform flexibly in the classroom, was far less relevant. Rather than teaching responsively, addressing needs as they arose, lessons via videoconference were planned in more detail, requiring more time in preparation. Additionally, in common with everyday school life, Judy also had meetings during her non-teaching time, via videoconference.

Even teachers who were not teaching their regular timetables by LRT could have very intense workloads. Julia, a secondary teacher, taught each of her classes just once by LRT each week, but described her workload as worse than under normal conditions:

“Those one lessons are very intensive, and I'm having to be very particular with the resources, because if the resources aren't right the kids won't be able to do them…We then have to provide feedback, so obviously I'll give live feedback in a lesson, but I also need to provide a feedback sheet.”

Julia’s account illustrates extra workload challenges, additional to facilitating science learning online. Her non-teaching workload was dominated by electronic monitoring of pupils’ online engagement, and providing feedback. She viewed the feedback mechanisms as contrived, and described the monitoring as *“pretty horrific.”* It involved checking whether pupils had emailed her with completed tasks, and whether they had logged on to online portals that the school paid for. Sometimes she had to judge pupils’ levels of engagement and apply colour codes accordingly. Julia conceded that this did help teachers to judge whether the tasks they were setting were effective, but it was clearly onerous.

June was another secondary teacher whose workload was dominated by non-teaching activity. She spent a lot of time creating science teaching resources to be sent to pupils, either electronically or by post, for immediate use. This was time-consuming, and consequently frustrating:

“I think all teachers are used to actually getting an awful lot done in a very short time…and the fact that it was taking me such a long time to achieve very little was really, really frustrating and quite demoralising.”

Like Anne’s experience, June’s account underlines how teachers were not simply sending out pre-existing materials for pupils to use. Resources often had to be re-designed or made from scratch to be suitable for independent use by pupils. Partly this reflected how existing resources were intended to be *printed* for use in school. Sometimes resources were not editable, meaning pupils could not type directly on to them. One option was for pupils to print these, hand-write their responses and then scan this physical item before returning it electronically to the teacher. This process sometimes worked but was often untenable because many homes did not have printers.

For other teachers, workload was less intense. Nigel, an early career teacher, found himself doing very little for most of lockdown as work for pupils was mostly supplied centrally by more experienced colleagues in his department. After the first six weeks, during which he had contracted the COVID virus and did no teaching, he then taught one day every fortnight. He estimated he had done seven episodes of teaching in total during lockdown 1. This was similar for Beatrice, a Teach First trainee, whose workload decreased over lockdown. When not teaching, both Nigel and Beatrice were able to spend their time planning, for instance for the new school year.

Eleanor, who taught her timetable by LRT, described her workload as *"different, really, rather than more or less."* Some differences arose because working from home provided flexibility, allowing her to plan her day better and pursue personal interests more. She thought she normally spent more time in school than she was spending teaching from home during lockdown. Monitoring pupils' work was also different. In the classroom she could get a feel for the quality of pupils' work without poring over it for a long time. This was harder with online platforms. Rather than rapidly viewing pupils' work and writing comments, as would happen when looking at an exercise book, each piece of work was a separate file to be opened, with feedback for pupils written in a different location. Scaling this up to a whole class, who might have completed three pieces of work during an online lesson, was a more time-consuming process than marking exercise books.

Jack also described his workload in terms of a difference to normal working:

"I do think I probably worked more hours during lockdown actually, in terms of, you know, starting earlier than 8:00 o'clock and finishing definitely after 4, but I think it has been quite thoughtful work and more time being strategic and thinking, "okay let's try getting the team operating like this," because, you know, not only is it my practice that I've been trying to help coordinate."

Jack was unusual, though not alone, in that his experience of lockdown had revealed new practices that he had found interesting and exciting, motivating him to work harder. His interview evidence suggests that his school leaders allowed teachers time and space to innovate, which was beneficial.

4.3.3 Teachers' experiences of the ease or difficulty of lockdown

Although the sudden imposition of lockdown and the 'new normal' of providing education remotely was potentially a cause for difficulty, this did not always materialise. Similarly, the level of difficulty teachers experienced did not remain the same throughout lockdown. Survey responses about how easy or difficult teachers had found science education provision in lockdown, and how this had changed, reflect a wide range of experiences. While some teachers experienced difficulty throughout lockdown, others did not. These different experiences applied to both primary and secondary teachers, with no clear pattern. Similarly, analysing these data by years of teaching experience did not demonstrate any clear connections. As mentioned previously, experience was not always an advantage because of the newness of online education.

Of 68 teachers who expressed an opinion about whether their experience had been easy or difficult, a majority (40) stated it had been difficult. Of the 62 who gave a response about how their experience had changed, half found things became easier; just under a third experienced no change, and around a fifth found it became harder.

Interviews reveal several reasons why some teachers found things getting easier. Anne referred to pupils acclimatising, and her own growing familiarity with what she needed to do. Parents of her pupils often bought them their own device (e.g. a laptop), highlighting an advantage children from more economically advantaged backgrounds enjoyed, in contrast to those from families with fewer financial resources. She also thought Microsoft had recognised that teachers were using their 'Teams' software for teaching, improving its functionality. Rachel described her experience as *"an evolution"*. She had learnt what materials and instructions were needed to improve pupils' independent learning, giving her more confidence. She also mentioned an online platform which had made its premium services available for free, allowing her to give pupils more variety. In Ella's case the easing had been the result of school leaders reducing how many online 'lessons' teachers had to provide for pupils. She saw this as a reduction in quantity but probably an improvement in the quality of what teachers were providing.

Teachers sometimes relayed accounts of other people's experiences. Despite finding lockdown becoming easier, Rachel was aware of others who were having very different experiences:

“I think initially lockdown was very hard for teachers. They were having to learn a whole new system of working; they were being held accountable. We were lucky - we had a supportive management team who weren't making huge demands on us, but I have friends in other schools who had literally to sit at their laptop from 8:45 in the morning until 4:00 o'clock in the afternoon and, you know, it's almost like, don't break eye contact. It was very, very tough on them at the same time as dealing with everything else.”

Amongst the interviewees, two primary teachers found their work becoming more difficult. Elspeth, who taught a key stage 2 class, cited the main issue as her limited resources for science:

“Once I'd exhausted my links, you know, for different websites, it was like right … where do I go? You felt like you constantly had to be refreshing and providing another site to go to … and I think I don't have the materials, you know.”

Celia’s reasons were slightly different, although still related to uncertainty about how to proceed. Her school had received feedback that parents were feeling overwhelmed by the amount of schoolwork and their limited capacity to help their children. The outcome was to make science optional for pupils, so that the focus could be maintained on English and Maths. Celia became unsure what science she should provide in these circumstances.

Overall, the ease or difficulty teachers experienced during lockdown reflects several issues. Many teachers’ experiences changed over the duration of lockdown as they learnt how to provide better online education, easing workloads as they became used to the conditions and more confident at what they were doing. However, vastly different workloads for teachers could arise, even within the same school, due to management decisions about curriculum priorities or centralisation of provision, for instance.

4.3.4 Teachers’ wellbeing during lockdown

Wellbeing, of both teachers and pupils, was a topic that spontaneously arose at numerous points during interviews and was an underlying theme of relevance to various aspects of lockdown working. Interview evidence suggests school leaders took it seriously. Jack was able to avoid going into school because of his COVID-19 vulnerability, and Nigel caught the virus and was ill for a few weeks at the start of lockdown, preventing him from working effectively. These were circumstances that schools supported. Similarly, allowances were made for teachers’ home situations, particularly for those looking after their own children.

Despite these considerations, other issues of teacher wellbeing were less well catered for. In terms of physical wellbeing, a significant component of lockdown working for most teachers was prolonged time sitting down, working at a computer screen. It is possible this was overlooked due to other challenges schools were facing. June, who did not use much videoconferencing, still estimated her screen time as 6-7 hours each day, and found this a struggle. She suspected it had affected her eyesight:

“My eyes now need testing because they're not the same any more and I'm fairly sure that's because of having to spend so much time on the computer.”

Judy, who did all her teaching via LRT, described how tiring this was:

“We all of us found that at the end of the school day, having spoken on a computer screen all day, to be extremely exhausting, much more than being physically present in the class.”

Josh had found that his physical health had also been affected because his small house meant he had had to work at his kitchen table, where the unsuitability of the chair he was using began to cause him back problems. It was not so much the computer time as the time spent sitting down which had been problematic:

“I've put on quite a significant amount of weight during lockdown… I do 15 to 18,000 steps a day when I'm at school… even though mentally and emotionally I've engaged really well, I think there has been a toll on my physical health…”

Some schools made decisions intended to support teachers' mental wellbeing that inadvertently produced negative consequences, illustrating the challenges both school leaders and teachers faced when attempting to gauge appropriate responses under lockdown conditions. Beatrice, Sharon and Lisa identified a problem with how the responsibility for providing work for pupils had been organised. If teachers had set tasks for each of their classes, it was recognised that this would probably result in duplication of their efforts. Instead, tasks were set by just one teacher for a whole year group. Duplication was thus avoided, and teachers’ workload was reduced. However, this strategy probably resulted in poorer engagement from pupils: not only did they often not know the teacher communicating with them about their science work, but the teachers themselves did not know many of the pupils either. Sharon explained the problem:

"My year 10s, if I sent them an email saying, "come on get this work done," they know me… they would have done it I'm sure… but if it was somebody else they'd think "yeah, whatever," so I think that was the issue with engagement."

Beatrice echoed this when describing her work with classes she did not normally teach:

"With the two classes that I don't actually teach… I haven't got those relationships with them, so they're not going to want to work for me."

Lisa had a similar experience. Not knowing pupils affected her ability to help them because she did not have the background knowledge of them as learners in science. Sharon suggested that the decision, taken with good intentions to help improve teachers' wellbeing, had ultimately let pupils down.

Elspeth described another negative outcome. She perceived that her school leaders had not prioritised science so that teachers would not be over-worked. She thought greater focus on English and maths had arisen because there were more ready-made resources in these subjects that pupils could use. It meant that pupils missed specific science topics that they would not meet again:

"We weren't really following the curriculum … they've missed two or three units of work …huge chunks of things like rocks and fossils in year three that they'll never come across again…there are huge chunks of work that they haven't really done anything on."

The wellbeing issues described above are a further reflection of the unprecedented nature of lockdown. Nevertheless, there are clear lessons to be learnt about how teachers' physical wellbeing was affected by providing online education, as well as how management decisions could unwittingly have negative outcomes.

4.4 Teachers' views on science education in lockdown

Although most questions in the teacher survey focused on teachers' experiences, two questions specifically sought their opinions. These explored their views on the quality of the education they'd provided, compared with normal, and whether they thought science had maintained its importance in their school's curriculum during lockdown.

4.4.1 Views on the quality of science

The predominant opinion expressed by teachers was that the quality of lockdown science provision was worse than normal science lessons. Data from this question are shown in Figure 15.

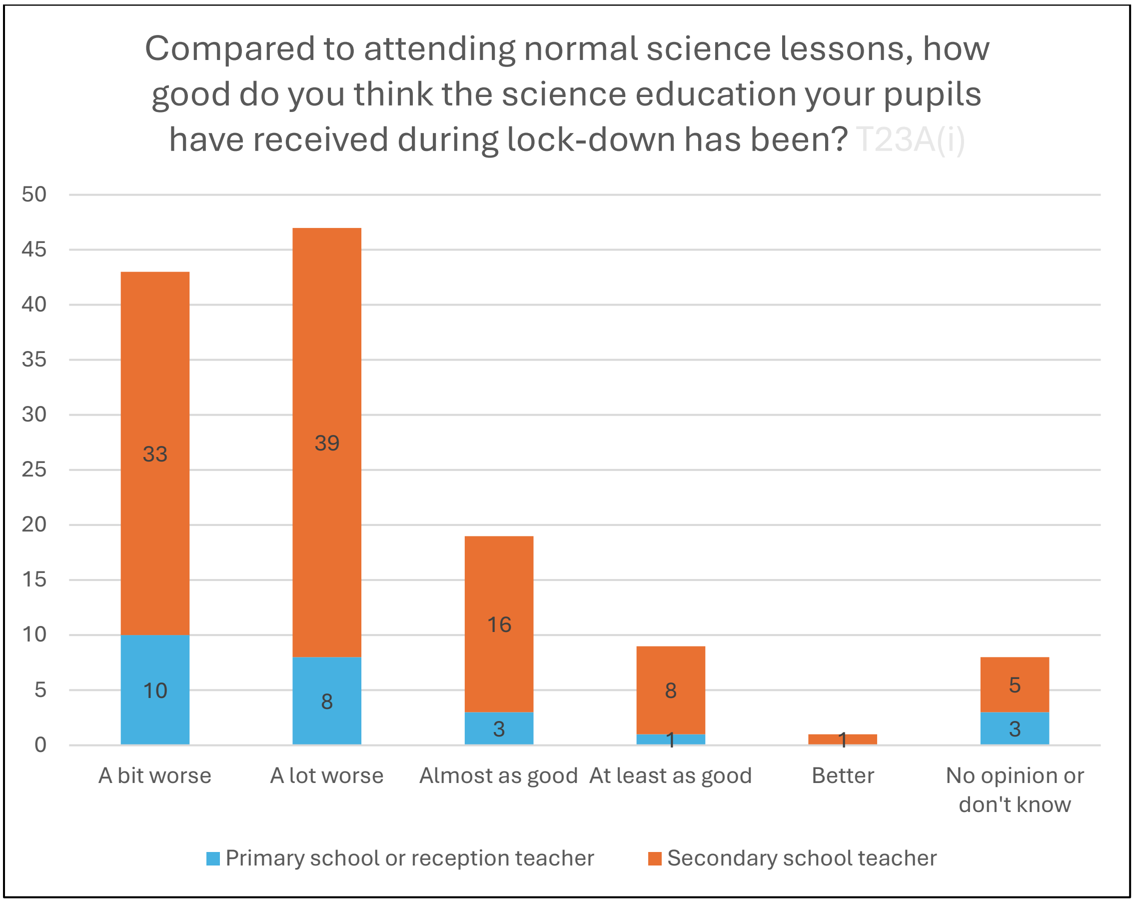


Figure 15: Teachers' responses to a question about how good they thought their lockdown science had been compared to normal science lessons. Columns are labelled with raw numbers of responses for each category. N = 127.

Figure 15 shows that responses of primary and secondary teachers were similarly distributed, with the commonest response being that lockdown science was ‘a lot worse’ than normal science lessons. These data suggest most teachers felt dissatisfaction with what they had been able to provide. The views of the interviewed teachers broadly reflect the data for the whole sample, with most expressing a ‘worse’ opinion. In chapter 5 further analysis suggests that teachers who used LRT tended to have a better opinion of the quality of what they had done. Most teachers did *not* use this approach, implying absence of direct contact with pupils could have been a factor influencing ‘worse’ views. Without direct contact it was difficult for teachers to know how tasks they were providing were being used by pupils, or whether they were helping them learn. Nigel described his own experience:

"I don't know the actual impact of my work to the students. I don't know where I've fallen down or what I could have done better. I'm at that level of not knowing anything about it…. I don't know where the gaps are. I'm missing the entire picture."

Lisa expressed a similar view, adding the sense of frustration arising from communication problems:

"'Cos we're not having that day-to-day contact with them… are you sure it's being done? If they're in the lesson that's half the battle, but if they're not even picking their emails up how can I ensure that they're doing what I need them to do?"

These factors are returned to in section 4.6.1, in discussing levels of engagement. They are not the only reason teachers thought lockdown science had been worse. Rachel raised problems pupils had when trying to learn independently away from school:

"It's just not a rich experience being at home trying to learn science without anyone to interact with, without any practical work, without receiving that immediate feedback where someone says, "well done" … or class discussions."

Impoverished experiences of learning from home were repeated by other teachers. June had first-hand experience of this through her own children:

"I've got two children who are secondary school ages …they were bored. There's only so much "go and find this out for yourself, watch this video, fill out

this piece of paper, answer these questions," that you can be bothered to do in a subject that you don't like."

Despite limited science teaching during lockdown, Nigel spoke to pupils in his form group every week, discovering they were bored and lacked motivation:

"They were just bored of online quizzes. Online quiz after online quiz: there was no differentiation or breaking up of the routine, so they just got bored of doing online quizzes and …they saw that people didn't do them and there were no repercussions so why worry about it?"

June suggested the absence of a teacher was a major setback for many pupils:

"For those that just aren't really that bothered you need people. It's people that keep pushing you …you keep working because your teacher's there …nudging you and nagging you and pushing you… and they didn't have any of that so it was easy to ignore it."

In the survey teachers were also asked whether they had received any feedback, for example from pupils or parents, which had influenced their opinion of the quality of the science education they'd provided. Cross-referencing teachers' opinions with responses about feedback suggests that the views expressed were dependent, to some degree, on whether teachers had received feedback or not. Figure 16 shows these data.

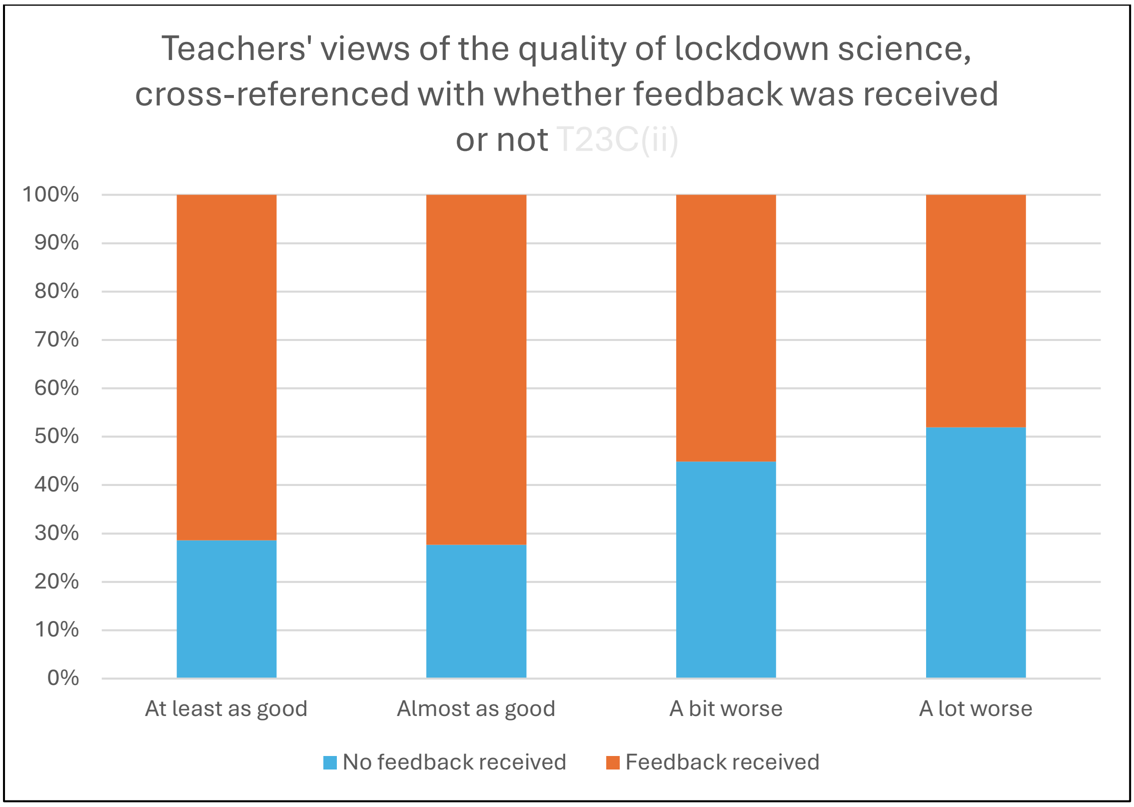


Figure 16: Teachers' views of the quality of lockdown science, showing the factors influencing their views. Each column is scaled so that relative contributions of each factor can be compared across columns. N = 117.

Figure 16 shows that teachers who rated the quality of what they'd done as worse than normal (either 'a bit' or 'a lot') were less likely to have attributed their view to feedback. It is noticeable that this connection is most pronounced in the category of 'a lot worse'. Teachers may have held more pessimistic views when they received limited information about the impact of their teaching. Conversely, it is plausible that those who viewed the quality more positively had received more feedback, enabling them to evaluate their efforts more accurately and improve what they were doing.

4.4.2 Views on the curricular importance of science during lockdown

Figure 17 shows responses to a survey question asking teachers whether they thought science had maintained its importance in their school's curriculum during lockdown.

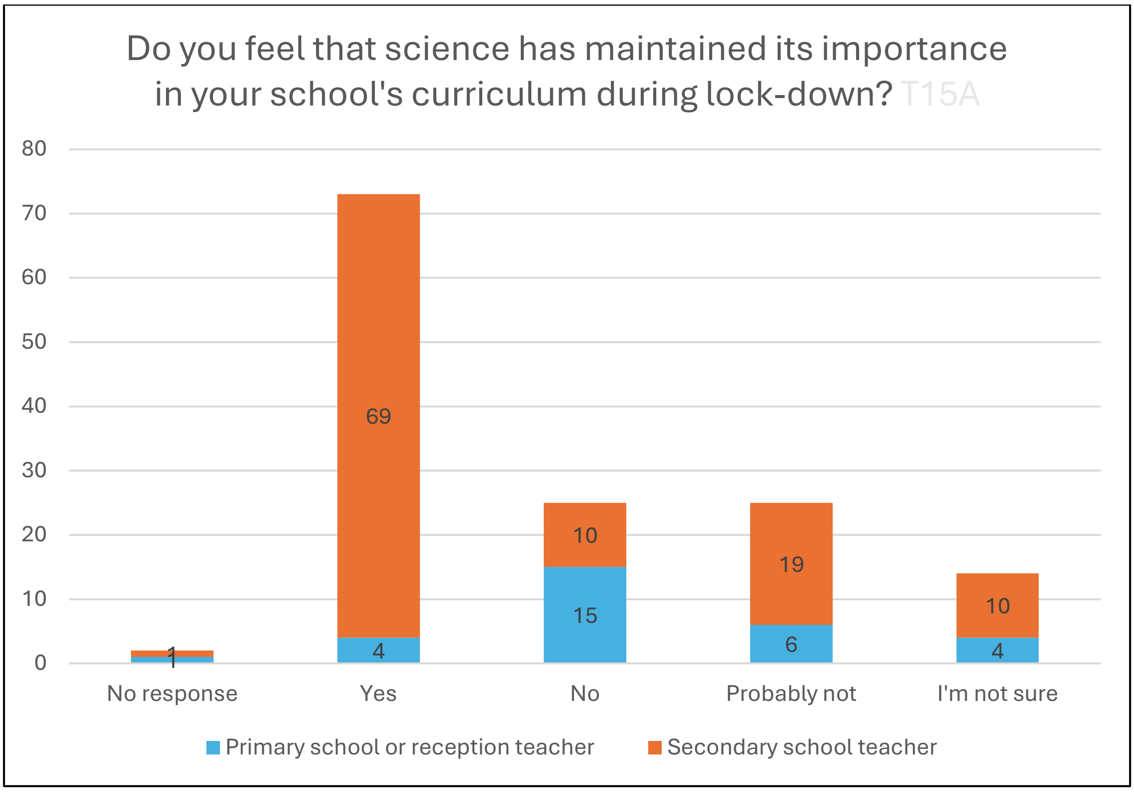


Figure 17: Teachers' responses to a survey question about whether science had maintained its importance in the curriculum during lockdown. Columns are labelled with the raw numbers of responses received. N = 137.

As Figure 17 shows, most teachers thought science had maintained its importance, although this does not reveal what that level of importance was. The majority is not overwhelming, however. The discrepancy between primary and secondary teachers is striking: half of the primary teachers thought science had not maintained its importance. Meanwhile over a quarter of secondary teachers expressed ‘probably not’ or ‘I’m not sure’, suggesting they had reasons not to select ‘yes’, even if they couldn’t be certain.

Not all the interviewed teachers thought science had maintained its curricular importance. Those who expressed doubts or a negative opinion all gave reasons related to English and maths being given higher priority. Elspeth described these subjects as the culture of her school, and thought most other primary schools in her area were similar in this respect. Science, despite being a core subject like the other two, had been relegated to *“a poor relation”*. During lockdown pupils at her school were expected to submit their maths and English work, but science and all other subjects were effectively optional, with no expectation communicated to parents to suggest otherwise. Some secondary teachers also described school policy downgrading science. When Julia’s school reduced the workload for pupils in recognition of them not coping well, English and maths were allocated more time than science. As head of science, she complained to school leaders, and the situation was rectified.

School leaders were not the only reason given for the prioritisation of English and maths. Some teachers thought pupils and parents prioritised these subjects over science. Hilda thought this view existed before lockdown, resulting in lower engagement for science. Lisa thought that lockdown events might have had an effect. In her school English teachers had set the most work of any of the school subjects, which she thought influenced pupils’ and parents’ views of its importance. Joelle, whose school *did* prioritise science, suggested that for families with primary-aged children, no subjects were valued as highly as English and maths.

4.5 Science learning tasks set by teachers

This section examines the tasks that teachers set which did not involve LRT; chapter 5 is dedicated to an in-depth analysis of that approach. As already described in section 4.2.2, a significant majority of teachers who set some science tasks during lockdown (117 out of 129) reported that they required pupils or their parents to use the internet. The requirement was not exclusive; 77 of these teachers also set work that did not require pupils to use the internet, although interview evidence suggests this work was still communicated to pupils solely via the internet. More detail of the activities that did not require the internet are given in section 4.5.3.

4.5.1 Tasks that required pupils to use the internet

4.5.1.1 Communication of tasks

Survey data from 117 teachers who stated that science tasks required pupils or their parents to use the internet show that multiple methods were used for communication of tasks, but with email the commonest: 76% of teachers emailed pupils, and 62% emailed parents. Primary teachers were much more likely to email parents than secondary teachers. Putting instructions on a school website or social media platform was also significant, with 68% or teachers stating this had been done. VLEs were used by about half of the secondary teachers. Social media messaging was not widely used.

Interviews reveal that multiple online communication methods were usually necessary for what teachers did. For example, resources or instructions placed in a specific location on an online platform required guidance for pupils to find them; often the guidance was via email.

4.5.1.2 Gauging how much work pupils could complete

Interview evidence highlights challenges teachers faced in task-setting. Lacking experience of remote education, they were initially unsure how much work to set, struggling to accurately predict how long pupils needed to complete tasks independently. There were concerns that setting too much could lead to pupils becoming overwhelmed and consequently disengaging. However, it was also about ensuring work was meaningful, as Jack discussed:

"It's probably fair to say that at the beginning staff didn't actually know how much work to set, because obviously …when that exposition isn't there you kind

of feel like you need to give the students meaningful things to do. And you often end up missing the mark and …end up giving them like 'busywork' …we were mindful …that could happen."

Interviewees gave examples of too much, too little and the 'right amount' of work being set. Josh believed he had set the latter, comparable to what would have been done in the classroom. He felt that his structured approach helped pupils understand how much work was required for his online tasks. In other subjects where teachers had supplied less structure, he thought pupils tended to over-estimate the work required, spending too much time doing unnecessary things:

> *"With some of them it was actually* reducing *the amount that they did, because of the distinction between physical work and work that is for learning."*

Hilda and her colleagues realised they had initially been setting too much science work. However, this only became apparent when they started sending out paper packs, equivalent to the online work. The number of printed sheets made it clear that the quantity they were setting was too high. Considering that her school only began using paper materials for pupils without internet access about halfway through the lockdown (as described in section 4.2.4), this suggests many pupils received too much work for several weeks. Hilda thought this resulted in many pupils choosing not to engage fully:

"I think we were expecting them to do too much work… and actually it just meant that because they were asked to do so much they were actually doing a lot less …I think they focused on English and maths."

Another uncertainty was whether to prioritise routines and simplicity for pupils, but risk boredom and disengagement as a result. The outcome was often a compromise, recognising the need to satisfy competing needs. Many teachers' approaches developed by trial and error; trying things out and finding out how well pupils responded. Jack described his early lesson format:

"It was probably Word documents, PowerPoints, question sheets, web-links and maybe YouTube videos…that would probably have been a good or well-resourced lesson early on in lockdown."

As lockdown progressed, Jack perceived other opportunities, as well as deficiencies with what he had been doing. Like most teachers, the format of his online lessons evolved: he set up a YouTube channel to host his own short videos that formed the basis of lessons, linking these to other online activities.

4.5.1.3 Types of internet-based learning tasks

Data showing how many teachers set tasks of a specific type requiring the internet are shown in Figure 18. Tasks for which the internet was solely for communication are included.

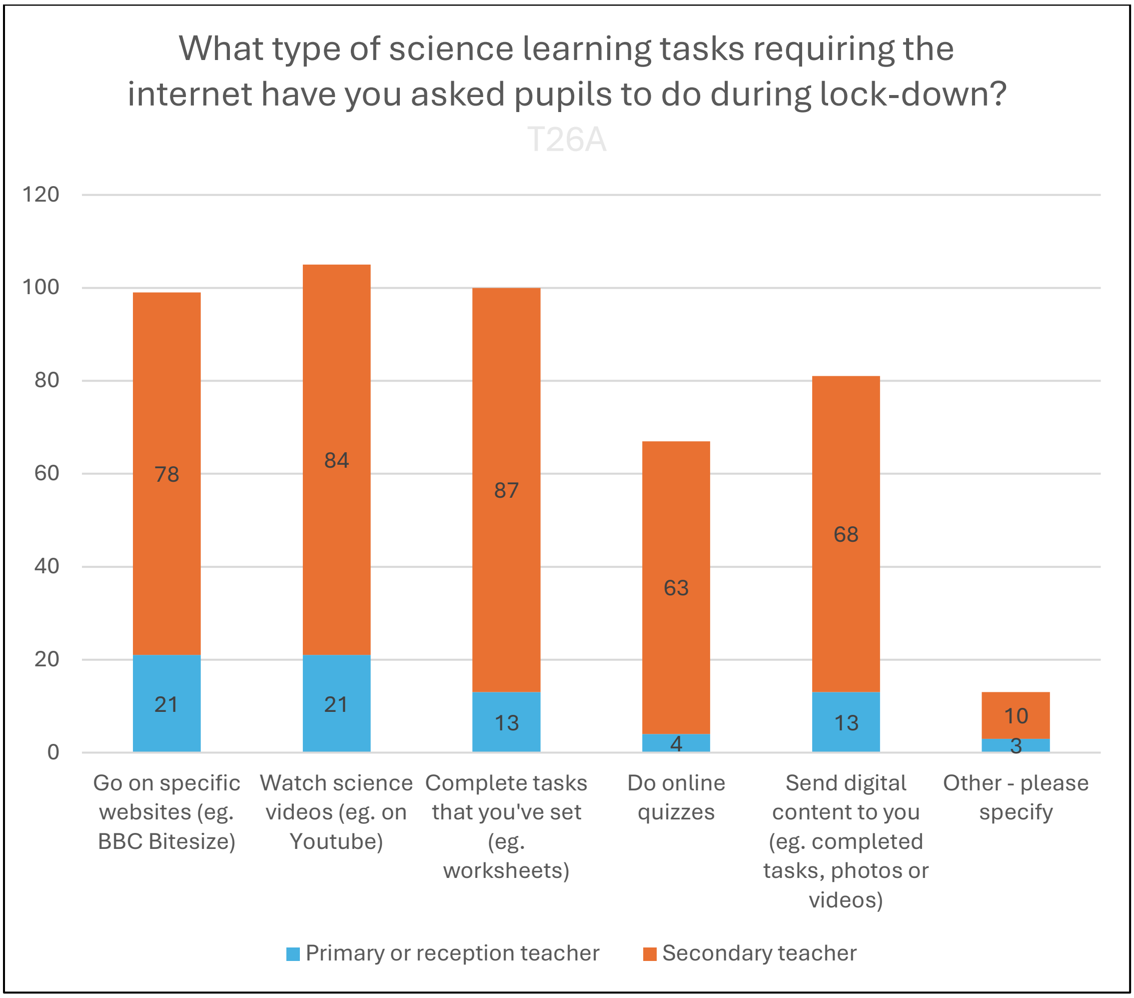


Figure 18: Categories of science tasks teachers asked pupils to do which involved the internet. Columns are labelled with the raw numbers of responses received. N = 117.

All the activity types specified in Figure 18 were used by most of the 117 teachers. Watching online videos was commonest, and online quizzes least common. The small number of responses in the 'other' category suggests the other five activity types constituted most online tasks set.

The similar height of some columns in figure 18 masks differences between individual teachers. Analysing how many specific types of activity individual teachers used gives a better sense of variation between teachers, and is shown in Figure 19.

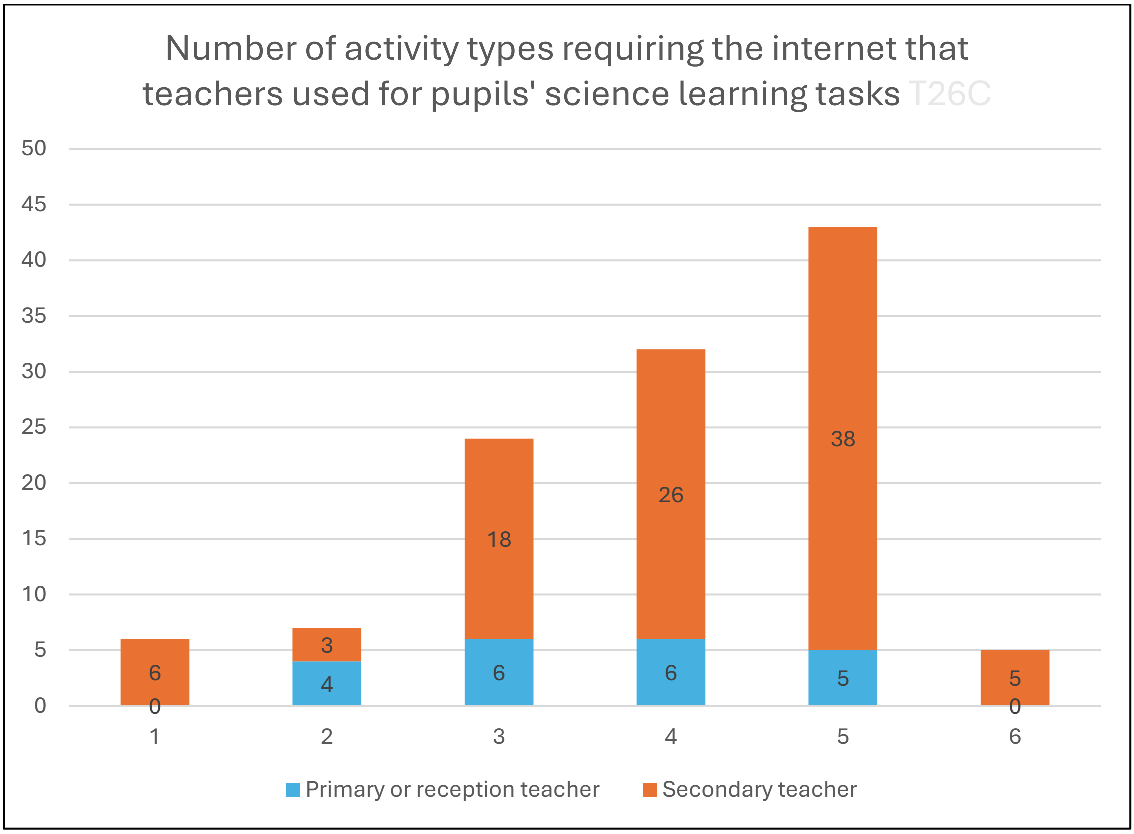


Figure 19: Number of activity types requiring the internet that teachers used, from the options given in Figure 18, for pupils' science learning tasks. Columns are labelled with the raw numbers of responses received. N = 117.

Figure 19 shows more variation between what teachers were doing than Figure 18. Most teachers were using four or more different categories of online activity; in contrast, a small proportion were using two, or just one. For the six teachers who set only one type of activity it was commonest for this to be online videos.

Like Jack, who made his own videos, in time other teachers gravitated towards a combination of home-grown multimedia content with linked activities. Typically, this was designed so that the time pupils would spend on a self-regulated online lesson was comparable to a normal lesson in school. Ella described how her school recommended 20 minutes of self-created video, similar to the Oak National videos (*Oak National Academy,* 2024) available online, with an activity connected to the video content.

Lisa and Sharon changed their approach when it became apparent how long pupils were going to be away from school. PowerPoint presentations, that had previously been sent out for pupils to make sense of by themselves, had not resulted in much engagement. They began narrating over the presentations instead. Interspersing their exposition with tasks, and aiming to provide one hour of science in this way each week, pupil engagement improved. Lisa suggested it was more like a classroom approach, albeit with a shorter duration.

4.5.1.4 Websites teachers used

Secondary teachers were asked in the survey about their use of twelve specific websites, along with a free response 'Other' option, and an option to state that none of the twelve had been used. For primary teachers, nine specific websites were given as options, most of which were different from those for secondary teachers. The data obtained are shown in Figures 20 and 21.

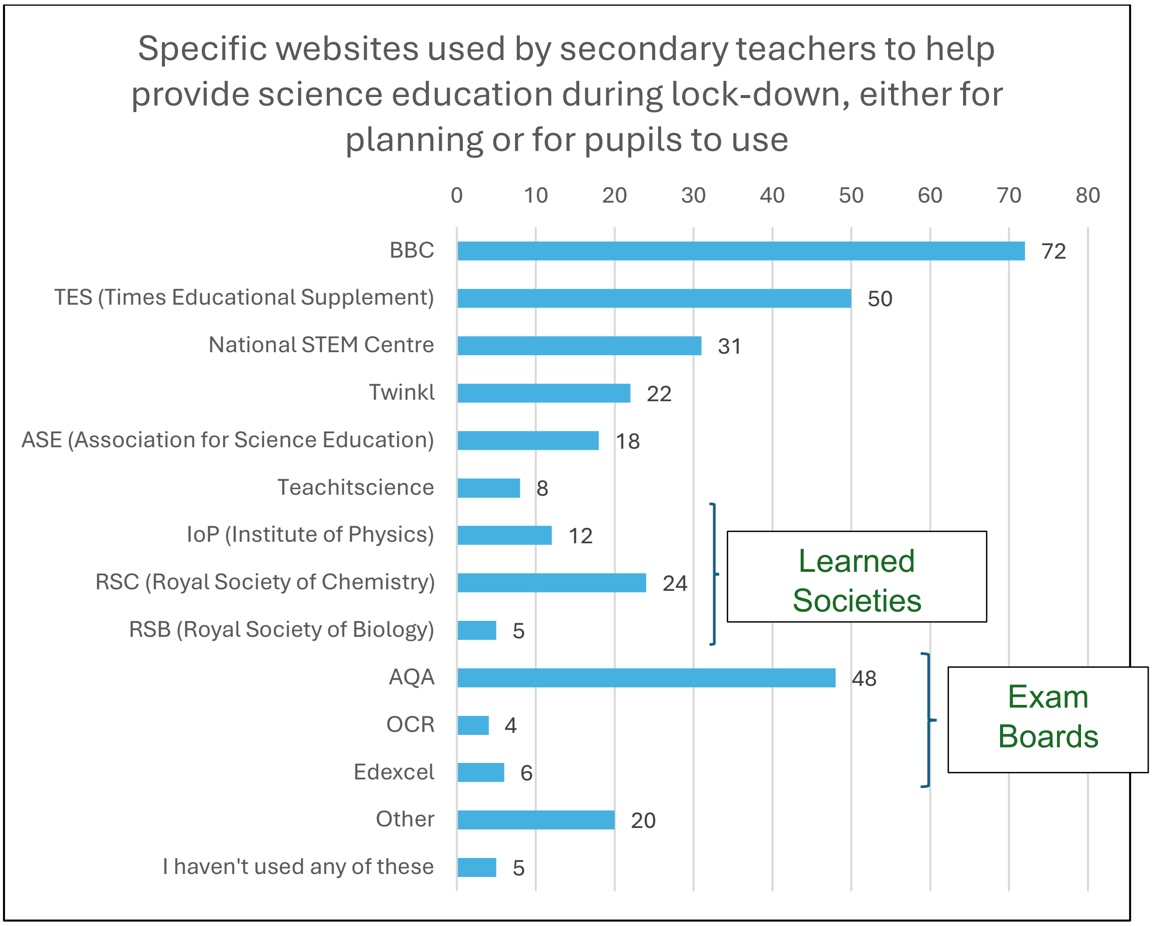


Figure 20: Specific websites used by secondary teachers during lockdown. Most of these sites featured content relevant for both pupil use and teacher planning; it is not possible to distinguish the different types of use. Bars are labelled with raw numbers of responses. N = 94

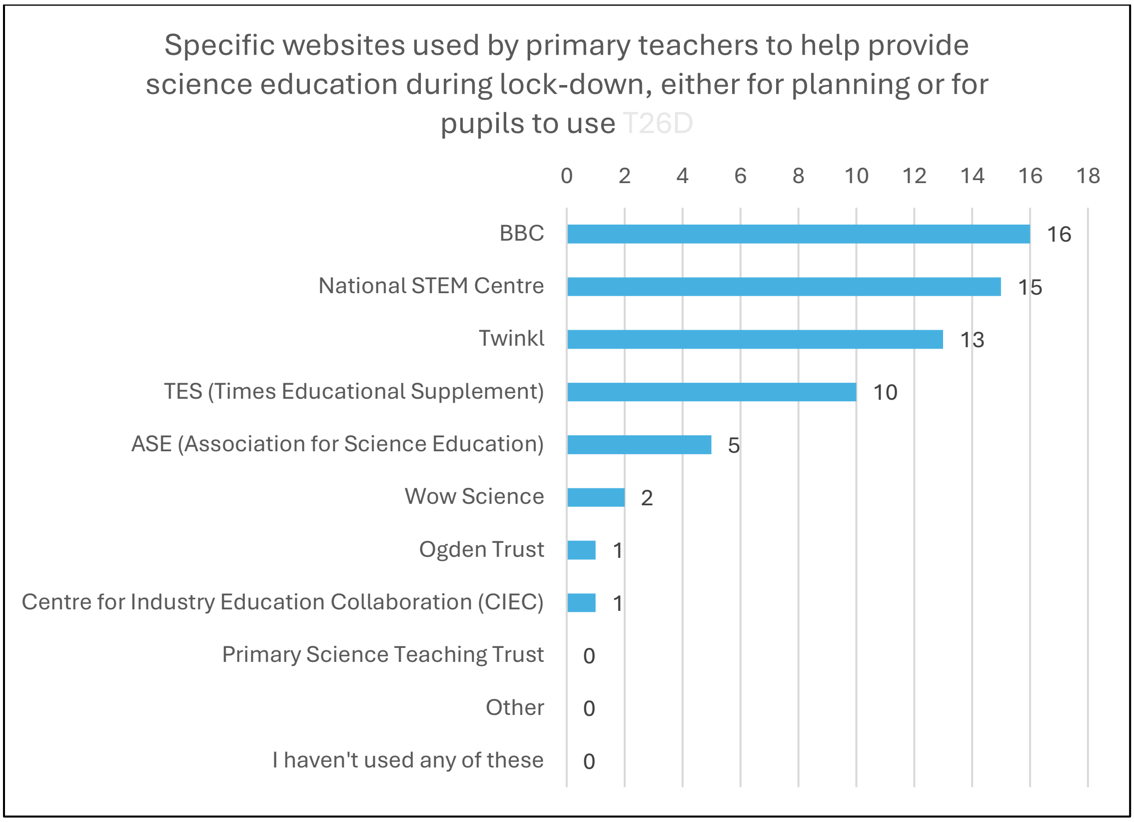


Figure 21: Specific websites used by primary teachers during lockdown. Most of these sites featured content relevant for both pupil use and teacher planning; it is not possible to distinguish the different types of use. Bars are labelled with raw numbers of responses. N = 21.

Figures 20 and 21 show the BBC was the most popular website for both primary and secondary teachers, although others were also popular. Further research would be needed to investigate why teachers chose these websites. For secondary teachers there was a noticeable disparity between the use of the websites of the three learned societies, possibly reflecting differences in content, or different levels of teacher confidence in the three science subjects. The noticeable disparity between numbers using the three main exam board websites closely mirrors the distribution of GCSE entries for the main science subjects between these boards (AQA, 2020; Edexcel, 2020; OCR, 2021).

For primary teachers it is noteworthy that the websites of organisations that are dedicated to primary-specific science content and guidance (Ogden Trust, CIEC and Primary Science Teaching Trust) were barely used, or not used at all, suggesting many primary teachers may have been unaware of them. The commonest responses in the ‘Other’ option are shown in table 5; some of these were for online platforms, (i.e. sites for which users have their own unique login and profile).

Website/Platform	Description	No. of responses
Seneca	Free revision platform	6
Educake	Subscription-based quiz platform	5
Oak Academy	Website set up during the pandemic to provide resources for online teaching	5
GCSEPod	Subscription-based revision and content platform	4

Table 5: Websites/Platforms teachers used, other than those given as named options in the survey.

Almost two thirds of teachers identified specific websites that they had found particularly useful, through a separate free-response question. Forty-two websites or platforms featured, seven of which were the same as options featuring in Figures 20 and 21. Those mentioned by five or more teachers are shown in table 6.

Website/Platform	Description	No. of responses
Seneca	As in table 2	12
GCSEPod	As in table 2	8
BBC Bitesize	Free interactive content at various levels	7
Oak Academy	As in table 2	6
Educake	As in table 2	5
PhET	Free animations / simulations of scientific concepts	5

Table 6: Websites/Platforms teachers stated were particularly helpful during lockdown.

There were twenty-seven unique mentions of websites or platforms, suggesting teachers were acting on their initiative to find material that was relevant or interesting for pupils. Some of those mentioned are indicative of teachers making their own online content, like how Jack had made his own YouTube channel.

4.5.2 Practical work

With hands-on practical work a prominent and longstanding feature of science education in the UK (e.g. Abrahams & Millar, 2008; Toplis & Allen, 2012), an obvious drawback to providing science education remotely during lockdown was the difficulty in setting practical tasks. Several interviewees voiced concerns about this, and it occasionally featured as a reason why teachers had thought the quality of lockdown science provision had been worse than their normal teaching. Several emphasised the value of practical work in helping pupils understand concepts. Josh, an experienced physics teacher, gave the example of teaching his year 12 group about electricity:

“The thing I always find about electricity is that you've got to …do so many lessons of measurement, measurement, measurement, do this, do that…You've got to have that hands-on experience to fully understand something.”

Judy described it as *“bizarre”* to be explaining to her chemistry students how to use a piece of apparatus without them actually handling it themselves. Alina was concerned that the long-term absence of practical work would result in pupils losing familiarity with both equipment and the skills of working scientifically. However, as the following sub-section details, compensating activities could be found.

4.5.2.1 Compensating for the lack of practical work

The absence of practical work could be partially compensated by teachers using surrogate activities that bore degrees of similarity to the real thing, such as websites which offered simulations. Alina used these, suggesting that it was the closest thing pupils could get to the actual procedures themselves. To reproduce the practical experience as faithfully as possible she gave pupils results tables to complete, using the simulations to generate pseudo-experimental 'data'. She thought this helped to provide some of the scientific process skills she had been concerned pupils would be missing. Josh similarly described how he had increased the focus on theoretical aspects of practical work, such as learning about uncertainty and error analysis. Anne also used simulations, but thought they were often inferior to hands-on experience:

"I just got to the electricity topic, and normally a huge part of that would be them building circuits, troubleshooting circuits … there's a whole bunch of really good simulations online that unfortunately work really well, so when we come back … you'll have to figure out how to troubleshoot a dead battery or a broken bulb filament or a wonky connection or whatever."

Anne's point was that a significant part of the learning from using real equipment is understanding how and why it works: difficult to achieve with simulations that work faultlessly every time, and do so by clicking a computer mouse. By contrast, Julia thought that the time pressures of the curriculum meant some simulations were preferable to using the real thing precisely because they *did* work every time.

Nick, a primary teacher who normally incorporated a lot of digital technology into his lessons, provided more authenticity than a simulation. Using a webcam to film his bird feeder, he prepared a video for his pupils to collect data from, and identify the birds.

Other approaches to compensate for a lack of practical work were through alternative activities that varied the diet of online work. Judy's post-16 students undertook personal projects as part of the 'World Studies Extended Essay' component of the International Baccalaureate. They selected topics of global significance and conducted literature research on those with chemistry relevance. Nick exploited opportunities presented by lockdown, arranging for pupils to be involved in videoconference events with external organisations such as the Field Studies Council. Although alternatives such as these were rare, they are good examples of creative approaches which some teachers used.

4.5.2.2 Practical tasks that pupils did at home

Interview evidence indicates teachers were concerned about the amount of screen-time pupils were experiencing. Hence, despite the central role of the internet in lockdown science learning, most teachers also set some work that did not require it. These data are shown in table 7.

	Number who indicated work set required the internet	**Sub-group who set additional tasks that did not require the internet**
Primary or reception teacher	21	17
Secondary teacher	94	60

Table 7: Incidence of additional non-internet-based work set by teachers who required pupils or parents to use the internet.

Many survey respondents gave examples of the non-internet tasks they had set, some of which were practical, hands-on tasks. Thirteen of the primary teachers gave such examples. ‘Bug hunts’ were popular, highlighting the fortunate coincidence of lockdown occurring during warmer months of the year. Some primary teachers mentioned other simple experiments that pupils could do safely at home, using equipment they were likely to be able to find. Celia recounted how pupils found these tasks motivational. Joelle similarly described how she learnt which sort of activities were likely to get the best response from pupils:

“One I set was can you drop an egg out of your window from the top of your stairs without it smashing … making foil ovens and spinners and all those sorts of things that you know children can take photos of but didn't require any printed resources…”

For the secondary teachers, 50 gave examples, 39 of which included practical tasks. There was a wide variety, showing that teachers were devising imaginative ways to give pupils hands-on science experiences at home. The following list captures the variety:

- Creating 3D models of leaves.
- Observations on growth of beans.
- Experimenting with ramps and forces.
- Growing crystals.
- Dissecting flowers.
- Testing acids and alkalis in the kitchen.
- Building a ‘bug hotel’.

- Birdwatching.
- Sampling.
- Measuring items of cutlery and crockery to investigate variation.
- Timing boiling of volumes of water in a kettle.
- Investigating solubility of salt.
- Investigating the speed of sound.
- Measuring shadows.
- Modelling the solar system.
- Making chemical indicators from plants.
- Making a pinhole camera.

These practical activities were inevitably limited in scope compared to laboratory activities: teachers were aware that they could not expect pupils to have access to more than the most basic materials for practical science in the home, and health and safety considerations imposed other restrictions.

Some teachers managed to combine practical work with digital technology, although examples of this were not common. Jack's pupils used an app on their smartphones to analyse birdsong and identify the birds, while Anne's pupils performed an experiment in which they analysed the bounce of a ball by filming it using the slow-motion setting on their smartphone's camera app. Nick simply encouraged pupils to film whatever investigations they were doing and send the footage to him.

4.5.3 Teachers who did not ask pupils or parents to use the internet

In the survey, seven secondary and four primary teachers responded that they had set science work which had not required pupils or their parents to use the internet at all. None of the interviewed teachers were from this group. Although some subsequently listed things which did, in fact, require the internet, usually tasks were simply sent home in paper form. These included suggestions for science-related activities pupils might do independently at home.

Several reasons were given for pupils or parents not being required to use the internet. Poor internet connectivity for pupils was the most common reason given, with one secondary teacher adding that it had been to avoid discrimination against those without internet access. For two of the primary teachers, it was because pupils were not old enough. One primary teacher stated that it was easier not to use the internet, and thought they could provide better learning experiences without it.

4.6 Pupils' engagement with science work

This section focuses on whether pupils responded to the tasks teachers were setting. The term 'engagement' is used here as a synonym for 'responding' or 'participation', rather than indicating a particular level of interest or enthusiasm. It is acknowledged that the data can only show engagement when teachers had evidence of it. Pupils could have completed tasks and not communicated with their teachers; it is impossible to know how much this occurred.

4.6.1 Response rates of pupils engaging with work

Data shown in Figure 22 reveal similarities in response rates for science tasks from primary and secondary schools. Neither were very high: although the data are not fine-grained, they show many teachers had no response from most of their pupils for the whole of lockdown. Approximately 13% of primary teachers stated most of their pupils had engaged; for secondary teachers the corresponding figure was 22%. Just over a third of teachers indicated about half of their pupils engaged with the tasks set. For a similar proportion it was fewer than half their pupils.

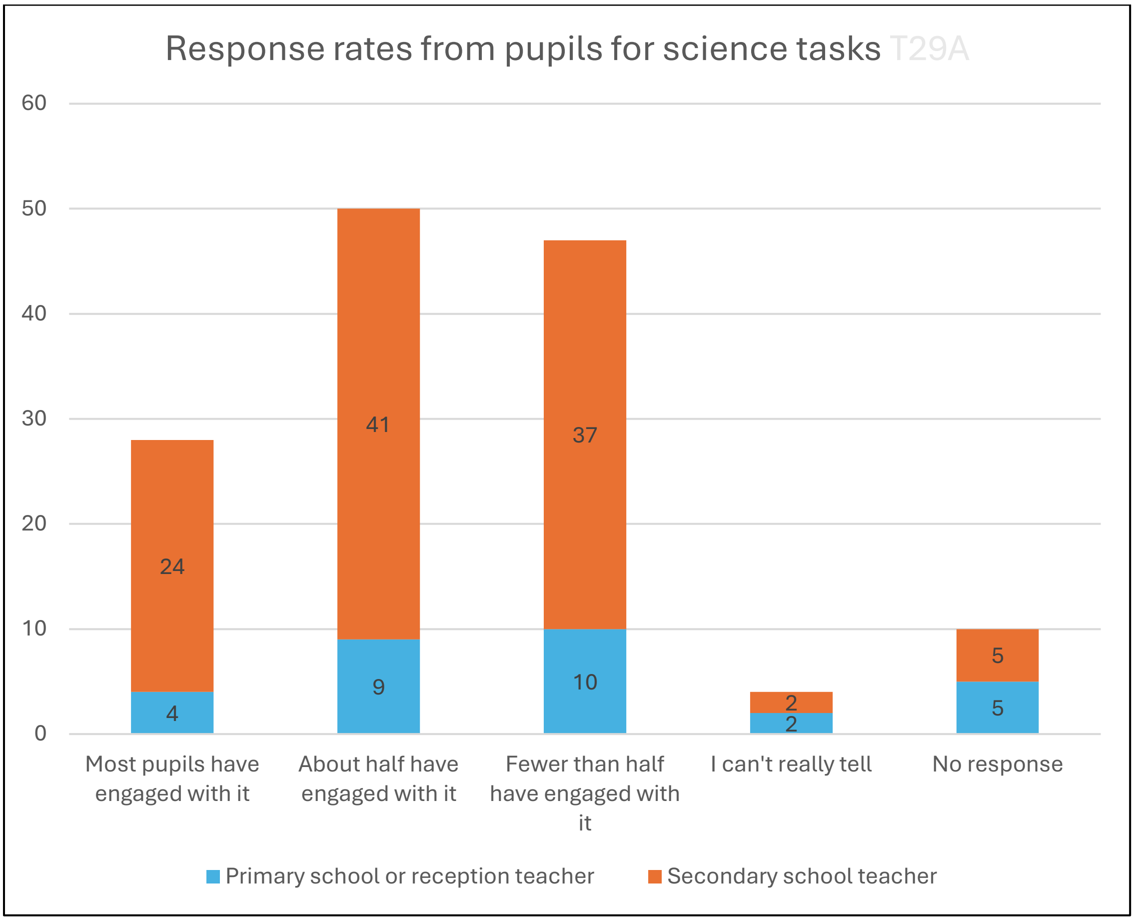


Figure 22: Teacher responses to the question "What sort of response have you had from pupils for the science education you've provided?" Columns are labelled with raw numbers of responses for each category. N = 129.

There is some association between levels of engagement and schools' last inspection rating. Schools rated 'Outstanding' engaged most pupils; schools rated 'Good' engaged slightly more pupils than those rated 'Requires improvement'; those rated 'Inadequate' appear to have engaged fewest.

Interview evidence suggests teachers usually lacked accurate knowledge about whether pupils were engaging or not. Teachers experiencing poor response rates tended to conclude that pupils were not attempting tasks, but lacked evidence to confirm this. Hence, figure 22 does not show whether pupils were attempting tasks or not; just whether teachers had received evidence of this. Lisa, for example, estimated she had set tasks for 120 pupils each week, but received only around ten completed pieces of work back. Unless teachers used online platforms which showed when learning materials had been accessed, it was difficult to tell whether pupils had looked at tasks or not. They would have to wait until pupils submitted work, or contacted them, before engagement could be confirmed. Sometimes teachers did *not* ask for anything to be submitted, and were hence largely oblivious to what pupils were doing.

Some teachers subsequently began using online systems after struggling to judge engagement, but although these were helpful, they could also have their own distinctive problems. Ella's school, like many others, used an app called 'Show my homework', which gave parents or pupils notifications on their smartphones when teachers had set tasks. Although, in theory, this should have meant tasks were not missed, the reality was different. Many pupils and parents did not know how to use the app. Ella made a video to help, but it was hard to tell whether this made any difference. She also suggested the frequent 'pings' the app made whenever a task was uploaded might have led some parents to switch off the audible notifications, contributing to lower response rates. Beatrice encountered a different issue. She was initially pleased to see that 80% of her pupils had completed online quizzes set as follow-ups to lesson materials. After speaking to children of key workers, however, it became apparent that pupils were not using the lesson materials at all; they were just doing the quizzes. Hence engagement had occurred, but not with all the learning materials Beatrice had sent.

4.6.2 How engagement varied during lockdown

Another survey question explored how the engagement indicated in Figure 22 had changed during lockdown. These data are shown in Figure 23.

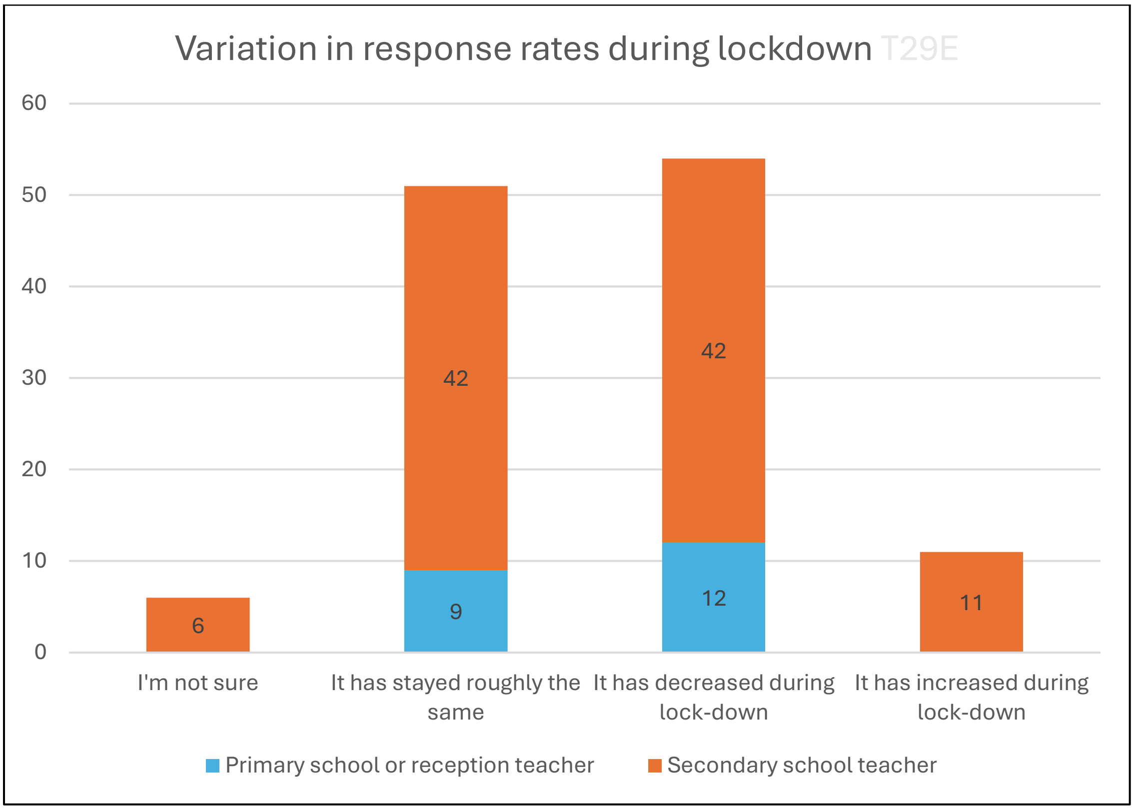


Figure 23: Responses for how proportions of pupils responding to science work changed over the duration of lockdown. Columns are labelled with the raw numbers of teacher responses. N = 122.

Figure 23 indicates that no primary teachers experienced increasing engagement during lockdown; for them it was commonest for engagement to decrease. A small number of secondary teachers experienced increasing engagement, suggesting something had motivated more pupils to engage over time, but evidence was not collected to reveal what this was. Across all teachers it was commonest for engagement to decrease.

These data were cross-referenced with the response rates shown in Figure 22 to investigate whether changes in engagement corresponded with teachers' judgements of engagement overall. The resulting analysis is shown in Figure 24.

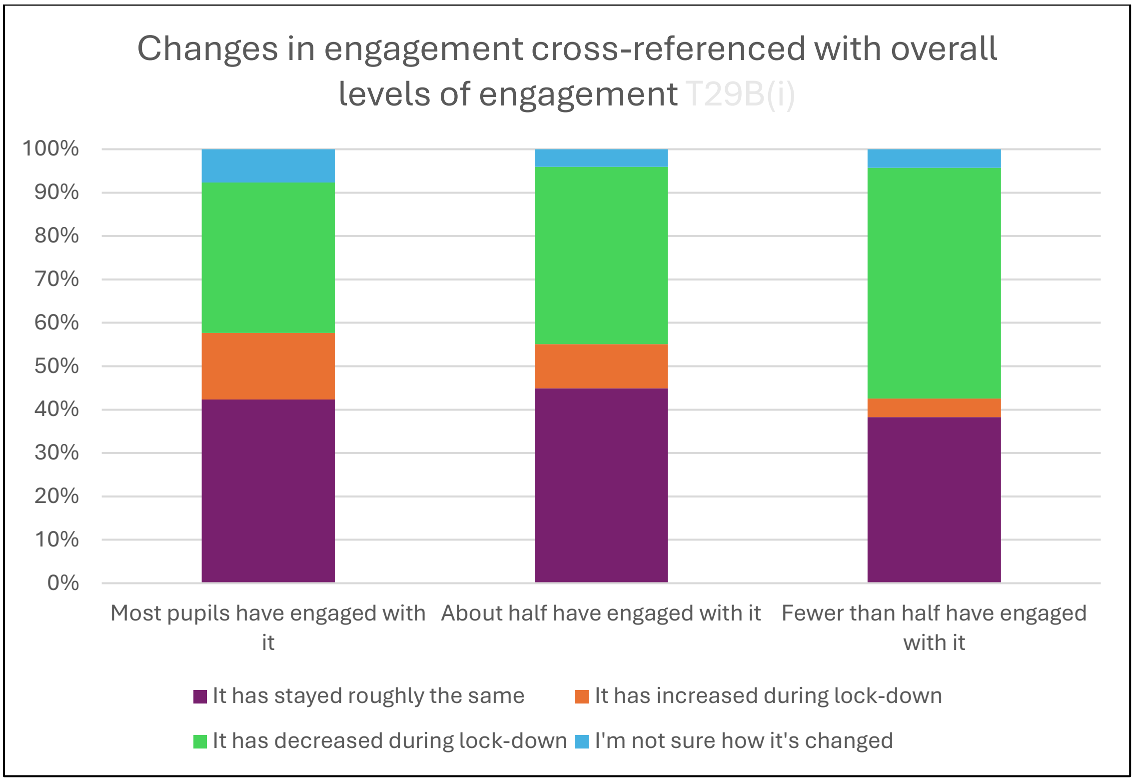


Figure 24: Proportions of pupils engaging with science learning tasks set, broken down by how the response changed over lockdown. To enable comparisons the columns have been scaled to equal height. N = 122

Figure 24 shows increases in pupil engagement (orange segments) occurred no matter what level of engagement teachers reported. Increases were more likely, however, when teachers thought most pupils had already engaged (left hand column). Teachers who judged that fewer than half of their pupils engaged (far right column) included a far smaller proportion who saw an increase in engagement. Overall, these data suggest that if engagement increased, it was more likely to do so when it was already higher; conversely, if it decreased (green segments), this was more likely to occur when it was already poorer.

Only two interviewees, Jack and Josh, experienced an increase in engagement. Though no cause can be confidently attributed, their circumstances had some common features. Both their schools were in relatively affluent areas, and both teachers were confident users of digital technology. They were prepared to experiment with different approaches during lockdown, and given autonomy to do this. However, neither attributed increased engagement to his actions. Jack attributed the reasons more to parental and peer influence:

"I don't actually think it was anything specific or tangible that I did. I suspect it was the realisation that this was not going to end anytime soon … if 60% of kids are participating and you're not one of them, but your mates who you're messaging …are telling you about the work they've done, I think a part of you is going to go "okay maybe I should"… I think it's a psychological element as much as a change in provision sparking anything."

Jack's account suggests the academic culture of the school and its intake were key factors, which could explain why some schools did not experience such increases in engagement. Josh suggested he experienced increasing engagement due to his timetable, which had a higher than usual proportion of academically inclined classes. However, he also attributed the increase to the shift to LRT, which benefited his less academic pupils:

"When they started shifting to delivering things 'live', so effectively simulating a lesson, everybody's here together, first 20 minutes. We're going to go through the PowerPoint, we're going to go through these ideas and discuss them, then you've got 40 minutes of you working…the end of which you can take an image and you send to me. That then really benefited …the lower down students who were finding it much more difficult to kind of self-regulate and self-motivate, 'cos if they were just being set work to do at any time they were either not doing it or they weren't sure what to do."

Secondary teachers, who would have normally taught several classes, were also asked how levels of engagement varied across their classes. Data show it was commonest for the level of engagement to depend on the specific class, rather than age. Where there was a difference, younger pupils tended to be engaged in greater numbers.

4.6.3 Engagement and teachers' views of the quality of lockdown science

Teachers' views about the quality of lockdown science have been discussed in section 4.4.1. Cross-referencing these with levels of engagement suggests a connection, and possibly causation. These data, shown in Figure 25, indicate that when engagement was higher (right hand column), teachers were more likely to rate the quality of the work they'd provided more highly. Conversely, a large majority of teachers for whom fewer than half of pupils engaged (left hand column) thought lockdown science had been worse than normal science lessons. Though causation between these two factors cannot be established solely by these data, it is plausible that teachers' views of the quality of lockdown science were partly influenced by the numbers of their pupils responding to their efforts.

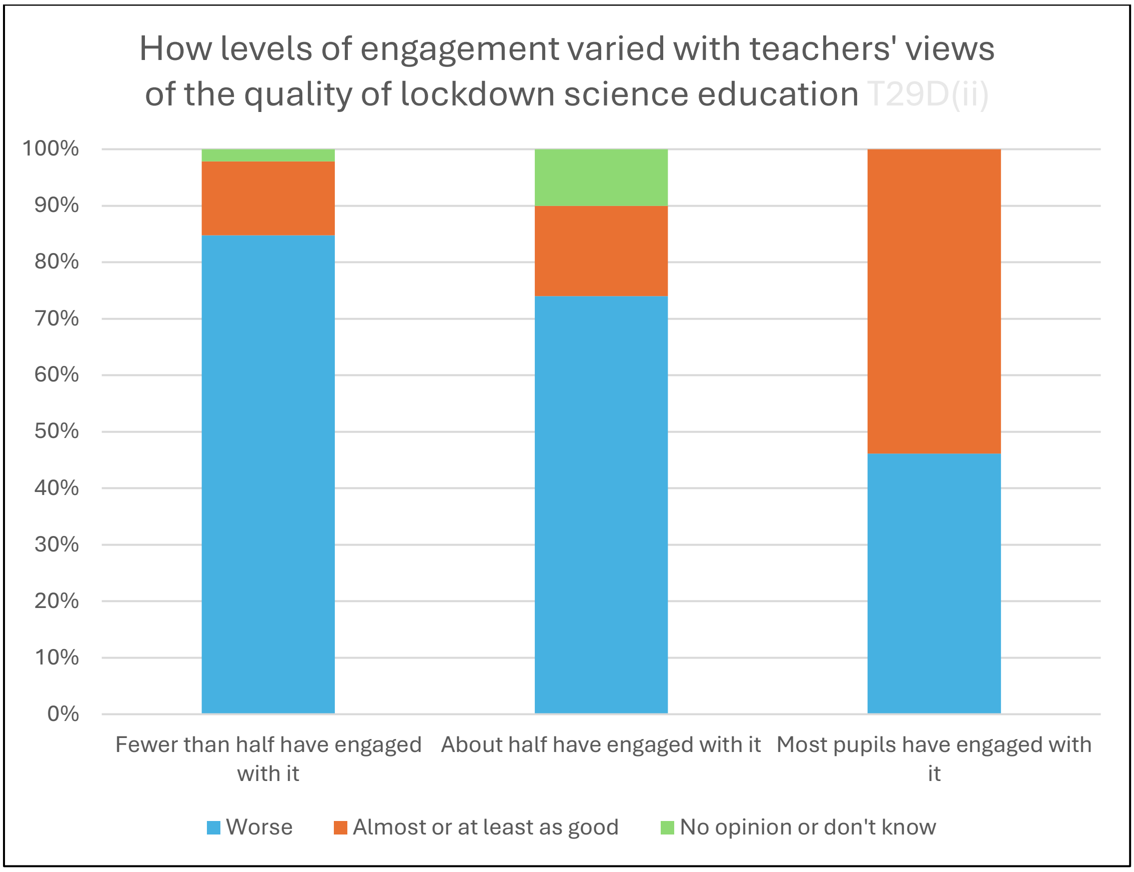


Figure 25: Levels of engagement of pupils cross-referenced with teachers' views of the quality of science education they'd provided over lockdown. Columns are scaled to the same height to enable comparison of the proportions within each category. N = 117.

4.6.4 Specific communications between home and school about science

To explore further the extent and nature of engagement pupils had with their science teachers during lockdown, teachers were asked about two specific interactions:

- Whether pupils or parents had contacted them with science-related questions.
- Whether any requests had been received for additional work.

Most teachers received science-related questions, mainly from pupils, but this was far less common for primary teachers. This could reflect the lower curricular importance of science reported by most primary teachers.

Interview evidence suggests many questions were related to tasks or information supplied by the teacher. Judy and Nigel each described similar queries about why specific answers on online quizzes had been correct, while Lisa described requests for help with concepts from her narrated PowerPoint presentations. There was little evidence of pupils initiating questions to their teachers about things they were curious about, as might happen in a classroom setting. Some of Nigel's pupils asked about contemporary science issues such as vaccines, but he conceded that he had had to lead this interaction.

Most teachers received no requests for extra work. However, given the large numbers of pupils who did not appear to engage with tasks (Figure 22, section 4.6.1), it is difficult to attribute any significance to this. It is probably better to regard requests for extra work as another aspect of pupil engagement, rather than a metric for how effectively teachers gauged the quantity of work they set. Indeed, Figure 26 indicates a relationship between levels of engagement and requests for extra work.

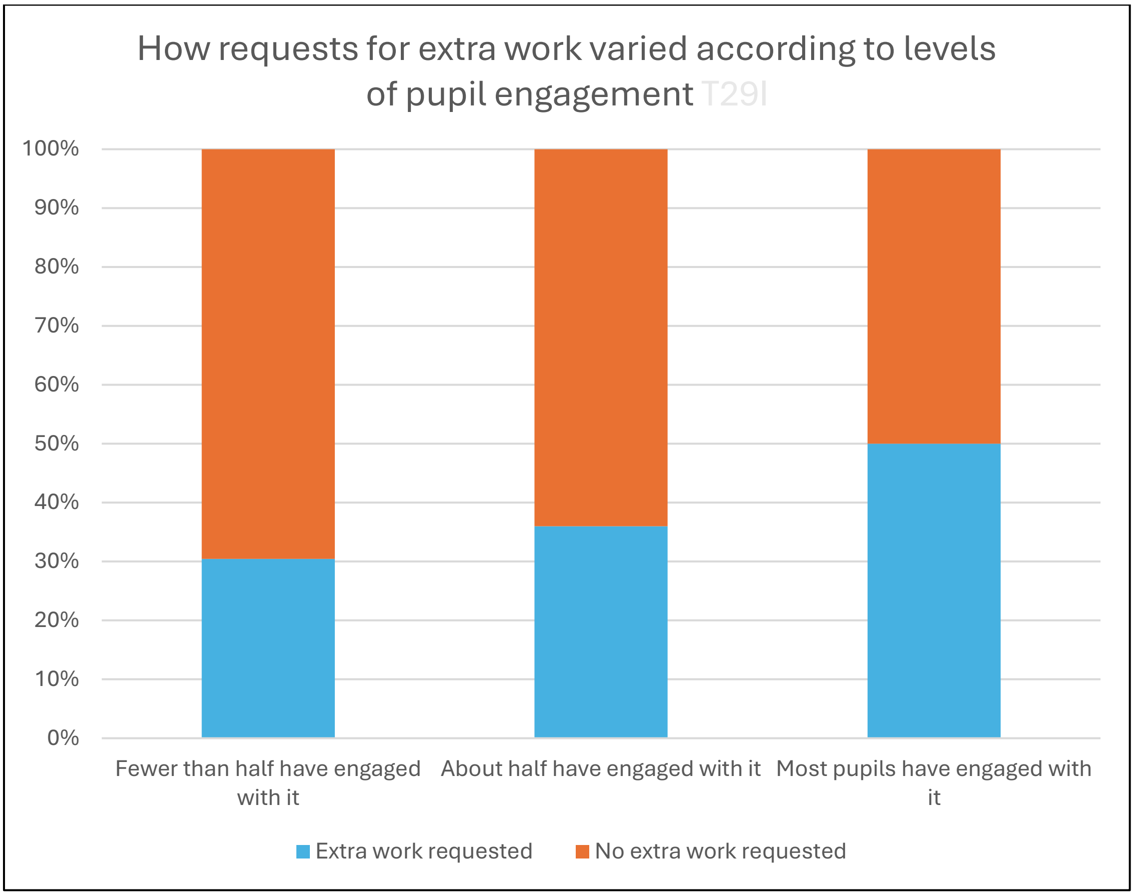


Figure 26: How requests for extra work varied according to levels of pupil engagement. Columns are scaled to the same height to enable comparison of proportions. N = 122.

4.7 Teachers' Professional Development during lockdown

This section examines the professional development (PD) teachers participated in during lockdown, an activity affected by conditions of remote working. Schools had different expectations about teachers' participation. Hilda's school directed participation, with teachers required to centrally log their PD, but most teachers described a less rigid regime, with useful courses brought to their attention but no compulsion about attendance.

Teachers mentioned several forms of PD in interviews. Elspeth enrolled on some self-directed online learning units, which she would not normally have found time for. Some found more time for reading or pursuing specific aspects of relevant professional practice. Mostly, however, 'live' online courses formed the bulk of the PD that was discussed during interviews, and they are the focus of discussion for this section.

4.7.1 Teachers' views of 'live' online courses

Many teachers participated in 'live' online courses, with mixed views. Before lockdown most were unfamiliar with videoconference for educational purposes. As Lisa put it:

"I didn't even know Zoom existed before this. I didn't have a clue… it was weird to start with, really weird."

Nevertheless, teachers identified some significant advantages of these events over face-to-face PD. The convenience of 'attending' from home, with no travel and hence lower costs, meant that many teachers availed themselves of more PD courses than they might otherwise have done. Looking ahead, Andrea was convinced of the benefits:

"I've done quite a lot of CPD courses as a result of lockdown and I thoroughly enjoyed it …you spend an hour on the Internet and you're still gaining the same knowledge that you would have actually physically being in the room. A lot of staff that I've spoken to are in agreement this seems to be a really good way forward."

Nigel felt it was a lot easier to participate in online PD than the face-to-face equivalent:

"Right, nine o'clock, 15 minutes before, I can get ready, get my workbook, sit down, cup of tea and watch and be ready, and as soon as it's done I can go off and go to something else. Actually it felt quite snappy rather than some of these CPD courses you go where… it feels like you're wasting a day."

Remote PD courses became more than a substitution for face-to-face events: teachers reported new possibilities because barriers of distance and location were removed. Lisa described this:

“You would meet people you don't normally meet because of the distance. So that was really quite positive seeing teachers and experiencing conversations with teachers you wouldn't necessarily see, because we'd be stuck round Yorkshire.”

Lockdown conditions also meant most teachers required no staff cover, because not following a timetable meant there was effectively no absence to cover for. Even those teaching their regular timetable via LRT did not require cover because adult supervision was not needed as pupils were at home.

Although an obvious drawback of online virtual PD was the lack of ‘hands-on’ activities, potentially significant for science teachers, Nigel described how one course he had attended had addressed this:

“The physics one was showing about how to do interesting practical. Practicals with the kids… the presenter he had it all set up on his laptop and a visualizer and I could follow along perfectly fine, and you could type questions and he'd send every so often a question and go over it… for me personally the benefit of having …every Monday 10 o'clock here's our physics … I think it was better for me personally, but I know some people did not like the lack of interaction.”

Online virtual PD courses did not meet with wholesale approval, as Nigel intimated. Although she appreciated the positives, Lisa recognised some disadvantages:

"A lot of people don't have their cameras on so you don't get that physical interaction…and just the connection issues, like, my little boy pulled the router out one day and that was it for the meeting…I couldn't get back in."

Although internet connectivity was essential for online virtual PD, few other teachers mentioned problems with this. The issue of cameras being switched off during videoconferences, however, caused significant concern when teachers used this approach for their own teaching, and is discussed in more detail in chapter 5. It is noteworthy, therefore, that a teacher should also identify with this when they were in the position of being the learner themselves. Anne, who taught entirely via LRT, found that attending online virtual PD made her reflect on her own practice when using the medium:

*"If we went back to online teaching I would have to change some things, like how much a lecturer would say, "Okay, go and watch this video for five minutes," and then continues talking…and it was just, like, I can't concentrate! And then I was thinking back and thinking oh ****, how many times did I do this with my students, where I told them to go away and watch a video, and then because it was silent and I'm insecure about silence, I would keep talking … and they just want you to shut up."*

Nick identified with the issue of not being present in the same physical space as other course participants:

"I suppose the disadvantage would be really sharing your ideas with people on another table, in gaining their perspective on what you're learning on the course."

Despite his positive views, Nigel also perceived drawbacks compared with a face-to-face situation:

“Some of the immediate feedback, particularly for group work, it's a bit lost because when you're doing over zoom chat you start stepping over people, or, “I'm sorry, you were talking,” you don't have that actual full conversation that you would do normally.”

Andrea mentioned similar points about the limited interaction possible during a videoconference call, relating them to wider issues:

“Obviously it's a very different experience to actually meet somebody in person than it is over the Internet. For example, we've employed three members of staff over the Internet, which is something we would have never done… there is a bit of a risk element with that because you don't actually see somebody teaching, as such. We set a virtual lesson and obviously they delivered the lesson virtually, but they haven't actually delivered it to the class.”

Hilda simply found the online courses not to her liking. Where others had seen benefits from wider participation, she saw a drawback:

“I found the content wasn't specific enough because you're delivering it to people from lots of different schools, doing lots of different exam boards… and it meant that it wasn't specific enough …when you're doing something that is for everybody … talking about very general stuff I just found that quite difficult.”

Sharon was also less enthusiastic, suggesting that the quality of face-to-face PD was better, and naturally engendered a higher commitment from participants:

“I did the course and … it didn’t benefit me at all, I just did it for the sake of doing it… I think if you’re booking CPD when you're in school, because it costs and you are out of school you put a lot more effort into what you’re actually going on… so in terms of the quality of the CPD, yeah, it was alright, lots of videos and, like, one person talking, and not very interactive.”

The gist of most teachers’ views about ‘live’ online PD, therefore, was that they appreciated advantages and disadvantages, and could reconcile these to form an overall view that was usually, though not always, positive. None suggested that it would, or should, replace face-to-face PD, but there was a general expectation that it would continue beyond lockdown.

4.7.2 Content of ‘live’ online courses

Teachers attended ‘live’ online PD on various topics, as during normal circumstances. Many were subject-related, such as subject knowledge enhancement. Others were related to pastoral or regulatory issues. As mentioned in the previous section, most teachers were able to take advantage of more opportunities than usual during lockdown. Most of the courses they described, however, were unrelated to remote teaching, despite this being a pressing need and the most conspicuous area of professional practice that they lacked experience in. As related in section 4.2.6 (and Figure 14), a significant number of teachers had specifically identified their lack of knowledge of remote teaching methods and resources as detrimental to their performance during lockdown. When PD was related to remote teaching, this was more often about the technical skills involved in using online platforms, rather than pedagogical aspects. Indeed, this was usually done ‘in-house’, often with more confident teachers helping those who needed support.

Teachers' experiences suggest that, although some PD providers had reacted quickly to offer courses about remote science teaching, there was limited professional knowledge in this field, and any practical experience being shared tended to be from the lockdown itself, rather than from existing knowledge about online education. Hence, there was no obvious source of PD on remote teaching because the lockdown had no precedent.

4.8 How teachers thought lockdown might influence their future practice

Changes necessitated by lockdown were a potential catalyst for developments in teachers' practice, and this was the basis of a question in the survey. Most teachers (84) answered affirmatively, suggesting lockdown had caused reflection and recognition of potential changes, as shown in Figure 27.

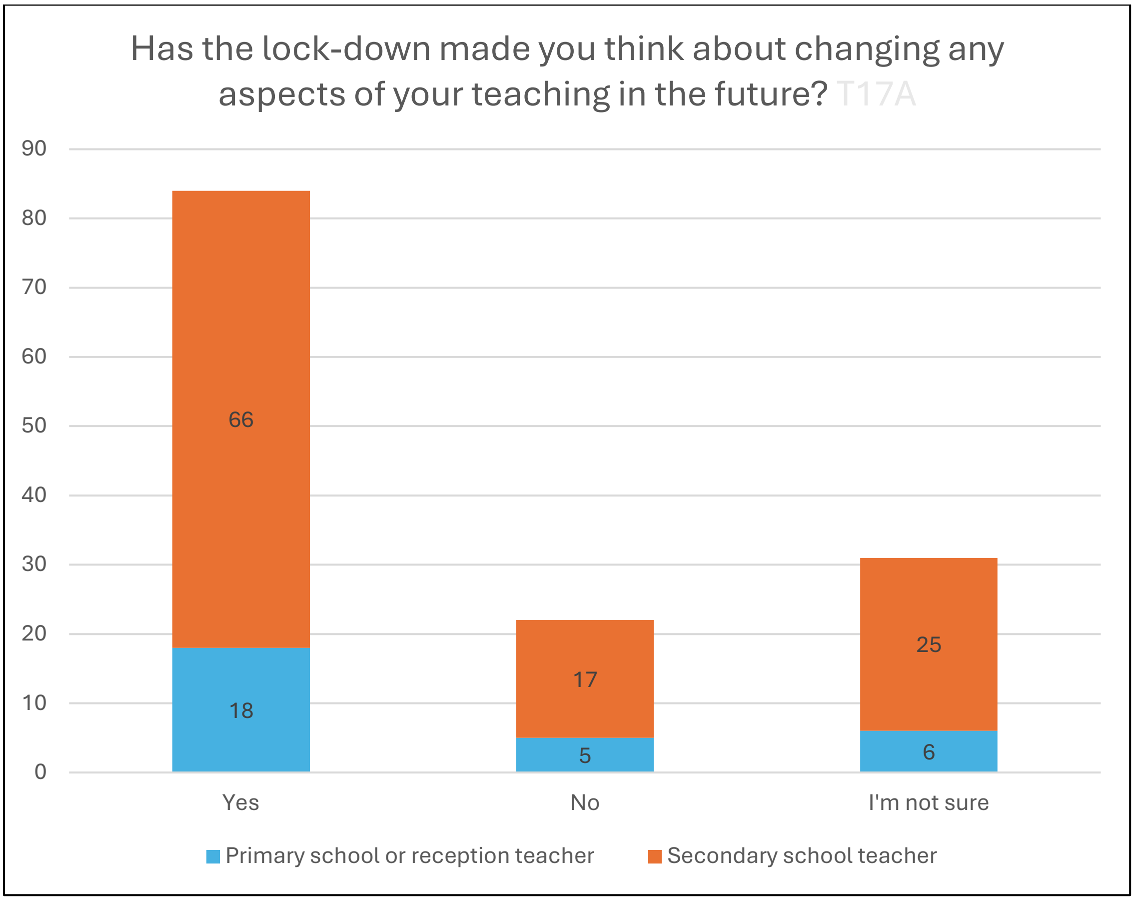


Figure 27: Responses to the question: "Has the lock-down made you think about changing any aspects of your teaching in the future - for example, making more use of online tools or resources?" Columns are labelled with the number of responses received. N = 137.

These data show similar proportions of primary and secondary teachers in each response category. There was little difference in the distribution of responses when the data was analysed by teachers' levels of experience.

4.8.1 Types of changes teachers described

Many varied responses were received when teachers were asked to specify *how* they thought lockdown experience would influence practice when they returned to normal working conditions. Most referred to technology. Analysis revealed some common themes in what teachers specified, as shown in table 8.

Category of change	No. of responses
Change related to using resources discovered during lockdown	55
Change related to named websites or platforms discovered during lockdown	29
Change related to use of video	11
Change related to home learning or homework	26
Change describing doing something ‘more’	34
Change related to some personal insight into teaching and learning	25
Change related to something supplementing classroom activities	16
Change related to planning	10
Change related to use of Google platforms	10

Table 8: Most frequently occurring categories of changes from analysis of how teachers suggested lockdown would change future practice. Categories with fewer than 10 responses are not included. Categories are not mutually exclusive.

The large number of comments relating to resources illustrates that this was a significant part of what teachers learnt about during lockdown. In most cases these resources were web-based and were often specified by name, as the table shows. It suggests that teachers were either previously unaware of the resources they subsequently intended to use or had not used them before.

Although some teachers were focused on the immediate future under infection control, rather than a return to ‘normal’, most seemed to be looking further ahead. Responses in which the word ‘more’ was used, usually in conjunction with a practice they had used, were given by 34 teachers. (By contrast, only one teacher gave a response in which they stated their intention to do something ‘less’, and two used the word ‘reduce’). Eleanor, for example, intended to continue using online submission of work by pupils to improve hand-in rates.

Others had realised some of the online tools adopted during lockdown were easy to use, and intended to continue. Parents at Joelle's school had previously been asking for homework to be moved online; lockdown had forced this issue. These examples highlight teachers had done things during lockdown, perhaps for the first time, that they thought could be continued during normal conditions.

Resources teachers had discovered were often intended for specific uses; 26 teachers mentioned home learning or homework, and 16 mentioned other activities that supplemented class activities. Video was mentioned by 11 teachers, with eight intending to make their own videos. Other aspects of video use were rarely mentioned, however. Only Nick mentioned the intention to use videoconferencing with external providers. Most teachers had not done this, but he had done it several times during lockdown and had found it beneficial for motivating his pupils. Another video-related practice incorporated the lessons that had been taught via LRT. Some schools had recorded these, and two teachers suggested these had value for planned cover lessons.

Table 8 shows 25 responses were categorised as personal insights into teaching and learning. This category was applied mainly where teachers described aspects of their practice beyond use or acquisition of resources. Various areas were mentioned, including pupils' learning and teaching outdoors. Minimising infection had prompted Celia to consider how much of the curriculum she could teach outside, and the scope for improving her school's outdoor environment. The exacting requirements of the lockdown materials sent to pupils had caused another teacher to reflect on accessibility:

"Making content more accessible for digital lessons has made me consider my approach in actual lessons."

Some comments reflect how lockdown had revealed things teachers were previously unaware of:

"Planning for students to be given increasing responsibility to manage time / projects. Many students that are very able academically have struggled to organise themselves."

Jack, meanwhile, had found that his creation of a YouTube channel to host his own videos had caused reflections about his own pedagogy:

"It has made me think about how I talk in the classroom, and how I use the time in the classroom… I would like to do more flipped teaching to get the kids to read up and watch about a topic first and then … have the dialogues in class… the bit where my exposition, whilst it's important that it's good, it's not necessarily the most important part of the learning process"

Several other teachers, though a small minority of those suggesting changes, mentioned a desire to use a 'flipped learning' approach or a change in the emphasis of some aspect of their teaching.

4.8.2 Comparisons with teachers' pre-lockdown uses of technology

Teachers' suggested changes to practice are also of interest considering how they used technology for teaching before lockdown. Data representing their pre-lockdown uses of digital technology are shown in Figure 28.

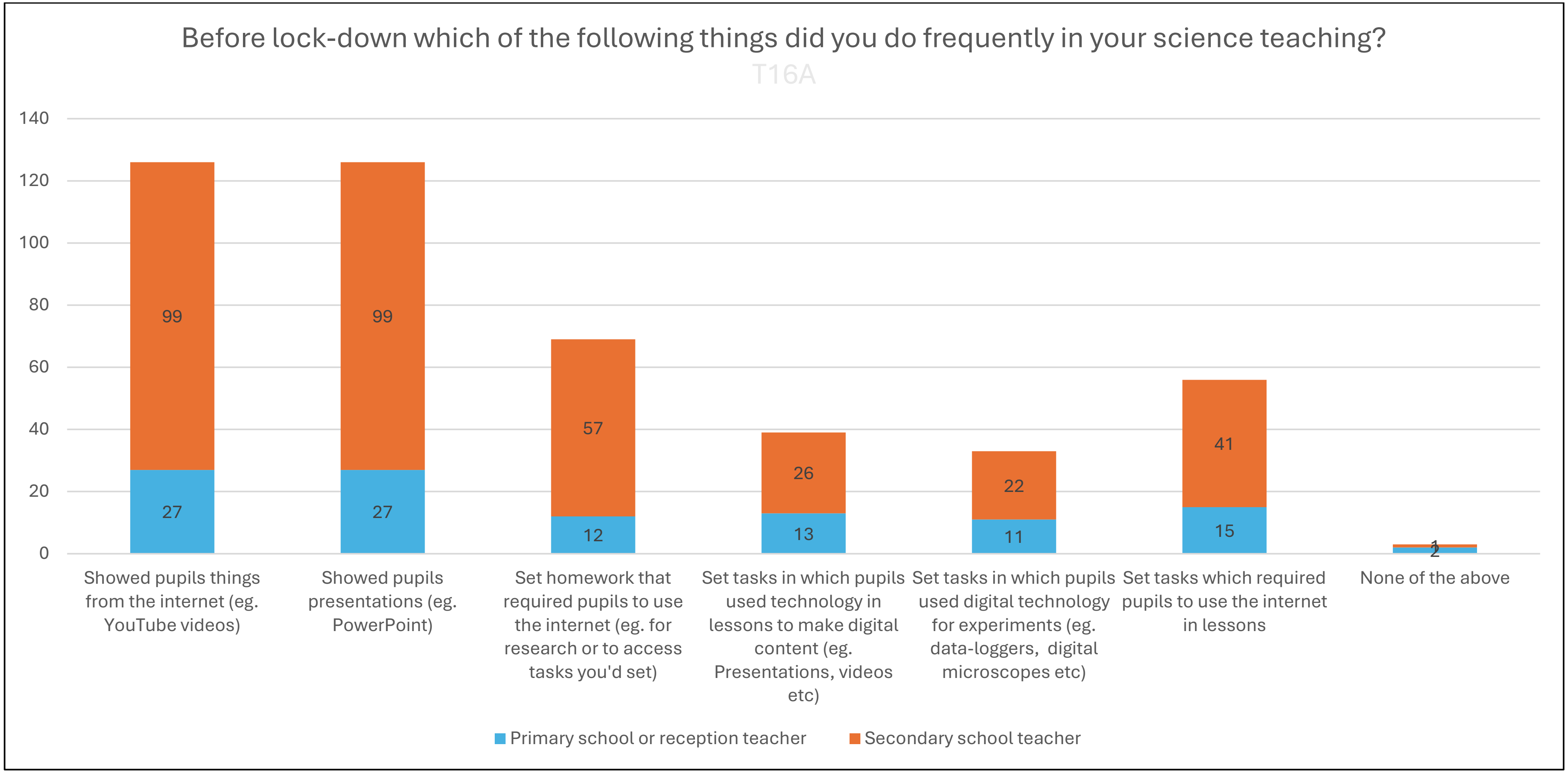


Figure 28: Responses to a survey question about what teachers frequently used digital technology for in their lessons before lockdown. Columns are labelled with the numbers of responses received. N = 136.

These data show a general similarity in how primary and secondary teachers used technology in their science teaching before lockdown. They highlight the predominance of digital technology for showing things to pupils, and the much lower incidences of pupils generating their own digital content or uses in practical work. Judging by historical school inspection evidence, these data suggest that science teachers' uses of technology had not changed appreciably in the twelve years before 2020 (Ofsted, 2008, 2011, 2013).

Some limited insights are possible from comparing pre-lockdown practice and post-lockdown intentions. Discovering useful online resources during lockdown might be translated into more instances of 'showing', suggesting a continuation of pre-lockdown practices, but this would need investigating further. Most lockdown-inspired changes, including those related to resources, do not have a clear-cut connection to any pre-lockdown practice categories. This could suggest teachers had been inspired to consider innovations more than minor enhancements to existing practices. Only homework featured noticeably in both existing practice and intended changes. Most teachers who described a change related to homework or home learning were *not* previously using the internet for setting homework tasks, suggesting that this change was an innovation.

4.8.3 Absent or less frequent comments about changes to practice

In addition to comments teachers made, some insights can be gained by noticing what was not mentioned, or featured minimally. Only four teachers in the survey explicitly suggested they might instigate changes involving pupils using technology more often in the classroom, though it is conceivably implied by responses about the increased use of online resources. Despite teachers' comments about pupils' IT skills (see section 4.2.5), specific changes to address this were largely absent. It is possible that teachers viewed this as an issue to be addressed at a whole-school level, and hence outside their remit as teachers of science.

Teachers tended to use familiar words rather than jargon when describing what they hoped to change, as well as their experiences. No teacher used the phrase ‘blended learning’ in the survey, and only two teachers used it in interviews. It is conceivable they were unfamiliar with the term, despite suggesting the incorporation of more online tools and resources that constituted some form of the practice. Similarly, no teachers used the words ‘synchronous’ or ‘asynchronous’ when discussing how they wanted to continue using videoconference technology. These observations suggest that teachers were yet to develop familiarity with some of the labels for educational concepts that had arisen during lockdown.

Few references to communicating with parents or pupils online were included in teachers’ responses about how their practice would change. Only four teachers made comments that included this specifically, although it is potentially implied in responses about greater use of online tools. Hence although it was something many teachers found problematic during lockdown (see Figure 14, section 4.2.6), they were presumably not anticipating this once pupils returned to school.

Nine teachers suggested changes that referred to practical work. Mostly their comments were about substituting or supplementing practical work, using online simulations or pre-prepared videos. No changes involving digital technology for practical work were mentioned. Given the limitations on practical activities that lockdown had imposed, this is perhaps unsurprising. Concern was expressed by some about possible longer-term threats to practical science activities because of lockdown. It was thought practical work might remain difficult when school resumed because of infection control, and could therefore suffer a gradual decline as lessons without practical work became normalised.

4.9 Discussion

To conclude this chapter, this section comprises a critical discussion of evidence and findings, detailing how it relates to extant literature in terms of similarities and, particularly, original contributions. Through this discussion, critical consideration is also applied to data, methods, and the generation of conclusions by triangulation.

It is relevant to emphasise again features of this study that represent its distinctive contribution. By employing mixed methods, it differs from most research into lockdown education, which was predominantly based on quantitative data from surveys (Bond, 2021; Howard et al., 2021). This study is additionally distinctive for its subject-specific focus on science, aimed at schools rather than higher education. It should also be emphasised that it is focused on the events of the first lockdown, when disruption was undoubtedly felt most keenly.

4.9.1 Data and triangulation

As discussed in chapter 3, a specific limitation of quantitative data from surveys is that complexity is sometimes reduced to categories that create a simplified impression of events. Rich personal experience is distilled, often to a ‘best-fit’ response, framed by the researcher’s decisions when devising the question. In this chapter, richness behind individuals’ survey responses has been revealed in detail through interviews. For example, while the types of learning activity teachers were setting for children could be discerned from the survey, it was only through interviews that teachers could give detailed accounts of barriers experienced in this area, highlighting issues such as pupils' IT skills. Findings like these would not have emerged from survey data alone, as the survey questions did not ask about these things specifically. Conversely, surveys were more effective than interviews at revealing broader trends or patterns across all respondents; for example, showing how teachers' perceptions of pupil engagement with learning tasks varied over the duration of lockdown – data show about half the sample thought engagement had decreased. The value of such data, however, is often contingent on other data. Knowledge of teachers' perceptions about changes in engagement does not reveal absolute levels of engagement – high or low. An initial high level of engagement that declined over the course of lockdown could still represent far more engagement overall than initial low levels which then increased. Hence, the accompanying survey data, showing teachers' perceptions of the absolute proportions of their pupils who engaged with learning tasks, are also required to draw more robust conclusions about pupil engagement. Overall, the combination of methods generating qualitative and quantitative data successfully achieved the intended goal of gathering data with both breadth and depth.

The combination of qualitative and quantitative data has enabled the investigation of themes emerging during analysis. One example, briefly mentioned in section 4.3.3., is an analysis of how the length of teaching career influenced the reported ease of lockdown teaching. This was initiated by qualitative data: an interview discussion in which an experienced teacher described some of their difficulties. Length of teaching career was the subject of an early survey question, partly to establish the heterogeneity of the participant sample; ease or difficulty of lockdown experience was a later, unconnected, question. This teacher's interview prompted a return to survey data to investigate how these two variables might be correlated; in the classroom it would be expected that newer teachers would generally find teaching more difficult than their experienced colleagues. The outcome of the analysis supports a conclusion that length of teaching experience did not correspond with how easy or difficult teachers found working in lockdown, and corroborates this teacher's own explanation: lockdown working was so new and unfamiliar that most aspects of previous teaching experience were rendered irrelevant. This finding reflects experiences of Swedish teachers in Bergdahl and Nouri (2021).

Triangulation is also possible between teachers' and parents' data. This is discussed more fully at the end of chapter 6.

4.9.2 Comparative observations

This sub-section critically discusses where evidence in my study both aligns with existing literature, and where it points to potentially new or under-reported findings.

Teachers' data in this study indicates a wide variability in experiences, as reported elsewhere (e.g. Howard et al., 2021; Müller & Goldenberg, 2021), and a significant contributory factor is undoubtedly the workplace transition they underwent when confined to their homes during lockdown (Goudarzi et al., 2023; Kraft & Simon, 2020). Although survey data convey a basic picture of *what* varied, qualitative interview evidence gives a much richer sense of *how* and *why* experiences could differ between teachers and schools, expanding understanding of variability to encompass a more complex network of contributory factors. This observation reinforces one of the limitations in many large-scale research reports (e.g. Allen et al., 2020a; Brink et al., 2020; Champeaux et al., 2020), which, as identified in chapter 2 (see section 2.2.2) tend to rely solely on quantitative data from surveys.

Some examples of variability in teachers' experiences are readily observable from data discussed in this chapter. They include the types of learning activities provided, use of LRT (discussed in more detail in the next chapter), perceptions about workload, and aspects of wellbeing. A critical examination of this study's evidence on teacher workload exemplifies how teachers' qualitative evidence contributes additional insights to existing literature in this area (e.g. Hilger et al., 2021; Kim et al., 2022; See, 2024), by providing further explanatory detail. It illustrates how lockdown experiences were often beset by chains of consequences, which could be novel or unanticipated, and, through teachers' accounts, shows how and why remote working conditions affected workload.

The example of Anne (page 165) illustrates how remote working increased amounts of electronic communication, because face-to-face conversations were not occurring. Hence, the time spent reading and responding to messages increased compared to normal, reflecting Zacher and Cort's observations (2024) about workload effects of increased workplace digitalisation. Anne's evidence suggests that some of this workload would normally have been relatively trivial, but also shows how remote teaching and learning often generated novel tasks because of the new conditions (for example checking and monitoring whether pupils' home internet access was functional).

Variation in workload reported by teachers in this study partly reflects Kim et al. (2022), who also report changes in the nature of workload, although, as in other sources (e.g. See, 2024), the emphasis tends to be on quantitative concepts of increased workload. While increases did affect many teachers in my study, and could be substantial, several described decreases, or expressed difficulty discerning changes from normal because their lockdown work was very different. This latter point suggests teachers' reckonings of workload could be somewhat subjective, incorporating factors beyond merely hours spent working, such as how tired the work had made them feel or perceptions of frequency and intensity of work. This possibility is upheld by the work of Spector and Jex (1998), who distinguish between concepts of quantitative and qualitative workload.

My study also shows workload variations arose not just because of the new demands of remote education, but because the organisation of remote teaching varied between schools, a consequence of decisions school leaders made in responding to the crisis. Hence, reductions in workload could occur because teaching was centralised or consolidated, usually for reasons such as maintaining consistency for pupils, though sometimes to deliberately ease the burden on teachers, whose wellbeing was being considered. However, unanticipated effects of these decisions, such as the tendency of pupils to respond less to communications from teachers who were not their 'regular' teachers, typify how lockdown created impact through 'knock-on' effects.

The previously mentioned critical sensitivity in relation to publication date of literature (Bond, 2021) is epitomised by some of my findings which demonstrate differences in detail from other literature sources, and which are conceivably attributable to the time of data collection. For instance, my data about teachers' views on the quality of their remote education provision show the majority were unequivocally negative, contrasting markedly with Ofsted (2021) whose findings indicate three fifths of their sample expressed confidence that they were providing high quality education. Such a contrast is strongly suggestive of the later, more widespread adoption of LRT (Howard et al., 2021), which had not occurred when my data were collected. However, it is also plausible that teachers in my sample were prone to more critical assessment because they were expressing views about science teaching specifically, for which lockdown had removed the staple activity of practical work, a powerful element of science's subject identity (Abrahams & Millar, 2008; Holman, 2017; Millar, R. & Abrahams, 2009). This plausibility is supported by literature reporting concerns about the effects of lockdown on practical subjects (e.g. Erduran et al., 2020; Howard et al., 2021).

The country in which research was conducted, along with other sampling variation, undoubtedly accounts for some differences between my findings and other literature. Data from Bergdahl and Nouri (2021), whose Swedish teacher sample was comparable in size to mine, suggests teachers were using a similar, if slightly larger, range of digital applications (websites, platforms, software) for online education. However, a clear distinction between these two national contexts emerges when usage of these applications is examined: more teachers in Sweden than the UK had begun using videoconferencing early in the lockdown (the researchers gathered data in March 2020). Data also indicate Swedish teachers were not as reliant on email for communicating tasks to pupils, from which it could be inferred that Swedish pupils may have been more familiar with digital learning platforms than UK pupils, before lockdown. Other findings suggest broad similarities, however: Swedish teachers reported a lack of adequate preparation, like the UK teachers in my study, and their experiences were similarly variable.

4.9.3 Original findings

4.9.3.1 Relating to online education generally

The following sub-section itemises and critically elaborates original findings with general relevance to teachers' experiences of online education during lockdown.

- While the issue of teachers' and schools' preparedness for remote education is widely addressed in the literature from the perspective of lack of prior experience and differences compared with classroom teaching (e.g. Bubb & Jones, 2020; Kovacs et al., 2022; Wisanti et al., 2021) less apparent is evidence of systemic conditions which exacerbated these difficulties; conditions which, had they been the focus of attention, would have been apparent in advance of a worldwide emergency. Three significant pre-existing factors, identified in this study, exacerbated the difficulties teachers experienced during lockdown:
    - Approximately one third of the teachers surveyed in this study had not previously been allocated digital hardware, such as a laptop, by their employer. This lack of parity across the workforce highlights a significant deficit in one of the key pre-conditions for effective implementation of online education. While related, more generic, factors such as underinvestment in educational technology appear in existing literature (e.g. Ofsted, 2021), this

specific factor is not observed. Although most teachers who lacked a school-supplied device used their own at home, this was fortunate happenstance, not a planned contingency that could be relied upon.

- Though pupils' IT skills and deficits in digital literacy are mentioned elsewhere (e.g. Golden et al., 2023; Müller & Goldenberg, 2021; Sandu & Taylor, 2025), the issue is predominantly presented through the lens of social inequality and access (e.g. Menzies, 2020; Tienken, 2020; Williamson et al., 2020). While access to technology at home was reported by teachers in this study, and clearly an important issue, this chapter's evidence highlights a different problem that is largely overlooked in literature. This is that teachers lacked knowledge of pupils' IT skills. At the start of lockdown, science teachers were unaware that pupils lacked the necessary skills to perform digital tasks in learning activities or to navigate their school's online systems. Pupils possessed digital skills, but these often did not align with the competencies the tasks required. Often the skills pupils lacked were rudimentary, and this study's evidence illustrates some teachers had assumed skills, perhaps taught elsewhere in the school curriculum. This raises questions, such as why pupils were unfamiliar with basic technological know-how like logging on to school systems and why teachers did not know about this beforehand. This issue compounded the faltering implementation of remote education in the first lockdown.

    - Teachers did not have information about pupils' access to technology, because schools rarely had accurate knowledge about home conditions, including what technology children might be able to access for online learning. While the tailoring of appropriate tasks to pupils' learning needs was challenging enough given the remote conditions, not knowing whether pupils could even access or attempt the work was an additional obstacle. Although Bergdahl and Nouri (2021) indicate Swedish schools also initially lacked knowledge of pupils' home technology access, it is not presented as a particular problem. Interview accounts from teachers in my study, however, raise the possibility that it could have exacerbated pre-existing social inequalities, because pupils with good technology access at home would have been able to make learning progress while those without could not.
- Although teachers accessed online CPD, and some suggested they had engaged in more activities than they would normally undertake because of the flexibility afford by the online format, my study suggests most content they reported was not related to online education, despite this being a recognised need they had expressed. This supplements Perry (2022), who observes a shift away from subject-specific CPD during the pandemic, and also provides further exemplification of how schools struggled to take targeted action to meet the challenges of lockdown.
- When discussing their wellbeing, teachers described specific deteriorations in aspects of physical health because of the nature of online education provision, such as the length of time in front of a screen

or sitting down. Existing literature on how lockdown affected teacher wellbeing (e.g. Katsarou et al., 2023; See, 2024) tends to focus on mental rather than physical aspects. With many factors affecting teachers' mental wellbeing during lockdown being consequences of non-teaching stressors (Katsarou et al., 2023), this highlights that in different circumstances these might not apply, but the physical requirements of online teaching probably would remain.

- Although lockdown-influenced changes teachers intended to make to their classroom practice feature in international literature (e.g. Li, 2022; Veugen et al., 2022), the UK-relevant context is absent, highlighting the contribution of this study to the field. As described in section 4.8, most teachers suggested their remote education experience would influence their subsequent classroom practice in some way. When specified, most changes were relatively modest, referring predominantly to the use of additional online resources such as websites, which may partly reflect how teachers were previously employing digital technology in their classrooms. However, some teachers were more ambitious, describing how they wanted to apply online methods used during lockdown to the classroom or to enhance out-of-school learning such as homework. It was noticeable that only a few intentions matched specified issues or shortcomings identified during lockdown, such as pupils' IT skills or learner independence.

4.9.3.2 Science-specific aspects

A shortage of literature about other school subjects in lockdown makes it difficult to highlight distinctive features of online science education, as opposed to more generic characteristics. However, evidence in this chapter confirms other literature suggesting lockdown was detrimental to practical hands-on learning (e.g. Howard et al., 2021; Rodríguez et al., 2021). Examples of home-based practical activities used during lockdown are available (e.g. Taylor, 2020): my study provides more examples of such practical tasks. Assuming these tasks were not used in non-lockdown conditions, this illustrates how lockdown stimulated teacher creativity and innovation. Secondary teachers provided proportionately more examples than primary teachers, reflecting the lack of science specialism among the primary sample. A few of these tasks involved digital technology; most, however, were achievable with simple everyday items, although teachers were aware of home limitations (including health and safety). Hence, although a wide range of activities were provided across the teacher sample (see section 4.5.2), this was limited compared to the classroom. Although a few teachers mentioned the use of digital simulations, my data do not show whether lockdown led to more frequent use than previously.

In closing, a final science-specific observation is worthy of emphasis. This relates to evidence my study presents about science's curriculum priority in primary schools. Although far fewer primary than secondary teachers participated in this study, evidence collected supports other literature (e.g. Canovan & Fallon, 2021) in clearly illustrating science was a lower priority than English or Mathematics in many primary schools during lockdown. This observation resonates with pre-existing concerns about science's 'poor relation' status (e.g. Ofsted, 2019). Hence, my study supplements existing evidence to policymakers and other stakeholders that, despite being designated a 'core' subject (Department for Education, 2014), primary school practice continues to place science behind English and mathematics.

Chapter 5: Live Remote Teaching (LRT) in science

5.1 Introduction

As previously explained, ‘Live remote teaching’, abbreviated to ‘LRT’ for brevity, is a term I use within this research for teaching in which teachers and pupils are not physically in the same room but communicate synchronously (i.e. in ‘real time’) by use of video conference technology. Commonly, platforms such as Zoom and Microsoft Teams are used.

As discussed in chapter 4, LRT saw limited adoption among teachers in this study. However, it was significant for several reasons. For those who employed it, LRT represented an entirely novel teaching approach that generated considerable discussion during interviews. Given its subsequent widespread adoption during the lockdowns commencing in November 2020 and January 2021 (Müller & Goldenberg, 2021), this chapter examines initial experiences with LRT in science teaching, charting the path toward its broader implementation.

Sections 2 and 3 analyse predominantly quantitative survey data, supplemented by relevant interview evidence. These sections examine various aspects including how LRT occurred alongside other online practices, pupils' internet access for LRT participation, and attendance in LRT lessons. While necessarily focusing on teachers who adopted LRT, they also explore why most did not. Section 4 comprises a detailed examination of science teachers’ personal experiences through thematic analysis of teacher interview data. The final section critically discusses this chapter’s contribution to the field.

5.2 Prevalence of LRT

When asked to specify reasons why their teaching had required pupils or parents to use the internet, teachers gave responses in which videoconferencing for LRT emerged as the fifth most used practice. It was not common; 37 individual teachers used it, just over a quarter of the 129 teachers who'd provided some science education during lockdown. Of the 37 using LRT, a significant majority (34) were secondary teachers. Of the 20 teachers interviewed, nine had used it, of whom eight were secondary teachers.

When asked why they required pupils or parents to use the internet, most teachers selected several reasons. As detailed in chapter 4, reasons included things like email, accessing the school website, and using the VLE. The teachers who used LRT all selected at least one other option, as Figure 29 shows.

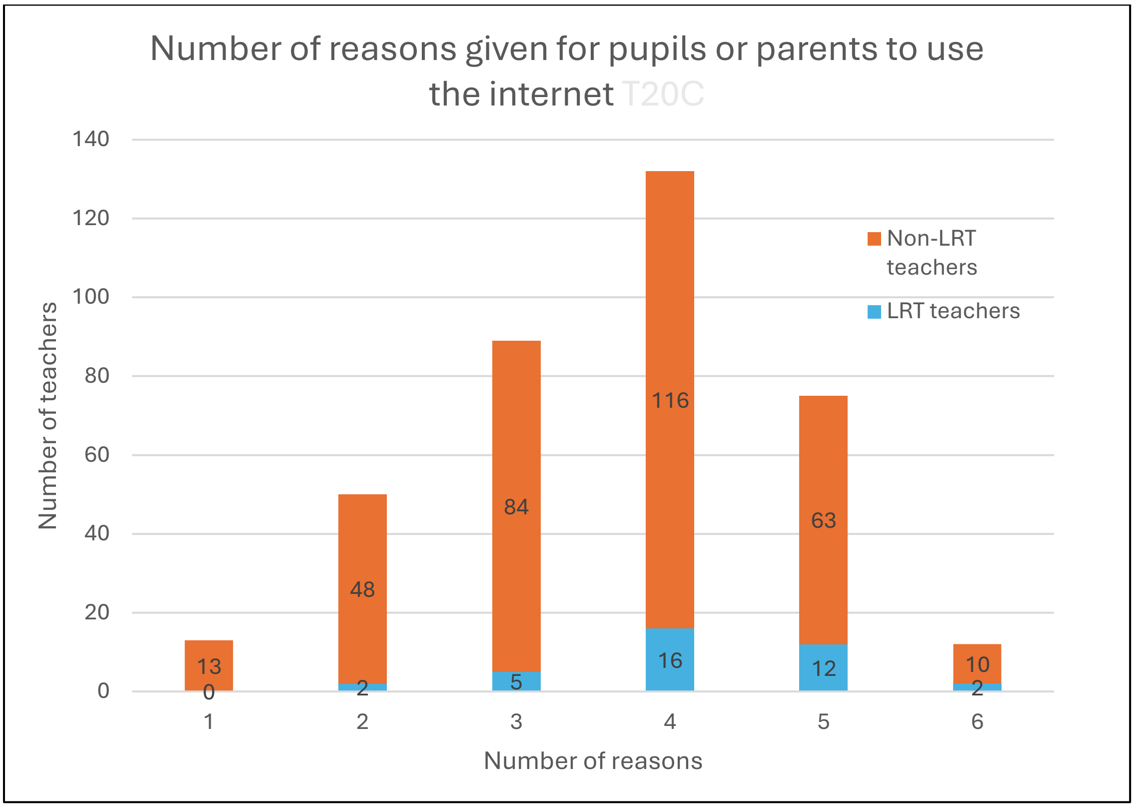


Figure 29: Number of reasons given for pupils or parents to use the internet by teachers who used LRT and those who did not. Data columns are labelled with numbers of responses. N = 117.

Since organising a videoconference required initial communication to confirm scheduling and logistical details, this explains why teachers using LRT selected additional reasons for pupils needing internet access. Additionally, interview evidence corroborates that teachers using LRT still used other online approaches such as placing work on a VLE. This practice persisted even where LRT was the default mode of lockdown education and had begun from lockdown's outset. Judy and Anne, initiated LRT almost immediately, had still posted work or instructions on the school website. However, this primarily supplemented their LRT and may not have been essential. Josh, a secondary teacher, described how he used the school's VLE to provide a back-up to the LRT, and because some pupils did not attend:

“There would always be something on the VLE, so even then when there was a live lesson there was always a VLE…because you didn't always have every student so students could always go back to it.”

Most interviewees using LRT did not adopt it when lockdown began. Other internet-led provision, such as posting work on a school website, was established before LRT was begun or ‘discovered’. This offers an additional explanation why, in Figure 29, most teachers who used LRT selected four or five reasons why pupils or parents needed internet access: the other reasons were the previously established practice.

5.3 Access, uptake and provision of LRT

5.3.1 Pupils’ access to the internet at home

To take advantage of LRT pupils had to have a good enough home internet connection and access to a suitable internet-connected device at the appropriate time. As discussed in Chapter 4, interview evidence indicates that many teachers lacked accurate knowledge about students' home technology access. Therefore, the survey data in Figure 30 below probably represent what teachers discovered during lockdown rather than pre-existing knowledge.

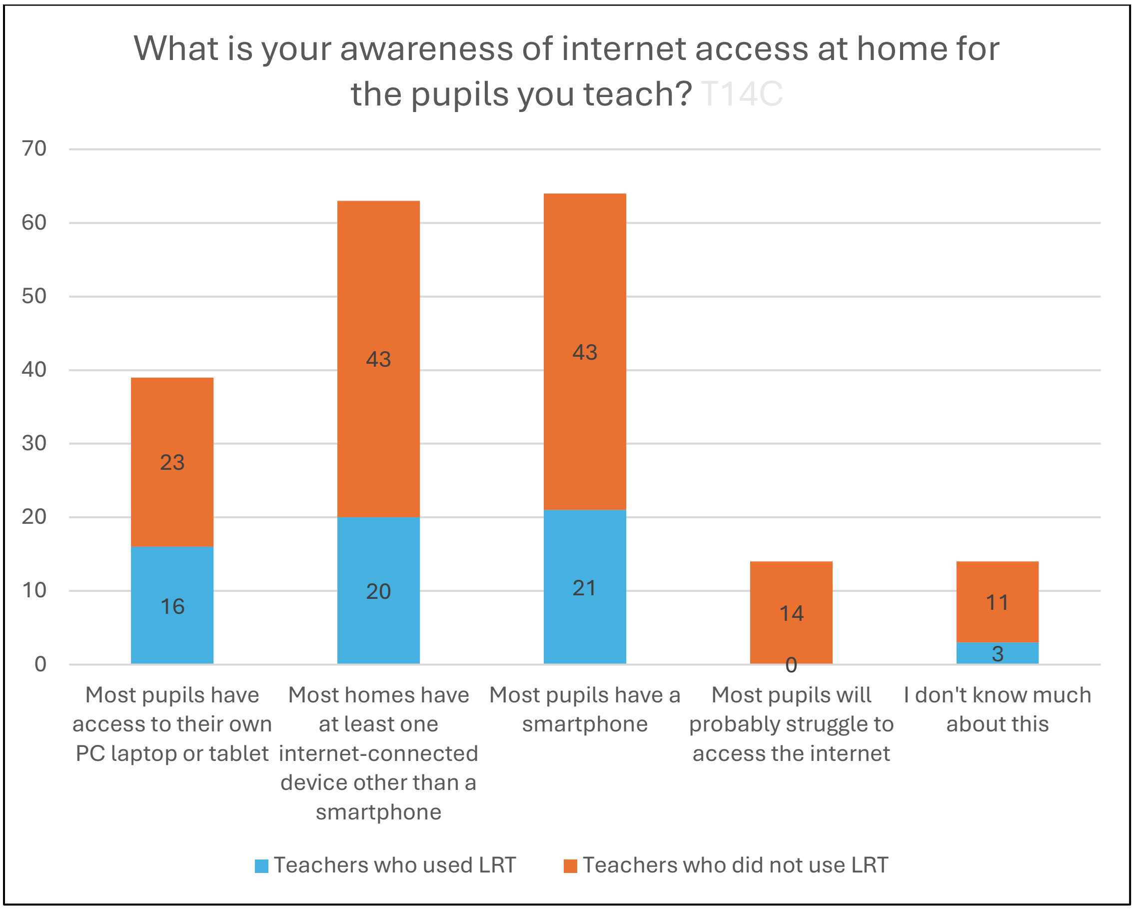


Figure 30: Teacher responses to the question "What is your awareness of internet access at home for the pupils you teach?" Data columns are labelled with numbers of responses. The question allowed for more than one option to be selected. N = 137.

Whether retrospective or not, there is little connection between schools' decisions about providing LRT and their knowledge of children's internet access. LRT was not offered by any teachers who had chosen the option, 'Most pupils will probably struggle to access the internet', but this could reflect lack of awareness of LRT as much as strategic avoidance. Moreover, of the 37 teachers who did use LRT, only 16 thought pupils had their own PC, laptop or tablet (far left-hand column). Additionally, most of the teachers who thought pupils had such a device did *not* use LRT. These larger screen devices allowed a better LRT experience than a smartphone: teachers whose pupils viewed PowerPoint presentations on smartphones reported being unable to read some text, which would have occurred during LRT when teachers shared their screens.

Besides knowledge of pupils' home internet access, interviews suggest several other factors affected teachers' ability to offer LRT during the first lockdown, including teachers' initially limited knowledge. This is discussed further in sections 5.3.3 and 5.3.4.

5.3.2 Pupil attendance in LRT lessons

Figure 31 shows that around half the teachers who used LRT were using it with most of their pupils; conversely a similar proportion were using it with fewer than half of their pupils.

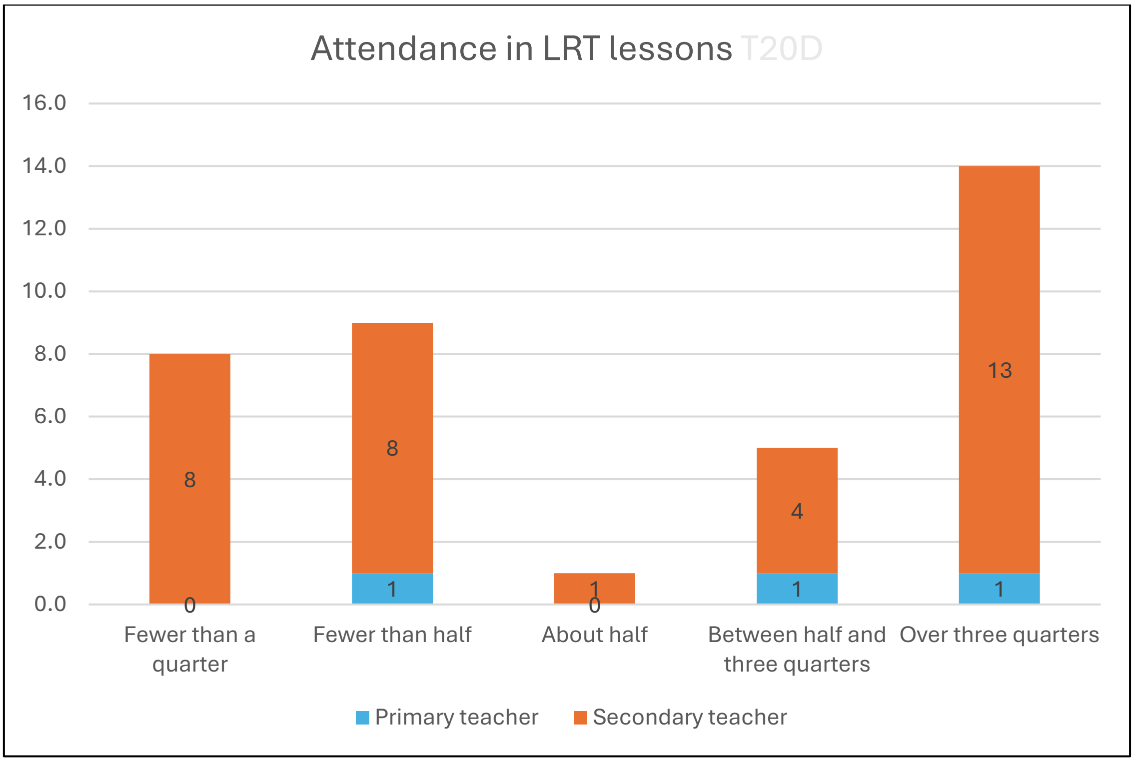


Figure 31: Responses indicating rough proportions of pupils attending LRT lessons. Each bar is labelled with the number of responses received. N = 37.

Teachers thought internet or device access issues were usually responsible for lower attendances. Julia explained that although her school had provided LRT, pupils sometimes could not attend because their parents were working from home and needed the computer. Jack suggested attendance might have depended on which classes were on a teacher's timetable:

"I did actually have a year 10 lesson where only one person out of 10 turned up …they are one of the lowest sets that you can have and …they don't like science very much. So that was probably the biggest challenge… ensuring that everybody who could attend will attend."

Jack's view highlights that teachers did not always know what was preventing pupils from joining LRT lessons, and reasons given were sometimes speculative. However, while internet connectivity could be a legitimate excuse, they could not rule out whether pupils were choosing not to attend.

5.3.3 Rate of adoption of LRT

Interview evidence shows LRT usually being adopted gradually, after other online approaches were used. The notable exceptions were the teachers from independent schools, where LRT was swiftly implemented following the regular school timetable. Anne, who was one such teacher, described feeling an expectation that all pupils would be able to access LRT, and pressure from parents, who were still paying school fees. She suggested the economic prerogative of maintaining their income was a pressing reason for these schools to avoid an interruption in teaching. Even so, lockdown conditions meant the school day needed shortening because extra-curricular activities had been suspended. She described how this led to parental complaints:

"Normally our school day would go on till 6:00 PM because there would be activities and sport, which obviously didn't happen, so the school day was cut

short by two hours to 4:00 PM and, oh wow, the complaints we got from parents about that, saying "why is the school day shorter?""

Teachers in independent schools were not necessarily better prepared for LRT than other teachers. However, Anne felt fortunate that, as a self-confessed 'geek', she had quickly learnt to use her 'Surface-Pro' tablet when staff received them 18 months before lockdown. Her existing proficiency meant she could incorporate it into LRT without much difficulty. She thought most other teachers probably hadn't taken theirs out of the box, however, meaning her experience of LRT might not have been typical for the school. Eleanor, who also taught in an independent school, described another factor enabling her school to implement LRT immediately - school leaders had pre-empted the lockdown in sufficient time:

"Two weeks before, there was, "Right we think this is going to be a thing. We are therefore going to have this school off timetable for these periods" …but we had to start with two afternoons of staff training to get the staff to know how to use Teams before we could then go on to training the pupils."

The foresight of Anne and Eleanor's school leaders was not unique, but plans could reflect degrees of luck. Rachel, who taught in a state school, described how her school's plans were undermined by the rapidly changing and unpredictable events of the pandemic. She subsequently did not use LRT because of such changes:

"We did kind of rush out Microsoft Teams in the week before lockdown but we prioritised year 11, before we were told that Year 11 weren't going to sit their

exam. So we'd done a quick job of trying to get everyone okay and then that didn't happen."

Other teachers offered various explanations for why LRT was not started at an early stage of the lockdown. Jack had no awareness of LRT as an option. He and his colleagues had effectively chanced upon LRT because of a planning meeting they had conducted by videoconference:

"I think it was a group of us who'd met together to discuss the sort of things we were doing, above and beyond what was expected of us really… when someone said, well, you know you can have meetings on Microsoft Teams, you can have meetings with the kids as well. So a few of us went away and planned that and worked out how that would go…and I wish I'd been using it sooner."

Jack estimated he had taught 17 lessons using LRT by the time the first lockdown ended. For Alina, the number was far fewer. When her school began LRT, the priority was to check how well pupils had been able to access and understand learning materials that had been provided through other online channels, rather than teaching lessons.

Sometimes there was uncertainty about whether LRT was the right thing to do. With no previous experience, teachers had no way of knowing how effective LRT might be. Josh raised questions about how suitable videoconference platforms were for education:

"A lot of people have sort of said "Why didn't teachers just shift to doing stuff straight away?" and it's because it's, well, it's not a meeting, you know. Teaching is not a meeting - it's an interactive process."

June raised similar concerns. She thought that LRT had been adopted without due consideration of whether it was the right thing to do:

“I think schools moved to do online lessons because they were told that they had to and they didn't stop and think what was needed, why it was needed, what the benefits to the kids was (sic). I just feel that that was missing. It was everybody… saying “Well I'm doing it ‘cos I've got to” rather than “I'm doing it because actually the needs of my learners are the priority”.”

June’s comments imply a ‘knee-jerk reaction’ in some schools’ adoption of LRT, raising the possibility that it had become an unofficial benchmark by which educational provision during lockdown was judged. However, her school’s approach to LRT could have contributed to these doubts: an initial period of trialling LRT with her own classes was followed by a mandated approach that was more like online lecturing:

“When we moved to the ‘directed learning’, we were being told how we had to deliver the online lessons and we had to deliver them to larger groups. So before I was just delivering to my own classes and then I was having to deliver it to, like, 60-odd kids.”

There were challenges in teaching to such large groups, and these are discussed in section 5.4.

None of the interviewed teachers expressed overwhelmingly negative views of LRT. Mostly the view, when expressed, was that LRT was a good strategy for teaching and learning during lockdown, though not without difficulties. Some indicated their regrets about not doing more, or not doing it at all. This is discussed in the following sub-section.

5.3.4 Reasons why teachers did not use LRT

As stated previously, LRT was not offered by most teachers in this study during the first lockdown. Various reasons were given for why they did not, or could not, offer LRT. Often individual teachers lacked the autonomy to make that decision. Where reasons concerned pupils' internet access, it was not just a case of homes having access or not. Beatrice thought school leaders had made the decision not to use LRT because of concerns about equitability:

"If half the kids can access it then half the kids can't - it's not fair on the kids that can't, like it's not their choice if they don't want to be in those live lessons, it's just that they don't have the equipment at home to do that."

Joelle thought pupil access to their own technology at home was good, but nevertheless her school decided against LRT:

"It was discouraged for lots of reasons. We didn't have the technology, really, up and running. We didn't have anything, and …some people were uncomfortable with how secure things like Zoom were if you're talking to pupils, you know obviously GDPR became a real issue… We knew that some members of staff were uncomfortable with being on video and we'd had no input with any kind of filming devices…apart from webcams, and we really didn't have anything else so a decision was taken that that would not happen."

Other teachers who did not use LRT suggested school leaders had either made conscious decisions to avoid it, like at Joelle's and Beatrice's schools, or were simply slow to respond. Alina assumed her academy trust rather than the school had made the decision, speculating safeguarding fears. She also doubted whether teachers would have been allowed to try things out, expressing some frustration:

“Maybe it's just my interpretation of how things have been discussed but … it was “we're just using Google drive because then the students know where everything is, it's all in one place, we're making it as simple as possible” … but what opportunities have we missed out on because of that?”

Sharon expressed a similar view that her school could have been more proactive:

“We got slated for that, yeah when (headteacher) apparently had his meeting with (head of academy trust) he said that some schools, some similar schools to ours, like in Manchester, had been doing live teaching and they'd had, you know, 20-30% uptake, so I think it's definitely something we should have looked at sooner.”

Lisa, however, wasn’t sure that more pupils would have engaged in LRT than with the other online work she had set. Telephone welfare checks, in which parents reported children still in bed at 10 o’clock in the morning, led her to speculate that some pupils’ sleeping patterns had been disrupted by lockdown. This was not isolated to Lisa’s school: Beatrice had phoned home and discovered some pupils were still in bed in the afternoon. Both teachers reported pupils sending emails to them in the early hours of the morning. It is possible, however, that LRT could have provided the sort of routine that pupils were lacking, helping to maintain more normal sleep patterns.

The issue of technology access was not confined to pupils. Rachel lived in a rural location where internet speed was too slow to support LRT. She suggested that lockdown presented other logistical obstacles for teachers whose children were at home with them:

"We had families that… with sharing laptops so, you know, Johnny would have it for two hours in the morning and then Amy could have it from 12 o'clock and so you couldn't do live teaching in that way because it just wouldn't have been fair…and members of staff had different pressures on their time as well. Some of them were looking after young children."

Childcare was an acute concern for Lisa who, notwithstanding her low expectations of LRT attendance, would have struggled to commit to it because of her own circumstances:

"It was difficult having my little boy about because I don't normally work with him rampaging round the living room and, you know… some teachers have got older kids and they can just leave them up to their own devices. With him only being one (year old) I can't, so I had to keep an eye on him."

Overall, the reasons teachers gave for not using LRT reflect a variety of educational concerns as well as highlighting the unpredictability of the pandemic and the lack of planning for lockdown. While some schools made decisions that, in hindsight, appeared to anticipate that LRT was the appropriate educational route, the situation was hard to predict, and it was clear that socioeconomic factors meant LRT was more difficult to implement for some schools than others.

5.3.5 Online platforms used

Although most of the LRT teachers tended to use just one platform, exposure to other platforms could occur if they engaged with external stakeholders: Julia described how her school used Microsoft Teams, regional Heads of Science used Zoom, and national online events she had attended used Adobe Connect. Multi-platform use by teachers was therefore not unusual, exemplifying the evolving and experimental nature of teachers' practice. Of the LRT platforms, Teams was used by most teachers, followed by Zoom and Google.

Multi-platform use also underlines that, though superficially similar, platforms could differ subtly. Switches sometimes occurred because teachers were discovering limitations and possibilities relevant to what they wanted to do. June had begun LRT using Microsoft Teams, but was limited at the time to 15 participants, requiring her to run two simultaneous sessions just to be able to teach one class. She subsequently switched to Google Classroom, which she preferred. Anne explained that her school opted for Microsoft Teams because they were already significantly invested in the software suite of Microsoft 365, with which Teams could easily integrate. The choice of videoconference platform was therefore a logical one based on what staff were already using and accustomed to. Indeed, several teachers who did not use LRT described using Teams to co-ordinate other online provision with their classes, because they could designate a class as a 'team' and organise the submission of online work.

No teachers reported any unwelcome, unplanned, intrusions into LRT lessons, but online safety was a concern for some. Similarly, cost concerns were not mentioned but could have been relevant for school leaders.

5.4 Teachers' experiences of LRT

Experiences of LRT were determined by various factors, but teachers' knowledge of the LRT platform's affordances and constraints, when teaching specific science content, was fundamental. Pedagogies were often discovered by experimenting with a platform's functionality. Judging by how much they talked about it during interview, LRT had made a significant impression on those who had used it.

5.4.1 The influence of technology

Technology was an inevitable determinant of teachers' pedagogy in LRT, meaning decisions about teaching were inextricably connected to possibilities of the hardware and software, which in turn could depend on the platform being a limited free version or full paid-for version. This sub-section discusses several ways in which LRT experiences were influenced by the technology.

5.4.1.1 Similarities and differences to classroom teaching

Anne, who began using LRT at the start of lockdown, thought there were similarities to how she taught in the classroom:

"In terms of instruction it was pretty much the same. They had the whiteboard and me talking; they had worksheets and me explaining; so that, I think, was all the same. We had the occasional break of 'Right guys watch this video for five minutes,' which is the same as I'd have done in the classroom."

The format of Anne's LRT lessons typically involved her speaking to the whole class, sharing material that was on her screen with them, and then assigning tasks. Microsoft Teams enabled her to monitor whether pupils accessed required documents, providing insight into their engagement. Pupils could ask for help if needed, either by using their microphones or the chat stream of the software. She could provide clarification by annotating electronic documents shared on the screen; particularly useful when teaching content involving rearrangement of mathematical equations. She had been prescient enough to bring several items of practical equipment home to enable demonstrations via her webcam. As a physics specialist, teaching mainly physics, this was probably more feasible than for a biology or chemistry teacher, for whom greater hazards would have rendered many practical demonstrations off-limits.

Despite Anne's comparisons to her normal teaching, most teachers dwelt on the ways that LRT was different to classroom teaching, suggesting this was what defined the experience for them. Although their LRT lessons bore similarities to Anne's descriptions, with teacher exposition interspersed with pupil tasks, they highlighted significant differences to classroom teaching. Interview evidence suggests these differences, whilst not entirely unpredictable, had not been anticipated. Not being in a classroom made it more difficult for them to be flexible, spontaneous or responsive. Resources had to be available in a suitable electronic format at the click of a mouse, requiring different levels of preparation and foresight.

5.4.1.2 The auditory environment of LRT

Teachers described how being online, on a screen instead of in person, affected lesson dynamics. Pauses or delays, sometimes for technical reasons, were harder for teachers to navigate using classroom experience. Pupils could not, for example, 'talk amongst themselves' while the teacher sorted a problem out: any conversation between two individuals could be heard by all, and it was virtually impossible to distinguish what was said if more than one person spoke at once. Hence when hitches occurred there would either be silence, or the teacher would have to 'ad-lib' while concentrating on whatever technical issue required their attention. Consequently, the auditory experience of LRT was very different to a classroom, in which multiple conversations can occur simultaneously. LRT, within one online 'room' at least, was limited to one sound source at a time, either an individual person speaking, or a single source of multimedia content being played.

Teachers also described how pupils were reluctant to contribute verbally during LRT. Teachers' own monologic input therefore dominated most LRT lessons. Dialogue between pupils was possible, but only meaningfully within breakout rooms – effectively sub-meetings – requiring a level of organisation that felt more contrived than in the classroom. Whilst Eleanor reported some success with this, Anne stated that apart from her sixth form classes, *"they still pretty much remained silent."* Anne knew this by using multiple devices – described further in sub-section 5.4.1.4. Evidence suggests breakout rooms were more suitable for longer collaborative activities with groups of an optimum size, rather than quickfire approaches teachers might often use in the classroom for formative purposes. As an example, although pupils could be paired up, this was different to asking a pupil to discuss something with their neighbour in a classroom. Once pupils entered a breakout room, they disappeared off the teacher's screen. Unlike in the classroom where a teacher can easily scan the physical space to monitor progress, monitoring breakout rooms required the teacher to enter each room separately in turn, a more time-consuming process.

5.4.1.3 Effects on lesson timings

Eleanor reported that she and her colleagues were getting less done during LRT lessons than they would achieve in the classroom, stating *"Everything seems to take longer."* Some of the issues related above, such as breakout room protocols, could have been responsible. Similarly, Anne initially found timing and pace a challenge:

“I didn't know whether a thing would take them 5 minutes or half an hour, and I had some lessons where I thought, oh God …this would take them 50 minutes in the classroom, but then you factor out any chatter, distractions, “oh, Miss, I've lost my pencil,” that's going on and suddenly they've done in 15 minutes, and oh, right, better find something else. And then the other way round where, when you realise that you're not sure if they get something or not, writing it out and describing stuff again, and going through worked examples takes a lot longer than you'd expect.”

The more pronounced segmentation of activities was an additional time-related aspect of LRT that contrasted with classroom teaching. Teachers’ accounts were of lessons alternating between mutually exclusive teacher-led input and independent pupil activity, with minimal blending of the two. The increased difficulty of being flexible, caused by issues such as needing resources available in an appropriate format, meant that teachers tended not to deviate from pre-planned schedules. Low levels of verbal interaction with pupils, caused by their reluctance to speak, also contributed to this: pupils typed questions or answers into a chat stream more often than speaking. Although formative assessment was possible, the techniques reported by most teachers were more limited than in the classroom. Eleanor thought she had reduced the demand of what she had asked pupils to do, just so she could be confident all of them would be able to do it. As discussed in chapter 4, classroom experience was not the rich resource it usually would be, as Judy explained:

“I've taught for a long time, so often I walk into a lesson and know I'll be able to just find the information from the top of my head, but I had to be more prepared when I was doing it online to have everything ready.”

5.4.1.4 Overcoming problems

Teachers' LRT experiences often included accounts of technological problem-solving. One difficulty was being able to see everything they wanted to see on screen – usually a single screen. Normally three things needed to be visible: the class - essentially a grid of either faces or, more usually, names; the content being shared with them; and the chat stream so that pupils' inputs could be addressed promptly. A single screen was often too small, and some teachers consequently used two screens. This could be done in multiple ways, however. An extra monitor could be attached to the main device (laptop or PC) to make an extended screen, or a different device could log into the session, enabling the teacher to see different content on each device. Anne mainly used the first method, and described what this looked like to her:

"So a typical lesson I'd have myself on this screen here, so that I'm a little face at the bottom, because we were told that apparently seeing a person's face is useful. And then I'd use my other screen, and what I'd have is Microsoft whiteboard up all the time, and… whatever I was saying I would write on the board… which the students said helped because if their Wi-Fi dropped out or whatever, they could come back and look at the whiteboard later - the notes were still there."

Josh used the latter method for dual-screen set-up. His laptop was dedicated solely to the chat stream, and his iPad was for presenting content. Unlike Anne, he did not think it was important for pupils to see his face if they could hear him and see content. He thought the Apple 'Pencil' had helped, allowing him to annotate content for pupils, like Anne had done via a different method. It is of incidental interest that the iPads Josh's school had introduced seven years prior to lockdown had been used *“hardly at all”*. He thought lockdown would, ironically, be the catalyst leading to their fuller integration into teaching and learning post-lockdown.

The examples above illustrate how teachers solved problems in LRT, but also highlight that teachers would probably have struggled without access to additional technology, or sufficient confidence using it. Anne occasionally went beyond the dual screen approach, using four devices. She logged into the videoconference on each one, allowing her to be in each of four breakout rooms simultaneously, unmuting the one she wanted to listen in to. This would not have been possible without extra devices, or the technical ‘nous’ to realise she could do this. It was how she had concluded that pupils had mostly remained silent, although, as pupils would have been able to see she was present in the breakout room, it is not possible to ascertain whether pupils’ silence only arose at those moments, because they thought their teacher was listening.

5.4.1.5 Influence of the chat stream

Although LRT tended to limit classroom-style pedagogies, novel pedagogical approaches could be discovered. Like many teachers using LRT, Josh had prioritised the chat stream when he realised pupils would not speak. However, he adapted the way he used it. He had observed that pupils typing answers to his questions would often wait until others submitted their answers, and then copy them. To avoid this, he gave pupils time to type their answer but instructed them not to press ‘send’ until told to. This way the answers appeared simultaneously, and pupils would not be able to copy their peers. This simple measure led to new teaching possibilities, compared with face-to-face teaching. As the chat stream became a permanent record, it could be referred to during the ongoing lesson, something which would have been difficult to replicate in a classroom. The things pupils typed also reflected minor but significant aspects of understanding which might have otherwise gone unnoticed: correct use of small or capital letters for scientific units, and appreciation of accuracy and precision when typing numbers, for example. Josh could, therefore, adapt his teaching productively in real-time by making use of chat stream evidence.

Presenting content while monitoring the chat stream could be challenging, however, because teachers could not concentrate on what they were presenting while simultaneously reading chat messages, especially if several messages appeared in quick succession. Thinking about suitable responses to messages was an extra cognitive demand. For Julia and her colleagues, double staffing was initially provided on LRT, with the extra adult monitoring the chat stream and alerting the teacher to relevant points. She thought a lot of what pupils put in the chat was irrelevant, and partly because of their unwillingness to speak:

“A lot of them will sit there with their videos off and then type in on the chat bar. We then have to be able to monitor that chat bar, so if you're teaching a lesson and they're going off on a tangent saying ‘hi’ to each other, how do you monitor that?”

June experienced similar issues when her school had moved to LRT with double-size classes of sixty-plus pupils. Though LRT made this class-size logistically possible, the large number of pupils made it even harder to monitor the chat stream and teach responsively. However, she discovered additional benefits of the chat: by allowing pupils to type messages to each other she could discover how lockdown was affecting them:

"The chat was really handy because it helped me work out where their heads were at, because they were talking to each other rather than to me. And obviously they knew I was reading it. It was really, really useful being able to see… they really needed it; they really needed to have something to look forward to. They were desperate to see people's faces. They wanted to be able to chat to each other, but talk to me as well. They needed that feeling that they were supported rather than that they were doing the work on their own."

Anne perceived similar benefits of the chat, particularly in allowing pupils to communicate privately with her:

"The private chat function in Teams worked really well for some of the quiet ones to send me a private message. Rather than putting it [in the public chat], or speaking out loud and saying, "Miss I'm stuck on question eight," they would type that, and only I could see that, and I could respond to that, and I think that made them feel a bit safer. And in the classroom I think that's the equivalent to me walking round and saying, "Are you okay with that question?" but saying it, you know, quietly."

Although incorporating the chat stream affected the flow of LRT lessons, it was sometimes essential if, for instance, pupils' microphones did not work. Other technical problems could occur, however. Chat had limited value unless timely responses occurred; either teachers responding to pupils, or pupils responding to teachers. This depended on consistently fast internet speed; if slow, the chat lagged behind real-time events and was less useful. Julia reported Microsoft Teams had tended to 'glitch' more often as more people in her school used it:

"We had …more issues with it slowing down, and the kids get frustrated with it getting a bit 'laggy' and writing an answer to a question, and not appearing for a minute or so."

5.4.1.6 Technological innovations

Teachers used other technological innovations during LRT, expanding possibilities of the medium. Although speaking in 'real-time' was the norm, Eleanor realised she could incorporate pre-recorded exposition. This worked well when specific new content needed explaining, ensuring pupils received her best explanation repeatedly and consistently. She also captured all the annotations she had written for pupils during the lessons, so that these could be accessed again, for example by pupils who had been absent.

Teachers also used extra cameras to show additional content or views. Sometimes a camera pointed at a piece of paper to screen-share what they wrote. This was essentially a 'low-tech' version of Josh's Apple 'Pencil'. Judy described how this had been useful:

"I put it [the camera] on a piece of paper and then I would have a whole load of coloured crayons like I would on the board. For my lower 6th I decided to do organic chemistry …less practical work, lots of theory, so I could do all my mechanisms, draw them all out."

Josh had a colleague who had simply pointed his camera at a classroom-type whiteboard and taught his LRT lessons by writing on this. As mentioned previously, Anne had used her extra camera for showing demonstrations using equipment she had brought from school. This and the other examples discussed here illustrate that while LRT included practice that reflected classroom experience, teachers were also beginning to identify distinctive and beneficial pedagogical approaches that embraced affordances of the technology.

5.4.2 Pupils' cameras being turned off during LRT

Teachers reported extensively that most pupils had cameras switched off during LRT. Teachers would see a black rectangle with a name or initials, rather than a pupil's face: the full class view was a grid of such black rectangles. Most interviewees who used LRT discussed this and had found it difficult. Judy stated:

"We all found talking to a screen without seeing a face really difficult. Big staff meetings of course everybody is there, everyone's showing their face, but the students don't do that."

There seemed to be two principal reasons why cameras were switched off. Occasionally teachers instructed pupils to do it, sometimes to conserve bandwidth and improve sound quality, and because some perceived safeguarding implications if, for example, pupils were joining LRT from their bedrooms. Others did not see this latter point as problematic. The main reason, however, was pupils themselves choosing not to have their cameras on.

Teachers mostly thought peer influence was responsible for the reluctance of pupils to show their faces. Eleanor encouraged her pupils to put their cameras on, with mixed success:

"I think teenagers are teenagers, and if you're not all doing something then the few that do, well, almost put their head above the parapet. They're going to get fired at."

June speculated similar reasons:

“Even when we'd stopped recording and I said, “you can turn your videos on and you can see each other”, there were a couple who I think probably would have done but the mass sort of movement was not to have video on, so none of them had it on.”

Judy described how not seeing her students’ faces was one of the biggest challenges of teaching in lockdown. She explained how the girls she taught were the least willing to turn their cameras on:

“Most of my students I never saw. So obviously I knew they were there, but I'd never see them in person, and particularly the girls… I also have a group of 15 students I meet every morning - like an advisory group - and on my last advisory group I said, “look can we see everyone, see each other,” and only the boys would then show me their [faces] and the girls go, “Oh no, no, I've got tape over the camera, no, no, no, I can't possibly…”

When they were unable to see pupils’ faces, teachers were not always sure of whether pupils were present or not, or whether they were on-task. Anne described the experience, initially, as *“terrifying”*, although over a few weeks she became more comfortable talking to a blank screen. Like others, however, she had no visual confirmation that anyone else was witnessing what she was doing:

“I kept saying, you know, tell me that you're there, tell me that someone is watching me. Is anybody here? Am I talking to an empty room? And occasionally there’d be one nice kid … who'd unmute themselves and go “Yes miss, we can hear you,” …but it's very, very strange, very strange getting no visual feedback ‘cos I don't know whether they’re bored…are they hanging on

my every word? Or are they off playing their Xbox? They've just logged in here and then they've buggered off to the next room, or, you know, do they understand it, do I need to say something again?"

Like Anne, many teachers described their experiences in terms of their own emotional response, suggesting that the impact of pupils having cameras off was psychological, as well as a practical inconvenience. Eleanor stated:

"I couldn't persuade them, no matter what I did, to turn their cameras on…I was just shouting into an empty room which I found really difficult. It was quite draining."

June described the effect of teaching larger groups using LRT:

"I was having to deliver it to like 60-odd kids. They can't all be visible …and they can't all talk, and you can't ask them questions, and you can't read their facial expressions, so you've got no way of knowing whether …everybody is following you, or if they've got lost. It's very, very intimidating."

As June explained, the inability to see pupils' faces affected teachers' judgements and decisions about teaching and learning. Julia echoed this:

"A lot of them did … prefer to work with their cameras off. You've got no facial expression to cue into. If you're sat in front of them in the class, it's really obvious when sometimes they're just not getting it or losing interest. In this… you've got no visual cues whatsoever."

These difficulties could be partly compensated by pupils who were willing to speak, as Anne explained:

“Some people would be vocal and say, “Sorry, miss, can you explain that again?” but I think a lot didn't. Whereas if I was in the classroom I'd be able to look around the room, and even if they don't say anything you can see if, you know, Johnny over there looked a bit confused. And even if you don't single him out, you would choose to maybe re-say the thing but with a different wording.”

Judy described LRT as *“going into a void.”* Overall, it was apparent that the visual environment of LRT was a significant factor in teachers’ experiences. It is conceivable that their emotional experiences might have been different had pupils routinely had their cameras switched on.

5.4.3 Observations of pupils’ behaviour during LRT

Pupils’ reluctance to speak was a conspicuous behavioural difference during LRT, compared with classroom teaching. Being unable to see pupils was also a significant difference for teachers. June had feedback from one pupil’s parents suggesting the different visual and auditory environments had made pupils feel exposed and less willing to speak:

“That individual didn't feel confident enough to ask questions because she didn't want to feel as though she was asking anything stupid. Now, she would feel exactly the same in the whole classroom, but in the classroom I could read her body language, and see her face, and then I could ask a question, or I could avoid asking a question but then go over.”

Anne’s evidence suggests LRT could have affected active involvement in the lesson because pupils were not visible:

“I have a feeling that a lot of them were on Snapchat or WhatsApp on their phones next to their PC, ‘cos sometimes when a video came on by accident

…you'd see they were doing this and you'd be just, like, "Get off your phone" and they'd be like, "Oh yeah, oh sorry miss.""

Jack suggested pupils related differently to LRT, compared to classroom lessons, because of the remoteness. Some of his pupils had posted messages in the chat which he couldn't be sure were deliberately provocative, or reflected them not understanding that the chat stream was visible to the whole class. He speculated about a disconnection:

"I think there's a bit of a disconnect between their conversation that they're having and the environment of the shared experience that actually is happening. They can't see a big picture. What you would have done in a classroom is you'd keep them behind for two or three minutes and say "Come on, you. That's not acceptable … let's have it differently next time." … I think without that potential for human contact … I don't think you have that in the same way. And the live lessons I think that's a potential issue."

Jack also noticed his pupils' attention spans were affected, speculating this was also due to them not being in school:

"I've learned from lockdown …attention spans are a lot less when you're not in the classroom. And, you know, we moan about children's attention spans in the classroom anyway but when you're at home surrounded by other things, it's even worse…"

Although potential for non-compliant and mischievous behaviour was different during LRT than in a classroom, some specific instances were reported. For Julia, it had involved the technology. By not setting the permissions for the attendees in her videoconference appropriately, some pupils had disrupted the lesson by controlling the platform’s functions, taking over the presentation and removing other pupils from the session. Although she initially put this down to the technical inexperience of herself and her colleagues, she thought the permissions issue was not particularly obvious. The mischief described was possibly aided by pupils’ cameras being off and microphones muted.

Teachers did not always anticipate the behavioural differences that would arise in LRT. However, they were an important feature of the experience, ultimately affecting how teaching and learning occurred.

5.4.4 Teachers’ views about the quality of science education during lockdown

Survey data reveal that teachers’ views about the quality of the education they had provided during lockdown tended to differ according to whether they had used LRT or not. Figure 32 shows a comparison of the proportion of LRT and non-LRT teachers who made specific judgements about quality.

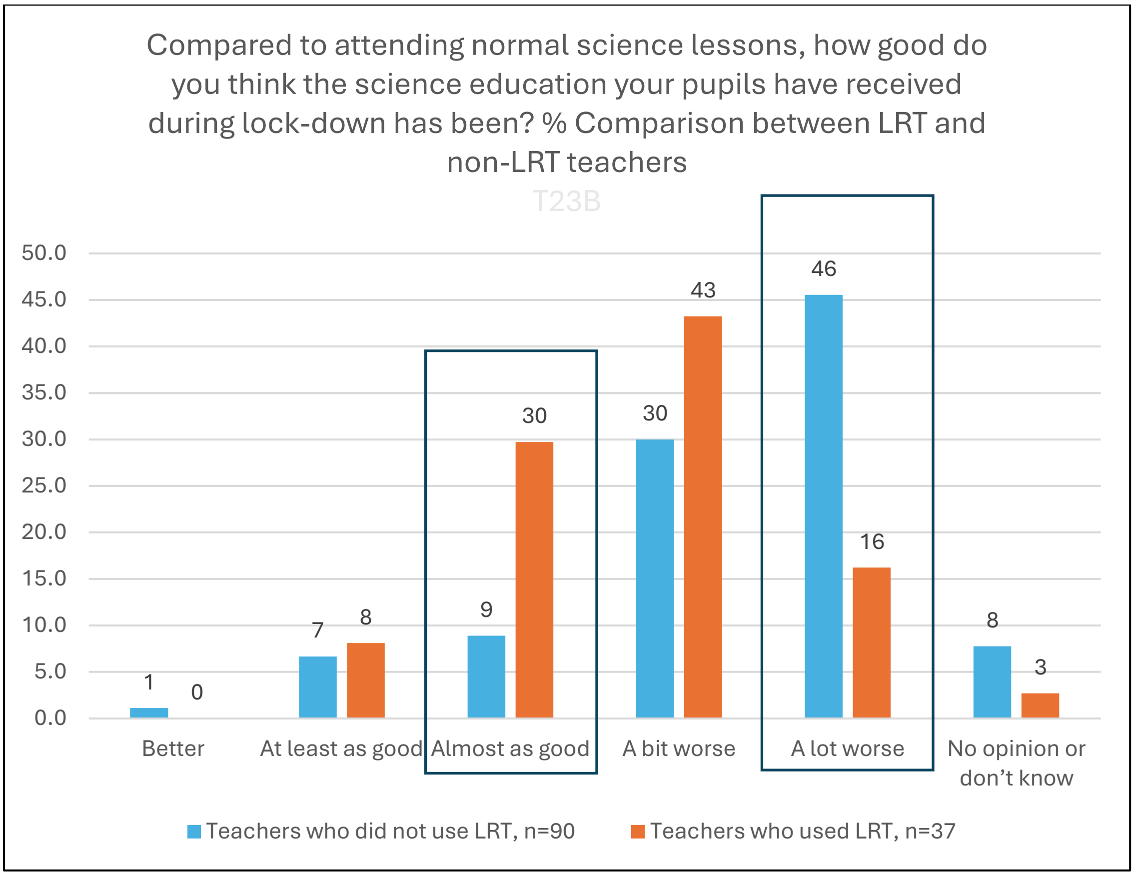


Figure 32: A comparison of views about quality of science education provided, between teachers who did and did not use LRT. The data labels are % figures for the two groups to enable comparison. N = 127.

Two data columns where the differences between LRT and non-LRT teachers are most pronounced have been outlined for emphasis. Overall, these data suggest teachers who used LRT thought they had been able to provide higher quality science education than those who did not use LRT. Although it is not possible to establish a causative link from the data, it is plausible such a link exists. Other data collected in this study show teachers using LRT were far more likely to base their view about quality on feedback from others, especially pupils and parents. Having real-time contact with pupils, LRT teachers would have been able to solicit feedback better than non-LRT teachers, or, at least, formulate judgements based on real-time contact. As discussed in chapter 4, the direct pupil contact occurring during LRT could have had a positive influence on teachers' views of what they had done.

5.5 Schools' decisions and priorities during lockdown

Drawing on evidence from the previous sections, 5.2 – 5.4, LRT provides a useful lens through which schools' decision-making during lockdown can be better discerned and understood. The difficult choices school leaders were faced with during lockdown, and what was prioritised at the time, often involved LRT in some way. LRT also exemplifies the interplay between technology, pedagogy and various other factors, some unique to lockdown, revealing the complexity of a large-scale educational crisis that was not planned for.

5.5.1 LRT's emergence and later dominance of lockdown education

Although this study and other literature (e.g. Cullinane & Montacute, 2020; Floyd et al., 2025; Green, F., 2021) relate the prevalence of LRT to socio-economic aspects of a school's intake, other evidence in this research also suggests that, for most schools, the decision to offer LRT was invariably neither strategic nor informed. Many teachers had no prior awareness or experience of LRT; moreover, when it was offered, schools lacked accurate prior knowledge about the technology pupils had access to at home (see section 5.3.1). The low attendance many teachers reported in LRT lessons (see section 5.3.2) probably reflects its untargeted nature: with a few exceptions, such as independent schools, it was initially just another technique in the trial-and-error approach most teachers were compelled to adopt in online education, an observation supported by literature (e.g. Floyd et al., 2025). Emerging as most similar to classroom teaching (Iglesias-Pradas et al., 2021; Tosto et al., 2023), (albeit with significant differences, as discussed in section 5.4), and as the only method by which real-time contact between pupils and teachers could occur, it is understandable why it became more widespread in later lockdowns (Cattan et al., 2021a). Despite lacking a pre-existing evidence-base about its educational effectiveness (Dabrowski et al., 2020), it probably had other benefits: evidence in this study suggests some children’s routines had been severely disrupted by lockdown (see section 5.3.4) and LRT could resurrect some semblance of routine.

5.5.2 Ethical dilemmas

Lockdown confronted school leaders with challenging decisions, including ethical dilemmas. This study's evidence suggests two such dilemmas. Evidence in section 5.3.4 suggests some leaders decided against LRT, not knowing the situation in pupils’ homes but aware of the likelihood that many lacked technology or a suitable internet connection. Knowing only more privileged pupils would be able to participate, this avoided exacerbating pre-existing socio-economic disadvantage in their school, but meant some pupils who could have participated were denied the opportunity. This conscious decision-making, to limit effects of inequality, is also reported by Andrew et al. (2020). The second ethical issue concerns safeguarding. In this study safeguarding was not commonly cited as a reason for LRT not being offered; primary teachers were more likely to mention being worried about pupils’ privacy than secondary teachers - by contrast, Hodgen et al. (2020) suggest it was a significant reason among their teacher sample. However, while focusing on the potential for LRT to undermine safeguarding, for example through risks of unwanted intrusion, teachers could have overlooked possibilities for monitoring pupils’ welfare. In terms of the loss of ‘line of sight’ during lockdown between schools and vulnerable children (Children’s Commissioner, 2020), LRT would have offered a relatively straightforward way for schools to achieve visual contact with children.

It is possible this positive potential was either overlooked, or that an ethical choice was made between risks and benefits. The later, more widespread adoption of LRT (Cattan et al., 2021a) suggests that related concerns about safeguarding had either diminished or been addressed, or that schools felt compelled to offer LRT despite safeguarding concerns; it is clear the UK government raised expectations around LRT after the first lockdown (UK Parliament Hansard, 2021; Whittaker, 2021).

5.5.3 Procedural decisions

Teachers' evidence in this study suggests that awareness of LRT was widespread towards the end of the first lockdown, raising the question of why more schools did not adopt LRT at that point, if not earlier. As discussed above, ethical dilemmas probably influenced some school leaders. However, procedural considerations illustrate other issues leaders were having to weigh up. LRT began in some schools because teachers were able to exercise autonomy, trying it out alongside other online approaches. Other teachers were less empowered, following directives about online teaching which did not include LRT. The conditions of lockdown meant that it was probably difficult, at the time, to judge which of these two leadership approaches would have the best educational outcomes for pupils, or indeed represent better leadership for teachers. As I have described, excluding LRT may have been done to prioritise consistency and inclusivity, reflecting what school leaders thought pupils were already familiar with. Allowing teachers to experiment, though more amenable to 'discoveries' like LRT, could have risked children being overwhelmed by a plethora of different online approaches. Evidence in chapter 6 reveals how frequently changing online systems were a source of confusion for parents and pupils.

5.6 Discussion

This section provides a critical discussion, similar to the concluding section of the previous chapter, examining this chapter's contribution to the literature.

5.6.1 Comparative observations

Detailed published empirical research on LRT during lockdown is limited. A lack of depth possibly reflects the observation, discussed in Chapter 2, that much lockdown educational research relies heavily on surveys, prioritizing breadth over depth (e.g. Allen et al., 2020a; Brink et al., 2020; Champeaux et al., 2020). However, detailed discussion of LRT is often absent even from in-depth empirical studies because it falls outside their specific focus. Hence, despite the implicit occurrence of LRT in Bubb and Jones's small-scale Norwegian study (2020), it is not discussed specifically. Similarly, Wisanti et al. (2021), whose small-scale study examined online science learning in Indonesian schools, does not distinguish LRT from other online methods.

In other literature in which LRT features in some way, additional contextual factors limit comparisons with my study. The mixed methods study of Yates et al. (2021) sought to apply Kearney et al.'s framework for mobile learning (2012) to the lockdown context. As well as confirming the relevance of the framework, it identifies additional characteristics that were important to students' learning. However, as participants were post-16 students in New Zealand, studying a range of subjects, comparability with my study is limited. Similarly, the medium-scale survey by Bergdahl and Nouri (2021), which finds lack of school preparedness centred on technical rather than pedagogical factors, differs from my research by its focus on Swedish teachers across all education settings and subjects. Many studies are of the HE sector, in which some contextual features overlap with schools (e.g. pedagogy), but many are distinct. For example, Watermeyer et al. (2021) focus on the broader implications of LRT and online course provision for the future of universities, identifying serious concerns in which *"afflictions"* outweigh *"affordances"*. However, for schools many of the implications would probably not apply, or apply differently, because of how the two types of institutions are funded, including the compulsory nature of school education in which learners cannot exercise the same consumer-like choices as university students. These examples typify how, while LRT represented an important, tangible aspect of the change engulfing educators during lockdown, teachers' daily experiences of using it were generally peripheral to studies' aims.

Despite the limitations mentioned above, comparisons are possible between my findings about LRT and existing literature. The low LRT uptake in state schools compared to independent schools, discussed in section 5.3, reflects multiple sources (e.g. Cullinane & Montacute, 2020; Howard et al., 2021; Müller & Goldenberg, 2021), which find significant disparity between the two types of provider, both in the first lockdown and in January 2021 when the third lockdown occurred. In terms of overall teacher usage, my study's 29% rate broadly corresponds with the literature, though variation exists across studies. Lucas et al. (2020) report 24% of teachers using LRT, while Brink et al. (2020) find a somewhat higher 40%. Sampling differences may partially explain the discrepancy between these two studies, since both studies employed large-scale surveys with thousands of respondents, in which the effect of random variations would be reduced, and each sample would better reflect the whole population than a relatively small sample, such as in my study. It is more plausible, given the evolving practices teachers describe in this study, that variation may reflect the rapid pace of change in lockdown teaching practices, particularly LRT adoption: Brink et al.'s survey (2020) was conducted in June, while Lucas et al. (2020) collected data earlier in May. However, by contrast, the study conducted between May and June by Hodgen et al. (2020) shows virtually no LRT usage among mathematics teachers from 115 schools. Evidence from these sources suggests, therefore, that LRT distribution remained somewhat uneven during the first lockdown, with usage confined to a minority of schools. Quantitative evidence in my study confirms this, with qualitative evidence providing examples to illustrate how awareness and adoption of LRT occurred. Although literature (e.g. Cullinane & Montacute, 2020; Müller & Goldenberg, 2021) emphasises teachers' rapid upskilling to begin using LRT, individual accounts in my study clearly show that many teachers started from a position of zero knowledge of the approach. Even teachers who were confident technology users were completely unaware of LRT at the start of lockdown. The teachers in independent schools had a short time to prepare to use it before lockdown, but only because their leaders' predictions about lockdown, and not because of widespread pre-existing knowledge about LRT. Hence, rather as other online teaching approaches were often begun haphazardly, so, in many cases, was LRT.

Müller and Goldenberg's report about lockdown education in UK schools (2021) is most comparable to my study in terms of methodology, detail and findings about LRT. It employed mixed methods, of surveys and focus group discussions, highlighting several specific issues also recounted in this chapter, such as:

- Assessing pupil understanding through facial expressions, a familiar classroom practice, was often not possible because pupils had their cameras switched off. Teachers found this aspect of LRT difficult.
- Pupils' attentiveness in LRT was lower than in the classroom, and teachers have various explanations for this, including cameras being switched off.
- Some teachers encountered difficulties facilitating small group work through LRT. Breakout rooms, though technically a solution, did not always facilitate the sort of group engagement teachers were hoping for.
- Teachers adapted to LRT, learning how to improve learning opportunities for pupils by effective use of tools such as the chat stream, for example.

While Müller and Goldenberg's (2021) use of focus groups involved more teachers in the generation of qualitative evidence (52, as compared with 21 individually interviewed in this study), the experiences of teachers of STEM subjects specifically are not explored, despite focus groups for some subject groupings. Additionally, the authors acknowledge some drawbacks of the focus group method. Such drawbacks, including issues of social conformity and normative discourse, unequal participation, and limited depth of individual exploration, reflect methodological literature (e.g. Ning et al., 2024; Sim & Waterfield, 2019; Smithson, 2000). Accounts of experiences elicited through semi-structured interviews in my study are therefore likely to provide more depth and candid detail, free from the social and normative pressures of focus groups, and have also captured perspectives specifically from a group of teachers existing research does not include.

5.6.2 Original findings

Despite the similarities outlined above, this chapter reveals additional detail about LRT, providing evidence specifically identified by Müller and Goldenberg (2021) as being absent from literature, such as authentic teacher voice, phase-specific differences and subject-specific challenges. These and other points are demonstrably addressed within this chapter. The following points summarise key findings:

- Most teachers were unaware of LRT at the start of lockdown. Awareness grew organically through various communication channels. However, uncertainty about benefits were expressed, and its adoption could not be based on prior evidence, as none existed.
- Using LRT as a lens for considering schools' decisions during the first lockdown illustrates how strategic planning was impaired by lockdown, and how decision making could be influenced by ethical concerns.
- Frequency of use of LRT was highly variable; some teachers used it on a few occasions only. Videoconferences were sometimes used for pastoral checks, rather than LRT. This variability further reflects the diversity of experiences discussed in the previous chapter. This underlines the shortcomings of quantitative data in conveying an accurate picture of how LRT was used, and its effects.
- By removing physical proximity of pupils, LRT affected how teachers experienced lesson dynamics such as timings. In comparison to

classroom teaching, this sort of difference nullified the benefit of much of teachers' past teaching experience.

- LRT's logistical possibilities, such as hosting larger than usual classes online, affected pedagogical priorities such as responsive teaching. This highlights a tension: while LRT demonstrated clear benefits through providing real-time educational experiences in which teacher and learner could directly communicate, its implementation could nevertheless undermine a key principle identified by several authors (e.g. Peimani & Kamalipour, 2021; Rodríguez et al., 2021; Yates et al., 2021), which is the placing of pedagogy at the heart of online learning.
- Despite disadvantages compared to face-to-face teaching, specific pedagogical affordances of LRT were demonstrated, such as the use of the chat stream as formative evidence of learning or for identification of misconceptions.
- Although some teacher demonstrations in science were possible using LRT, these favoured physics, emphasising additional challenges for teaching chemistry and biology online.
- Teachers reported LRT being tiring and contributing significantly to workload, but examples of innovations such as incorporating pre-recorded material suggest that these effects could be partially mitigated.
- LRT demonstrated potential for providing temporal structure for pupils that had been disrupted by lockdown conditions and other forms of remote education. As pupils' self-regulation and maintenance of healthy sleeping habits were both identified as problematic issues by teachers in this study, LRT demonstrated benefits beyond teaching and learning.

In summary, such findings fill gaps in the existing field about how LRT practices developed in the first COVID-19 lockdown. The qualitative data in my study, especially, enhance findings from the predominantly quantitative data in other literature, providing further understanding of the nature of LRT and teachers' early experiences of it.

Chapter 6: Parents' experiences of their children's science education during lockdown

6.1 Introduction

This chapter complements the previous two by presenting discussion and analysis of parents' experiences of remote science education. Unless classified as 'key workers', lockdown required parents to work from home, meaning that despite being together, they might not have time support their children's learning. As with teachers, no 'typical' experience emerged, with numerous variables influencing outcomes. These factors ranged from educational provision issues, such as having children at multiple schools or with special educational needs, to home circumstances including available workspace and internet access. Internet access was central to experiences, as Kieran, a father of four, testified:

"I don't think we'd have done it without it… with what we had in the house at the time - I mean we've got books, but certainly not enough, we wouldn't have got through without the Internet. It was invaluable really."

Enforced separation of children and teachers changed most parents' levels of involvement in their children's education, requiring roles they were less familiar with. These ranged from acting as intermediaries to help their children receive or interpret instructions from school, to being surrogate teachers helping them understand science subject material. In some cases, parents had to refresh their own science subject knowledge, and sometimes learn new things. Being physically present with their children during lockdown put parents directly in touch with what children were experiencing during lockdown; a different perspective to teachers who were setting learning tasks. (Although many teachers were themselves also parents, for this study no teacher's child was also their pupil at school).

Of the 76 parents who responded to the survey, most (42) did so as parents of primary school pupils; some also had children at secondary school but chose to answer questions about their younger child. There is hence more survey data reflecting primary school perspectives from parents than from teachers, an imbalance discussed in chapter 7. Five of the eight interviewed parents were parents of primary school pupils, again contrasting with secondary-dominated perspectives from teacher interview data. Sixteen survey respondents and two interviewees responded solely as parents of secondary school pupils. The remainder of the survey respondents were mainly home-educators and a few whose children attended special schools. As mentioned in chapter 3, though data from home-educators provide an interesting contrast, they have been omitted from discussions to focus on experiences relating to school, relevant in conjunction with teachers' evidence in the preceding two chapters. Additionally, only one interviewee was a home-educator, and these data were therefore felt to be limited.

6.2 Parents' accounts of the daily experience of lockdown schooling

This section examines aspects of daily lockdown schooling experiences, primarily through interview data. It explores challenges faced by parents and children, as well as factors that facilitated remote learning, such as the establishing of daily routines.

6.2.1 Technology-related aspects

Access to technology was essential if children were to get most benefit from remote learning. Children of parents in this study were generally well catered for in terms of suitable hardware: no child accessing the internet using a sole device did so on a smartphone, for example. Larger-screen devices were usually available, although not necessarily at convenient times. Social isolation, and the consequent imperative to exploit digital technology, led to some unanticipated benefits, as Karen described for her secondary-aged autistic daughter:

"She's probably become more social. We've allowed her to go on to her tutor group's WhatsApp group, and she's actually been having calls on that, and speaking to people that she wouldn't do, or feel confident doing in real life. So from an autistic person's point of view, doing that kind of thing helped…Mainly it's not with schoolwork, but just with social things."

Some children interacted socially through games consoles. Parents' accounts suggest this sometimes had an educational dimension. During multi-player online gaming children could discuss their schoolwork via their headsets, as Pat's secondary-aged son had done. She thought this had been helpful. Through his games console, he could connect with up to five friends at a time. Although an audio-only connection, he would also occasionally use 'Facetime' to add video. Pat also described how connecting via the games console, with its headset, was sometimes done without any interaction taking place:

"Sometimes just a bit of space, I think… he just pops the headphones on and just to be quiet… and he chooses when he wants to interact."

Even if minimal interaction occurred, the games console was an important way for her son to maintain social contact with his friends, and could facilitate schoolwork. Kelly, Dominic and Jim, all parents of primary-aged children, described similar social interactions for their children during online gaming. Lily, whose son was nine, had been reluctant to allow him to participate in online gaming because of his age, but after relenting she recognised it had helped his emotional wellbeing. However, maintaining strict control over this had led to tension because his friends were playing games she had forbidden. Section 6.4.3 discusses children's emotional wellbeing in more detail.

Several parents discussed the quality of home internet connections. Some experienced occasional breaks in service, causing temporary disruption to home-learning, although no major problems arose. Dominic described his experience:

"We did have occasional days when there were three kids using various devices and then the internet gave up. And then it was a case of "What do I do?" and then just trying to basically think on my feet to get them something to do to, you know, to use that time. But they couldn't access, you see, because my step-daughter - her school …they've got a wonderful platform, and so if you couldn't access that then obviously you were scuppered, and that did on occasion cause a few issues."

Karen experienced the most serious loss of connection, when her internet had gone down for two days. This had distressed her daughter, but a solution was found by accessing the internet via a mobile phone. In the meantime, the daily learning schedule was rearranged to offset the internet's absence, although Karen's daughter, who relied on predictable routines, found this difficult.

As lockdown could involve two parents and their children accessing the internet from discrete quiet spaces in a single property, this could stretch wi-fi network capabilities. Network hubs, usually placed centrally in the house, could not always cover the whole home. Some parents had either bought, or were thinking of buying, wi-fi boosters to improve this.

Having enough devices for internet access was sometimes a problem. Although schools were often generally aware of this, evidence from teachers (see chapter 4, section 4.2.3) suggests they had limited information about specific households. Although some schools provided laptops, none of the parents interviewed benefited from this, despite some arguably having a need. Kelly described her experience:

"At the time there were four of us trying to manage… both me and my husband were working at home …my oldest daughter did do homework everyday so she was on a laptop every day, and then my youngest daughter she was on a mobile…if both me and my husband were working we borrowed two laptops from work and then we had a home laptop, but that's three of you. And then trying to get my 11-year-old to sit and write things in a paper book, she just wanted to do it on the laptop. That was really challenging, and I was trying to balance the two, so I'd do a bit of work, then give her the laptop, where I might over lunch try and go off and do other tasks. And then I found that challenging."

Kieran had found older equipment for his children to use, and fortunately had skills to resurrect it - eventually four laptops were in operation in his house. With Kelly's evidence, this highlights how useful laptops were for children learning remotely during lockdown. Parents occasionally mentioned other hardware too, however. Pat thought a printer had been significant for her son:

“I think we were lucky because we had a printer…in some ways that was the more important resource than the Internet …even if you've got poor internet access you would be able to print stuff, so he was able to keep it in a folder.”

Despite Pat’s evidence, teachers had tended to deliberately avoid tasks in which printing was needed, to remove the burden for homes and because of even less certainty about printer access than internet access. Pat’s account suggests printing was sometimes advantageous, but many children might not have been able to do this.

6.2.2 Daily routines

All interviewed parents described setting up routines for their children, or attempting to. Their accounts suggest this was usually easier for secondary school children, who were accustomed to less supervision. Parents of primary school children reported more difficulties keeping their children motivated. Compromise was often necessary to accommodate parents’ own working requirements, the physical allowances of their homes or availability of computer hardware. Sometimes, however, children themselves were the key determinants of what worked best.

Dominic, who was a teacher himself, described how he had managed to implement a consistent routine:

“As far as the kids were concerned, they weren't too happy about it, but it was generally a nine o'clock start. We’d get the laptops out or the tablets, and the two younger children would sit in the dining room on the laptops and they would access the home learning from the school website, and then my teenage son would sit at my desk in the living room and then he would access his… they

would typically work from 9 till about 11, half an hour break, and then they'd work from half 11 till probably about half 12, one o'clock and then…I'd give them half an hour lunch maybe 40 minute lunch, and then they'd be back at it then until about 2:45, three o'clock…I kept that going most of the time actually; it was a routine for them."

Despite reservations about whether his children had liked it, Dominic thought the routine, which he attributed to his experience as a teacher, had helped them. For Karen's daughter, routines were particularly important:

"Generally, she kept to her timetable because…it felt right - it felt like school…even as part of her extended timetable at the end of the day we'd put down what activity she'd be doing, whether it was …baking or playing piano or something, to try and give her some structure."

This structure even matched start and finish times of timetabled lessons, and had incorporated physical education, involving walks or the trampoline. It had worked so well that Karen had even extended the structuring of time to weekends.

Not all parents had been as successful in their attempts at establishing routines, however. Kelly had tried to stick to one, but her youngest daughter had sometimes "*rebelled*". Lily described how her son's primary school was very relaxed in their expectations:

"The school was very much, like, we're providing this work, but we suggest to you that you don't do any of it. Do some reading with the kids, was their attitude. Reading's important, get them out in the garden, go for walks with them. That was their kind of attitude."

In the absence of school expectations, Lily had tried to instigate her own routine, but had struggled and became exhausted. She quickly abandoned it and subsequently did her own work until lunchtime, then taught her children for one or two hours in the afternoon.

Kieran's experience was different. As he often worked flexibly from home under normal circumstances, and his wife worked part-time, they could spend more time with their children because they were less constrained by their own work. They exploited the allowable time outside, following COVID restrictions, before schoolwork:

"Initially you only had an hour out during the day, so I think we took it upon ourselves as a family to just go cycling in a morning and that was kind of our routine really. We'd go out for that hour, come back, and then we'd kind of sit down, knuckle down a little bit really, and work till early afternoon."

Dominic, despite being a teacher, had not had a large workload that needed to be completed during the working day. He could also be quite flexible and devote more time to his children:

"It was ringing tutor groups mostly, and checking their well-being… I could probably get most of that done between three and five o'clock… I did planning of an evening when the kids had settled down and the youngsters were in bed. I sort of compartmentalised it really. I think it would have added to the stress if I was getting in their way by me doing some work and them getting in my way if they were interrupting me. So it worked really well."

It is relevant to add that Dominic had not been required to use LRT during the first lockdown, which might have restricted the flexible working he described.

When asked what they might do differently were a second lockdown to occur, some parents referred to better daily structures. Kelly felt more confident to plan things in advance because of her lockdown experience. Both she and Jim thought more structure would have been better. Lily's view was similar, but she thought the structure would reflect her own input into her children's education, rather than more formalised activities for her children:

"I think I wouldn't push the structured work like the worksheets and things. I would do more. I would try and structure a little bit more the getting out and about, and doing the other practical stuff… maybe do a bit of research myself …what is their level of understanding and what can they pull out of that activity… it's a lot of the collaborative stuff… that's where they're getting their learning from, not the sitting down and learning facts."

Parents' evidence in this section gives some indication of how they organised the daily business of learning during lockdown, but also demonstrates that they were themselves learning from their experiences. Further discussion of what parents learnt forms section 6.2.4.

6.2.3 Difficulties parents reported

Despite some parents finding successful approaches such as routines to help their children learn, it was clear that all had experienced varying degrees of difficulty. Invariably unrelated to the subject matter of science, problems occasionally involved technology. This section focuses on the main difficulties discussed during interviews, many of which were inter-dependent.

6.2.3.1 Family dynamics

Although it was not necessarily easier for parents of an only child, having multiple children could be challenging, especially if they were at different stages of development, as Lily explained:

“The younger one…he needs help with all the basics… his reading’s not very good, so he couldn't read the worksheets. So I had to be with him, but the older one wanted me to be with him - so I just couldn't, and I didn't. I was trying to work as well, so I didn't have enough time to try and split it up… I found that I could help my 9-year-old a lot better … what I found difficult was helping the younger one just to grasp the basics.”

Jim also had two children, both at primary school. They worked in separate rooms so they would not distract each other, but Jim and his wife still needed to take turns monitoring and supervising, ensuring the children were doing what they were supposed to be doing, instead of playing games, for example. No interviewees were single parents, but having two parents available did not necessarily halve the burden of helping children with home-learning. Two working adults in the home could lessen availability of computer hardware, and an imbalance of obligations if one became the nominal ‘teacher’. Jim was conscious of the need to preserve family harmony:

“We try not to be too strict, but obviously it's hard…we're all in one quite small house together, so you have to try and get along as much as you can, and expecting them not to do too much schoolwork a day. They have to enjoy themselves as well.”

Managing family dynamics alongside other lockdown challenges sometimes caused parents to experience stress, as discussed in the following section.

6.2.3.2 Parents' stress

Interview evidence indicates parents had felt a strong responsibility towards their children's education during lockdown, but this sometimes caused stress. Dominic, for instance, thought that if he had chosen to ease the burden on himself, it would not have benefited his children:

"It kept me very busy, you know, the structure. And as you can imagine it would have been so much easier to say, "Let's just get up and stay on iPads, and play on computer games all day," but that's not what I wanted. I wanted them to get something out of it."

Kelly also discussed the stress experienced while trying to balance her own work commitments with her youngest daughter's educational needs:

"I would have liked to have learned things that she was learning, with her. It would have also enriched her learning, but it was really stressful because I work part-time, my husband works full-time, so we were endlessly arguing for space between us, you know, working space, and then looking for computer time, and then trying to share that. And also I was left to be more of the teacher, so …I was probably feeling the guilt more. So if [daughter] hadn't done anything I was the one getting stressed…I think it was quite difficult when I look back."

Kelly also felt guilt from a sense that she had to appear to be working hard for her managers and colleagues, who were also working from home. She recognised they were not imposing this expectation on her, but the situation left her feeling *"uncomfortable"*, because she wanted to help her youngest daughter more than she was able to.

Lily’s attempts to organise her children’s learning had also been stressful. She thought the absence of the classroom dynamic, with its collaborative opportunities, had made her children bored and disengaged. She worried that, if she had to resort to sanctions to get them to work, they might develop negative associations with learning that would make things worse when they returned to school.

As these accounts demonstrate, parents' stress arose from complex combinations of factors, often specific to individual household circumstances. Lily and Kelly each thought their children’s schools had deliberately tried to avoid undue pressure for pupils and parents. However, while lowering stress in some respects, it had created it in others. Lily worried that her children might not be doing as much as those in other schools, risking them falling behind their peers. Kelly also had reservations about the lack of expectations on children, particularly as lockdown became a longer-term situation. She thought some benchmarks of how long children should spend on schoolwork would have helped, because she perceived her daughter thought there was no need to do anything without direct instructions from school.

6.2.3.3 The home environment

Parental stress was sometimes caused by physical characteristics of the home, such as its size and how easily family members could work undisturbed. Adapting homes to function as offices and classrooms could be difficult; Jim attributed some of this to distractions. For Kelly a compounding problem was the open-plan downstairs layout, where sound could travel easily. She had to move her youngest daughter around to accommodate her own and her husband’s work commitments, especially if they were on videoconference calls that required privacy. Sometimes when Kelly’s meetings finished she found her youngest daughter watching television rather than continuing with schoolwork. This made Kelly feel guilty, again, that she was not doing enough to facilitate her child’s learning.

Pat thought the size of her house had compromised her son’s learning. She had worked at the dining table, but he had not had a suitable space of his own. Kieran’s family had managed because he re-purposed a large ping-pong table, which he had previously intended to sell. Bringing it into the house, the whole family sat around it to work. Clearly in this case physical isolation, to allow concentration, was not an issue.

6.2.3.4 Managing school communications

As detailed in Chapter 4, schools lacked any precedent for educational provision during lockdown conditions and had no existing strategies to implement. As teachers experimented with different approaches and resources, this evolving provision created difficulties for some parents and children, exemplified by Kelly's experience:

“The things we were getting from school were quite chaotic… before spring bank we were barraged with things randomly and some people would engage with odd things. After that you were delivered something on a Monday and that would keep you going for the week… although I didn't particularly like the barrage… when you just got it at the beginning of the week it then became a little bit disengaged… and also the things they were set were coming from different teachers so we were getting things from the head teacher, but she was setting things for the whole school, and then we’d get things from someone that was engaged with the children's University, and they were setting things that

were all related to that, which were quite random, and then the teacher was picking up odd things…"

Although primary school pupils would usually have one class teacher, Kelly's account shows this did not necessarily result in communication from only one teacher. The school eventually settled on a system whereby the science work was organised by one teacher, but it remained difficult because the teacher introduced a web platform that she and her daughter were unfamiliar with and struggled to use. Consequently, she felt that her daughter had not engaged with science much. Hence, although web-based platforms were extremely valuable, their value could be diminished if different ones were used concurrently.

In summary, parents' accounts illustrate their experiences included difficulties that were complex, inter-connected, and often unique, reinforcing that there were no typical experiences of lockdown.

6.2.4 What parents learnt to help their children learn science

Just under half the parent sample had had to learn something to help their children learn science, according to survey responses. No difference was discernible between responses from parents of primary or secondary school pupils, nor any clear correspondence between parents' educational background and whether they had had to learn things or not.

A subsequent survey question asked about the nature of parents' learning. This was most commonly connected with subject knowledge, followed by curriculum knowledge. It is noticeable that few parents selected the option about how to teach at home, suggesting they were not thinking about pedagogy; perhaps not surprising given most were not teachers. Figure 33 shows these data.

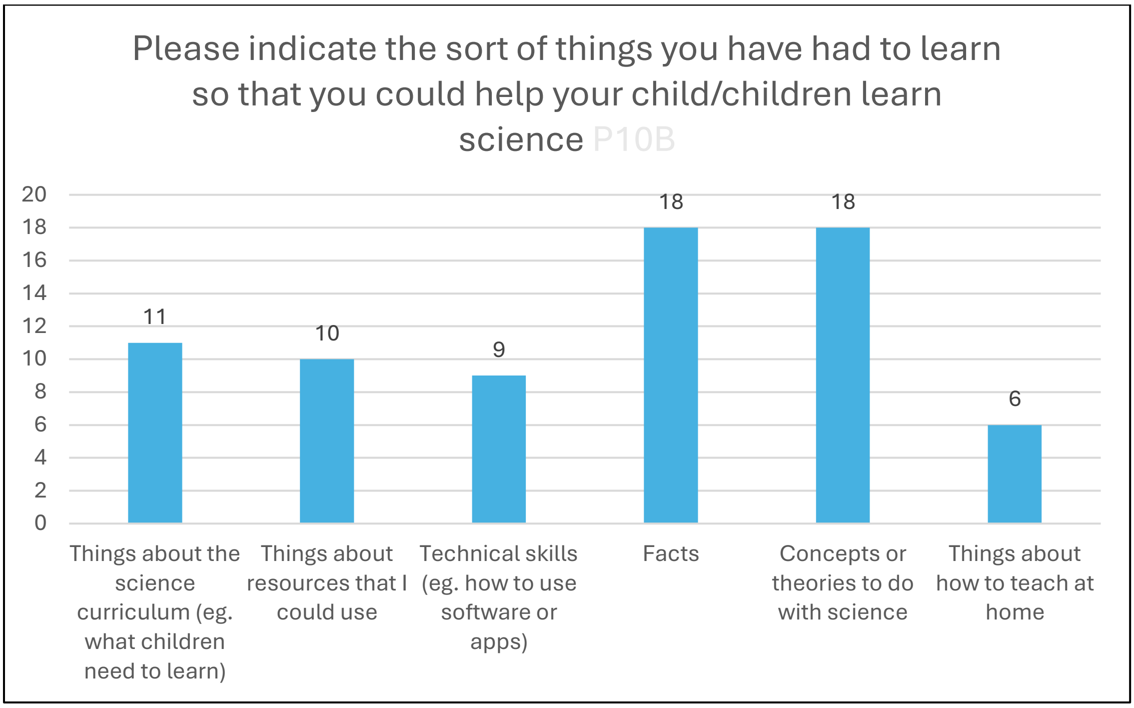


Figure 33: Data showing things parents stated they had to learn to help their children learn science during lockdown. Multiple options could be selected. Columns are labelled with the number of responses for each category. N = 26.

When asked how easy or difficult it had been to learn things to help their children, there was no clear relationship between levels of educational qualifications (either generally or in science or related subjects) and how easy or difficult parents had found the learning they'd undertaken. Two parents stated they had found the learning 'Quite hard', but the majority stated it had either been 'Quite easy' or 'Very easy'. Interest in the subject of science had sustained Jim; it had reminded him of his own education, suggesting some parents may have been motivated because of the opportunity to revisit past educational experiences.

Although survey questions stratify parents' learning through categories, discussions with interviewees present a more nuanced picture in which their learning did not readily align with single categories: instead, categories tended to overlap. As an example, Pat's comments suggest subject knowledge was hard to distinguish from knowledge of the science curriculum:

“I want to try and help him, as does my husband, but we've got to learn what's expected of the curriculum… it's so different, you know, it's a very long time ago and there's so much content, so much content. And obviously we don't have to know it all, but knowing what he needs to know… [my husband] could say “This is really what he needs for underpinning knowledge for chemistry. If he gets this he'll be fine.” With the other stuff, we don't have that knowledge.”

Even with good subject knowledge, Pat could not necessarily judge relevance without accompanying knowledge of the curriculum. Similarly, parents’ thinking about their own knowledge could spill over into reflections of their teaching skills, perceiving subject knowledge as an important pre-requisite for teaching. Hence when Kelly reflected on gaps in her own subject knowledge, she suggested they contributed to her daughter’s lack of trust in her teaching abilities:

“I think it's to do with the fact that we were trying to teach her, and the fact that she knows that we're not teachers, and we don't have this knowledge and we’re looking it up. So I think probably it was a lack of trust …in my ability to teach.”

Jim expressed similar thoughts. He had tried to foster his children’s natural curiosity by letting them bring up scientific topics of conversation themselves, which they had done informally while out walking. However, he suggested the way his children related to him and his wife, perhaps because they were parents, was different to other people:

“I think we are not experts at getting them to learn. They get round us more than they would with a teacher. I've always noticed, before, they'll always listen to

strangers a lot more than they do to us - well not strangers but people that are non-family members."

Jim's and Kelly's comments reflect another aspect of parental learning during lockdown. While there were things that parents had felt consciously compelled to learn, generally reflecting categories in the survey question, and apparent in advance, there were other things they had learnt *because of* their experiences helping their children during lockdown. These things had not been apparent in advance but became so afterwards, either on reflection or when prompted during their interview.

It appears likely that parents learned both consciously, driven by their perception of what their children needed, and unconsciously, through the experience of supporting their children's learning. While survey questions did not target this latter, experiential learning, interview evidence suggests it was valuable and probably assisted parents in subsequent lockdowns.

6.3 Science learning tasks that schools sent home

Of the 42 parents of primary school pupils, 36 stated that their child's school had provided some science during the first lockdown; four stated they had not and two were not sure. Among the 16 parents of secondary school pupils, all stated their children had received some science. These proportions are comparable with teachers' data about the setting of work (see section 4.5). This section discusses parents' experiences of the science learning tasks provided for their children.

6.3.1 How science work was communicated to pupils

Data on how schools made pupils aware of science work are shown in Figure 34.

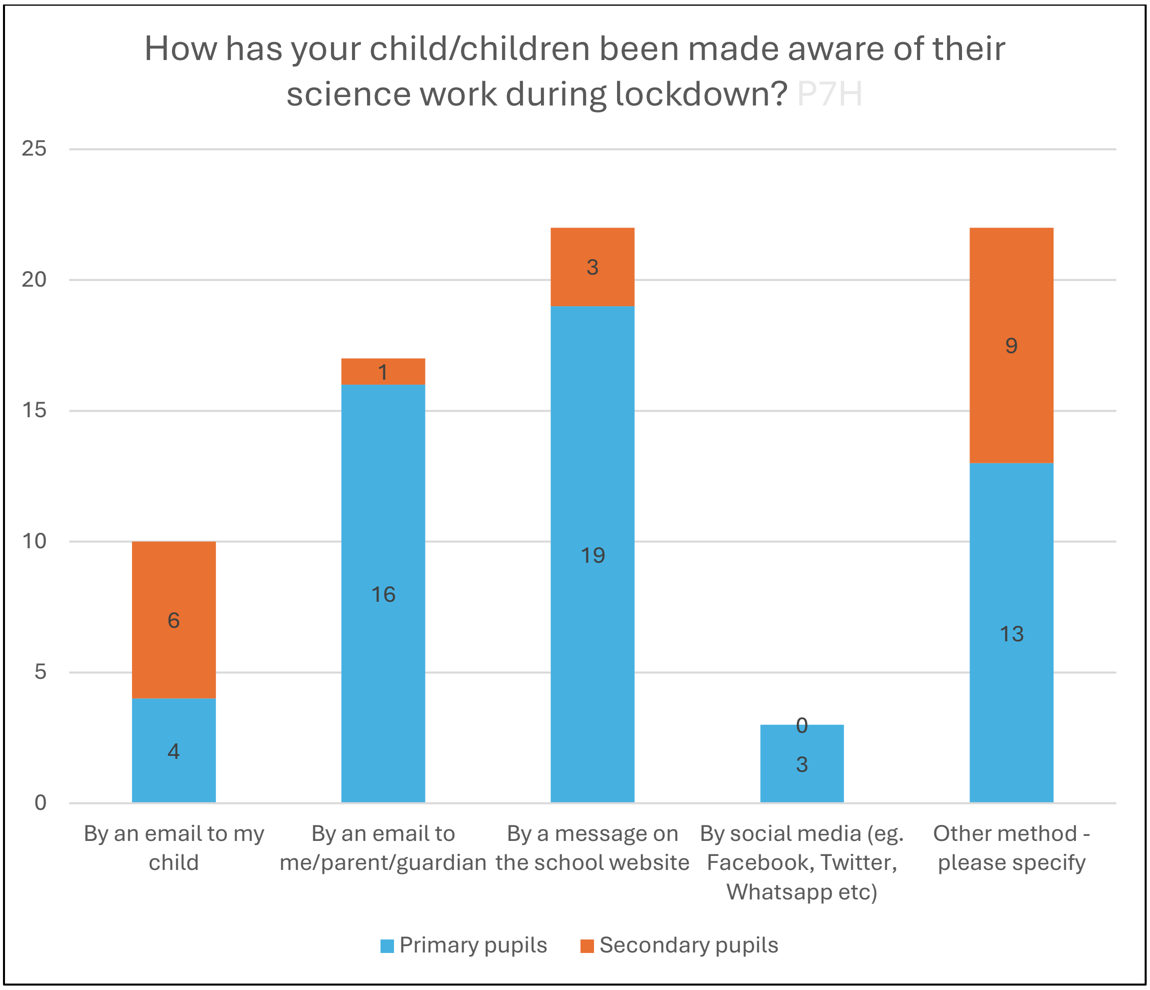


Figure 34: Responses to the question, "How has your child/children been made aware of their science work during lockdown?" Columns are labelled with the raw number of responses received. Multiple options could be selected. N = 57

Most parents selected just one option for this question, suggesting schools used mainly one mode of communication for conveying information to pupils about tasks being set. The data show many schools using email, corresponding with teachers' evidence. Pupils in secondary schools were more likely to be emailed by their science teacher than those in primary schools; in primary schools it was more likely that parents, rather than children, received email. Messages posted on the school website were also commonly used, but much more so by primary schools than secondary schools. Equally as common, overall, was for schools to use other methods, albeit ones which still used the internet. Although survey responses did not suggest schools had used post or telephone for communication about schoolwork, in his interview Kieran described how his older children's secondary school had initially sent out paper packs to all pupils, before changing to electronic communication. Lily also described a slight variation for her children's primary school, which used a hybrid system of physical resources that parents collected, with the same work available online, and extra online links. This suggests that not all schools automatically turned to the internet as their first or only choice for setting work.

Several platforms or apps were specified in the 'Other method' category. Most common were Microsoft Teams, ClassDojo, Seesaw and Show My Homework. While most did not comment on these in the survey, one parent elaborated on how successful they thought the school's adoption of Google Classroom had been for motivating their child to attempt the tasks set. Some interviewees gave detailed accounts of their experience of these apps. Kelly, whose daughter was in year 6 at primary school, described how ClassDojo worked:

"Each child is put into a class, or under a particular teacher, and then that teacher can communicate to the whole class, or the head teacher can communicate to classes, or the whole school. And then parents can email direct to teachers or people within the school, like staff, and from there you get ClassDojo points which added up to certificates."

Kelly explained that all communications came to her, as a parent, because her daughter did not have the app. Managing these messages on behalf of her daughter was challenging alongside Kelly's own work commitments. She occasionally found the app frustrating, especially as messages would rapidly be subsumed as more were added, making it hard to find what she was looking for.

Despite these difficulties she had liked the app and thought it had helped her daughter's learning.

Pat's son was in year 11. His school used a different app, called ClassCharts, which was already in use before lockdown. Pat had the parent version of the app, which enabled her to monitor when her son was responding to the tasks he was being set on the pupil version. She thought that it would have been much harder for the school to have functioned effectively during lockdown without the app; if they'd relied on email, for instance.

Survey data about the methods schools used for communicating about work are broadly consistent with teachers' data: primary teachers most commonly reported putting instructions on the school website, and most sent emails to parents rather than pupils.

6.3.2 Types of science learning tasks set by schools

Most parents in the survey stated that they were aware of the type of science tasks that had been set for their children. Only two, both of primary pupils, stated they did not know this, and nine stated they had a rough idea. The survey question about types of work allowed respondents to select multiple responses, based on several options, as shown in Figure 35.

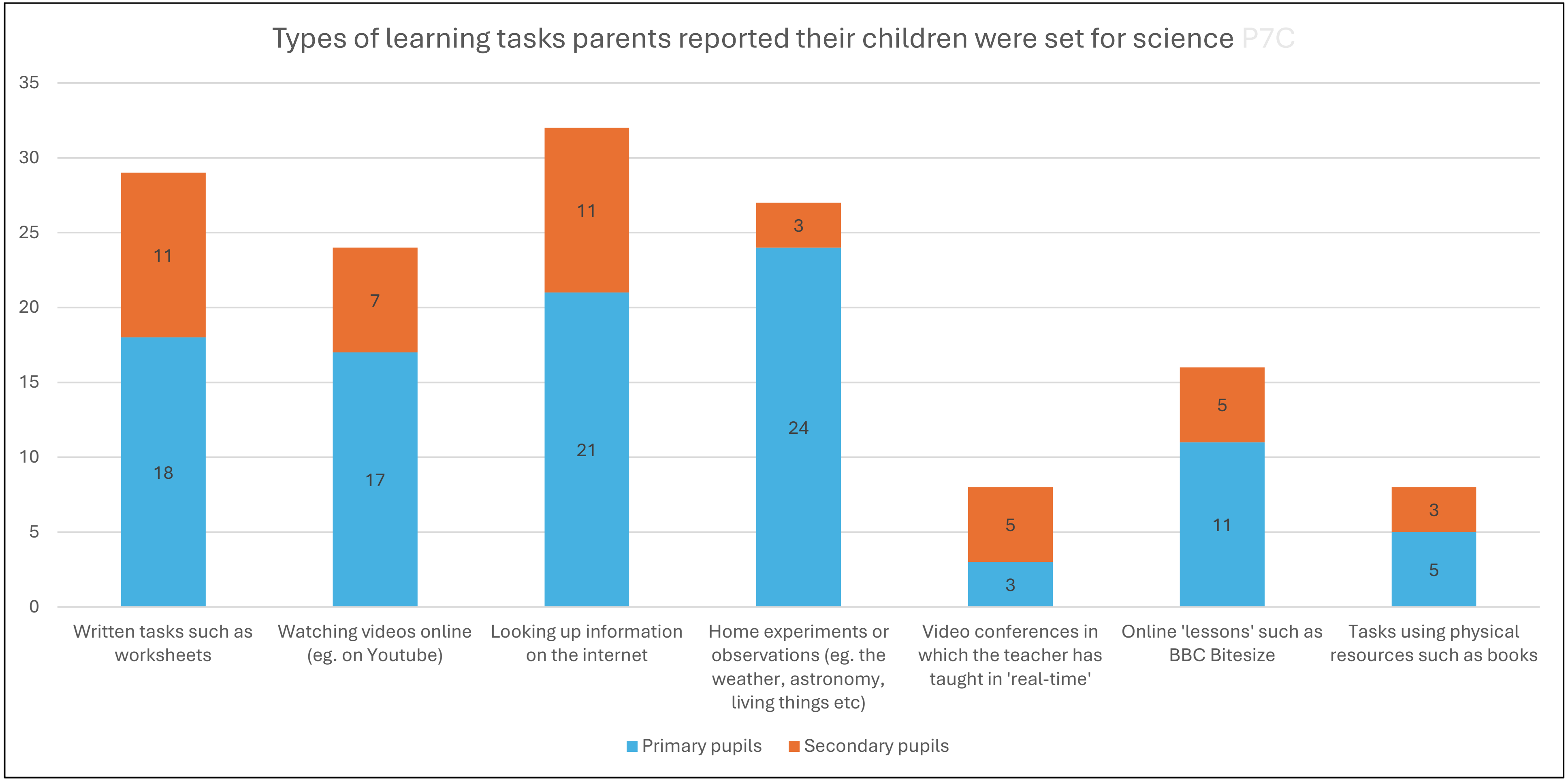


Figure 35: Types of learning tasks parents reported their children were set for science. Columns are labelled with the raw numbers of responses given. Parents could select multiple options. N = 38

These data generally reflect teachers' responses about the type of tasks they set, confirming the low incidence of live remote teaching, and the prevalence of other internet-based activities. Tasks in which pupils used physical resources such as books featured occasionally, but were less common, presumably as teachers had little knowledge about books at home, unless they were issued by school.

Figure 35 shows a noticeable difference in 'hands-on' work, such as home experiments, between primary and secondary pupils. Even accounting for the unequal numbers of parents of primary and secondary pupils in the survey, home experiments or observations of natural phenomena were far more commonly reported by *parents* of primary pupils, despite many secondary *teachers* reporting they had set this type of task. A possible explanation for the discrepancy comes from interview data suggesting younger children needed more attention with schoolwork than older ones, increasing parents' awareness of what they were doing. Dominic described his two younger children needing more help because they struggled learning independently, while parents of older children usually described them working in their own bedrooms or spaces with less supervision or guidance. Hence parents of secondary pupils were conceivably less aware of what their children were doing in their science studies than parents of primary pupils; secondary pupils could have been doing practical tasks that went unnoticed by their parents. However, if this did happen, it also raises the question of how parents knew enough to be able to respond to the other options in the survey question. Existing data are insufficient to account for differences between teachers' and parents' experiences.

Most parents selected multiple options for the types of science learning tasks schools set for their children. Counting the number of types gives a sense of how much variety children experienced in their lockdown science education. These data are shown in Figure 36.

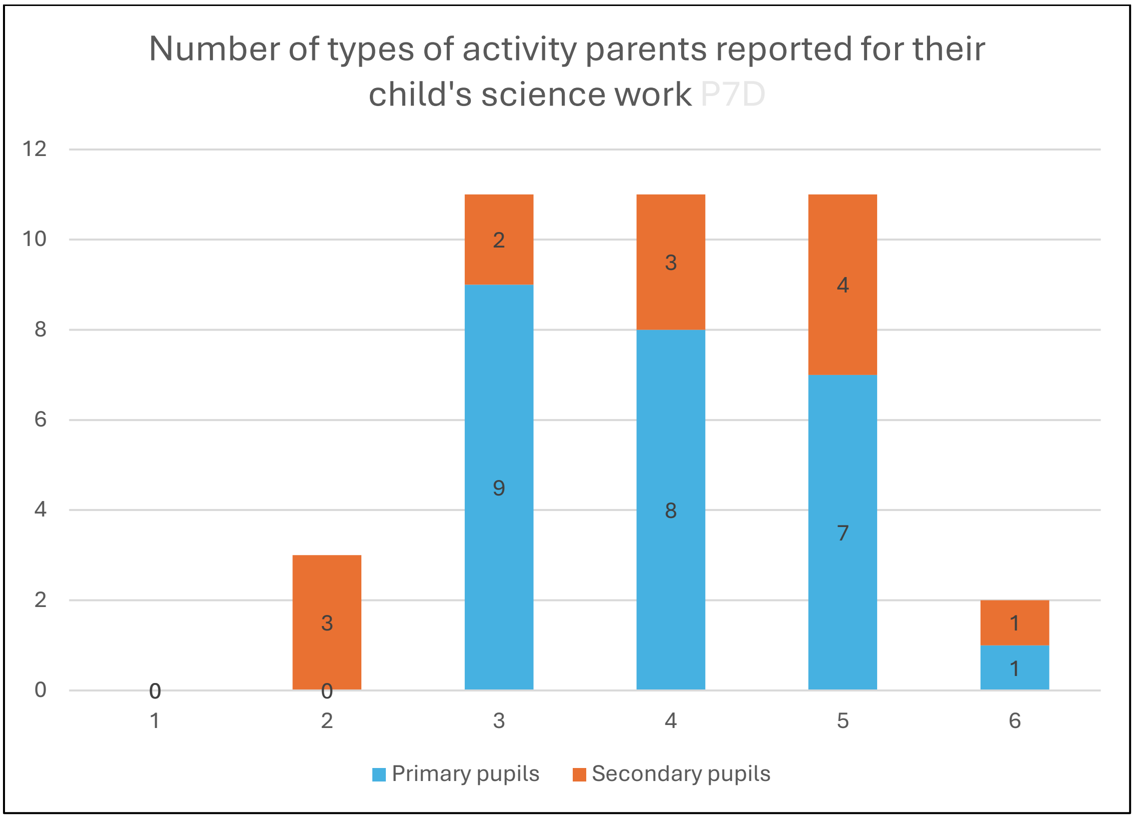


Figure 36: Number of types of activity parents reported for their child's science work. The horizontal axis is the number of activities parents selected in the survey. Columns are labelled with the raw numbers of responses received. N= 38.

Again, there are some similarities to teachers' survey data. Most parents reported their children doing three or more types of task for their science schoolwork. The parents who reported their children engaging in LRT also selected between two and six other activities, reinforcing the conclusion, stated in chapter 5, that LRT was mostly carried out alongside other teaching approaches, or after other approaches had been used first.

6.3.3 Parents' views of the science work schools set

Parents were asked about their views of the school's science work through two questions. The first asked them to indicate which of four statements they agreed with. The data from this question are shown in Figure 37.

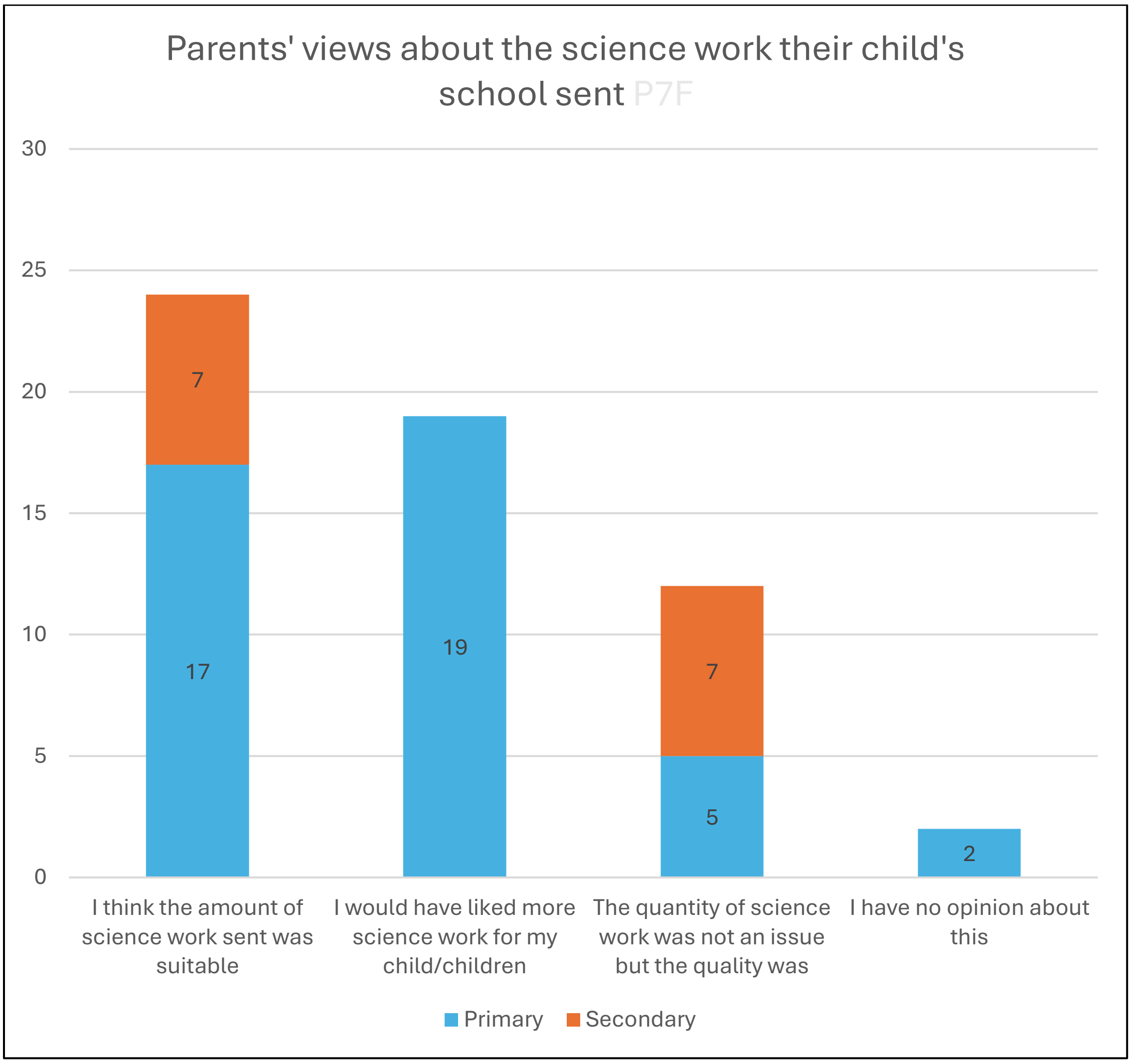


Figure 37: Responses to the question: "Please indicate which of the following statements you agree with about the science work your child/children's school has sent." Columns are labelled with the raw numbers of responses received. N = 57.

These data indicate slightly more dissatisfaction from parents than satisfaction. Most dissatisfaction was about wanting more science work for primary pupils, reflecting primary teachers' evidence about their schools prioritising English and Maths over other subjects. Most of these parents stated their children had *not* expressed an opinion of their science work, or that they were not aware of any opinion; hence the responses were, presumably, not a reiteration of their children’s views. Dominic stated that he would have liked more science, but wasn’t sure how important science was in primary schools. Having children at different primary schools, he could compare each school’s lockdown provision: sometimes he used materials from his daughter’s school to make up for perceived inadequacies in the materials his son was receiving, from a different school.

Overall, 24 parents were satisfied with the quantity of science learning tasks sent, suggesting many schools were meeting expectations in this respect. However, there was a high correspondence between these responses and reports of their children having a positive view of the science work (see section 6.3.4), raising the possibility that these parents had based their views on what their children had told them about their science work.

For the twelve parents who thought quality was more of an issue than quantity, most reported their children had a negative view of the science work from schools. Explaining why quality had been an issue, two parents, both of primary pupils, stated tasks were either *“boring”* or *“lacked challenge”*; another referred to tasks being set for the lowest level of attainment. Kelly speculated that schools’ organisation of science work might have been partly responsible:

“It tended to be set by one person for the school, so I think because they were trying to cover all age groups I think she found some of it …it was a bit young for her … she wasn't really engaged in that respect.”

Kelly thought her daughter had learnt more about science from a television programme than from the tasks set by school. Another parent stated in the survey that science tasks had been uninspiring, with children required simply to copy notes from a PowerPoint presentation into their exercise books. One suggested the school needed to use LRT – this is discussed further in section 6.3.3.1. Others referred to a lack of structure, with children left to self-regulate their completion of worksheets and online quizzes, and watch videos.

Despite most parents expressing some degree of dissatisfaction about science tasks, it was unusual for them to contact school about this during lockdown. Of the 31 who had expressed dissatisfaction, only four had contacted their child's school, and most were satisfied with the promptness and content of the school's response, suggesting these schools had dealt with queries effectively. Some interviewees specifically said they were aware of the difficulties schools were facing in lockdown, and did not want to make this any worse by making negative comments. Pat appreciated that although there were some limitations in what her son's school had done, the schools of her friends' children had provided less support for pupils. Dominic was satisfied with all his daughter's subjects except science. He was reluctant to be critical, therefore:

"I think maybe if there was one criticism it would be lack of science. We have been asked to complete a survey from my daughter's school about what we thought of the home schooling, but to be honest I didn't want to put any of those points down about the science because I really didn't want to criticise what they'd actually done."

Kelly expressed a similar sentiment:

"I was mindful that they were coping the best they could …and I was grateful they were sending things… so although I felt it was a bit chaotic and not enough

…I didn't really want to pull them up on it. They were doing a good job …I didn't want to say they weren't doing a good job.”

The second question about parents’ views asked them to rank the activities they had chosen, that formed the basis of Figure 35. Ranking allowed them to indicate how important they thought activities had been in helping their children learn science. Although quantitative analysis was limited by unequal numbers selecting each type of activity, some trends are suggested by the data. It should be emphasised these data reflect parents’ *opinions* only: firm conclusions cannot be drawn about how effective any activities were in helping pupils learn. Some of the more salient points from this analysis are discussed in conjunction with interview data in the four sub-sections that follow. Reference to relative rankings is to show whether activities were, on average, deemed more or less useful than others; rankings do not represent a scale.

6.3.3.1 Live remote teaching (LRT)

Although only eight parents selected the option of LRT, five ranked it in first position (most important for learning), representing a higher proportion in first position than any other activity. Conceivably, had more children experienced it, data might have shown more conclusively that LRT was the most highly valued activity of those listed. Kelly thought LRT would have been *“of most benefit”* to her children, had they experienced it, and Lily thought it would have helped keep her children more focused.

Kieran’s older children, who attended secondary school, started using LRT after the Easter holiday. They had participated with cameras switched off and microphones muted, interacting solely through the chat stream. This reflects evidence from secondary teachers who reported reluctance for pupils to speak or have cameras switched on. Despite this reluctance, however, he described how LRT had improved his daughter's motivation during lockdown. She had previously struggled to work independently with no direct teacher contact. His two younger children, both at primary school, had had a 'French club' lesson conducted via Zoom. In contrast, they had few inhibitions about interacting and having the camera on. Kieran described how the primary teacher gave the pupils time at the end of the session to talk with friends. He thought this had been a good idea as they would otherwise have had little social contact.

Karen thought LRT would have benefited her autistic daughter:

"There was very little chasing or contact from the school at all. I think I had one call from her form tutor, and then it was only through me contacting the SENCO and saying …my concerns…so everything was driven by me rather than by them, and I think it would have really helped her having some face-to-face teaching… maybe they did for some of the older students but not for her year group."

Participating in LRT required a reliable and fast internet connection. Parents whose children experienced LRT did not report significant impacts on the LRT because of internet issues, suggesting it could have been more widely used without such problems.

6.3.3.2 Home experiments

Of the four types of activity that were selected by most parents (written tasks, looking things up on the internet, watching videos online, and home experiments – see Figure 37), home experiments were ranked most favourably. Thirteen of the 27 parents selecting this option judged it to have been most important for their children's learning. However, despite this degree of consensus there was more variation in how parents had ranked it than the other three most selected activities. Six parents, for example, placed it lowest of all the activities they had chosen: while viewed favourably by many, it clearly split opinion. Interviewees discussed it enthusiastically, although examples that they gave were often ones that they themselves had initiated with their children, rather than what school had provided. Kieran acknowledged that the practical things he had done with his younger children had no connection to the school curriculum:

"Just experimenting or mucking about, or what you can do, you know, from home, that's science and really interesting for kids."

Examples Kieran gave were like practical activities children might do at school, and some were inspired by things he had seen on the internet. Only Dominic described a science practical activity his children had carried out that had been specifically recommended by school. This was a procedure to mix vinegar and bicarbonate of soda. However, this had been done in the context of volcanoes, and Dominic felt that the learning was more aligned to geography than science.

Examples of 'home-grown' practical procedures described during interviews illustrate how parents were inspired to use their own initiative to facilitate their children's learning. Lily, whose children attended primary school, described how she had ordered some caterpillars from a supplier on the internet, which had then formed the basis of some observational work:

"What I've tried to do is get the older one to keep a log, like a science log, but that didn't last very long. But even just that idea that this is what we do in

science when we observe, you know, you write it down and see little changes about, you know, they're getting bigger, or they've gone quiet now or whatever."

Jim and his wife had also ordered materials over the internet for their children to do some simple home experiments:

"We grew some crystals… Amazon was a Godsend, getting things through there. And we did making an egg so we put it in with white vinegar so it became like a bouncy egg. We made like a bug hotel down at the bottom of the garden, and we'd try to get them out in the sunshine as much as possible really."

Karen also described specific practical science she had done with her daughter, again initiated by her rather than the school:

"Some of the best science stuff that we did when she was at home was because we found an old microscope…They had an online microscope with online slides, which was really good, but it's not the same as actually trying to make up a slide yourself and then, you know, looking down that lens."

Although microscope procedures had replicated what would typically be carried out in school, such as scraping of mouth cells and looking at onion skin, having the instrument at home had allowed interest to be cultivated further, for example by looking at a dead insect from the garden. Reflecting how unusual it was for a child to use a microscope at home, Karen described her family as *"a techie household"* and she felt reasonably confident helping her daughter learn science. She helped her daughter build circuit boards, and her data suggest she was interested in supplementing the school curriculum, going as far as sex education. Lily was less confident, but her comments suggest she was personally engaged by practical learning, possibly because it offered more tangible connections with subject material than other activities, and placed her in more of a teaching role:

“I said, “Right, let’s try and spot how many primary colours we can see on our walk,” and then … we’d spot green and say, “Right, what's green a mix of?” and I would never have thought of doing anything like that. I would never have thought about how that links into to other things, you know, and really emphasising that this is, like, physics.”

Overall, evidence suggests that although practical work was highly regarded as a learning activity, parents’ views were influenced by more than tasks schools provided – if these were used. It is possible that increased parental involvement, both in initiating tasks and joining in with their children, created an impression that these activities constituted greater learning value. More evidence of actual learning would be needed.

6.3.3.3 Looking things up on the internet and structured online lessons

‘Looking things up on the internet’, a description intended to capture less structured searching for information on specified or unspecified websites, was not highly rated by parents, on average. Interviews suggest this activity featured mainly when schools gave less structured guidance, instructing parents to do what they could. A range of views were expressed, however, with some positive opinions. Lily had rated this activity as most useful, because it required her to be present, providing more guidance than, for example, watching videos:

“If it's looking up things on the internet, I was always there so it was a lot more collaborative. If it's looking at things on YouTube, and I'm thinking about just leaving them to their own devices, then…they would have had five minutes of it and then just been tempted to go and look at …whatever… that whole thing

about YouTube is … in their minds it's not a learning place, it's an entertaining place. So I think they would have just kind of drifted off, whereas if you're looking at things on the internet it's a bit more; it just feels a bit more structured, or a bit more formal."

More structured online 'lessons', intended for independent learning, were less commonly experienced but viewed more favourably on average than simply looking things up on the internet. Websites such as BBC Bitesize (BBC, n.d.) enabled children to follow carefully designed learning materials at their own pace. They were ranked third most useful, on average, for helping children learn science. The government's Oak National Academy website (*Oak National Academy,* n.d.), set up in April 2020 to support children's remote learning during lockdown, was not mentioned by many parents, suggesting it was not widely known, or used, at the time of the survey. Kelly had heard about it in the press, and described how she thought it had been good, but her daughter had struggled with it:

"They'd start at the beginning of the week, let's say maths for example, and then you had to do each one each day because it followed on, so that was quite difficult… she didn't always want to do it every day, so we didn't consistently go to it. So then when we did go back to it she'd be picking and choosing bits …but then she'd be, "Well I've missed that first one; I don't understand it," so then she'd sort of disengage with it because she couldn't follow it properly… I think if we'd have done it every day it would have been consistently good for her, but we were just dipping in."

Kelly's evidence suggests that her daughter's school had not identified a coherent approach because of several possibilities on offer, with Oak National Academy being just one. She thought this had been confusing.

Lily's 9-year-old son had used Oak National Academy, but became bored because he was by himself and needed extra stimulation:

"We started off with Oak Academy because it was really structured for different lessons, and they are developed, and he could watch it on his own, but he got so bored on his own…he needed that extra stimulation."

Lily's evidence highlights that despite the quality of online materials, younger children's attention was harder to sustain for longer periods because human interaction was needed. For parents working from home this could be difficult and, as discussed in section 6.2.3.2, this had caused some to experience stress. Dominic described how his 8-year-old son had benefited from the reassurance of his presence:

"He needed a lot more attention. So he was struggling until I sat next to him, but when I was sat next to him he wasn't struggling… I think he just wanted that handrail so to speak."

Evidence relating to activities described here reflects the important of structure to remote learning. For primary school children, looking things up on the internet could constitute productive learning, but evidence suggests an adult was required to provide focus and direction. More structured online learning, through sites such as BBC Bitesize or Oak National, required less adult intervention but younger children could struggle to maintain attention. Both kinds of activity underline the importance of parents as mediators during remote education.

6.3.3.4 Watching videos

Although ‘watching videos’ could result during ‘looking things up’, discussed in the previous sub-section, it was kept as a separate category to enable analysis that might identify criteria that other activities lacked. It was also kept separate as schools might have set tasks solely involving online videos, as opposed to tasks in which video featured within another internet-based activity. It was rated fourth most helpful to learning science, on average. While some parents had thought it had been most helpful, most ranked it lower than other activities. Interviewees again expressed a range of views. Dominic thought that videos his children had been directed to lacked context for them to learn from. For Karen’s daughter, videos on YouTube were difficult to learn from without additional structure:

“For her, watching something on YouTube is a leisure activity, so you …shouldn't necessarily know how to take notes off a video, for instance. I think that's quite a skill…[if] some of the online stuff was quite specific then it went well. Generally, if she was watching a video she'd not really pay that much attention, whereas if she had to answer some questions or even… do a graph …she’d do that well.”

Karen’s daughter was also critical of YouTube videos if they did not have a high production quality, and tended to prefer television programmes. Television programmes featured in some children’s lockdown science diet; Jim’s children’s school had suggested specific programmes on catch-up platforms such as BBC iPlayer.

Some teachers incorporated their own video content into their science provision. Pat's son's physics teacher had used the asynchronous video messaging tool, 'Loom':

"He put up the PowerPoint sessions, that he would have done… but he had like a little circle in the corner which was him talking, and actually he was a character. I mean, he put silly hats on… For [son's name] to see his teacher, and listen to him, and hear him talking it through made a big difference…he'd come and show it to me."

Pat suggested this approach had influenced her son's relationship with this teacher to improve.

Despite mixed evidence, when it worked well video was perceived to be an effective component of remote learning. While production quality for teacher-made videos was not high, the evidence suggests short videos featuring teachers could be well-received, illustrating their potential for remote education.

The four activity types discussed above reflect varying parental opinions. It is reasonable to conclude that each activity's success depended on its implementation quality. Evidence suggests the subsequent widespread adoption of LRT in later lockdowns was justified and demonstrates how other activities' effectiveness might be optimised. For primary school children, the extent of required parental involvement in some activities is significant and represents an important consideration for future remote education planning.

6.3.4 Children's views of the science work schools set, as reported by parents

The survey also asked parents about their children's opinions of science work sent by their schools. The data from this question are shown in Figure 38.

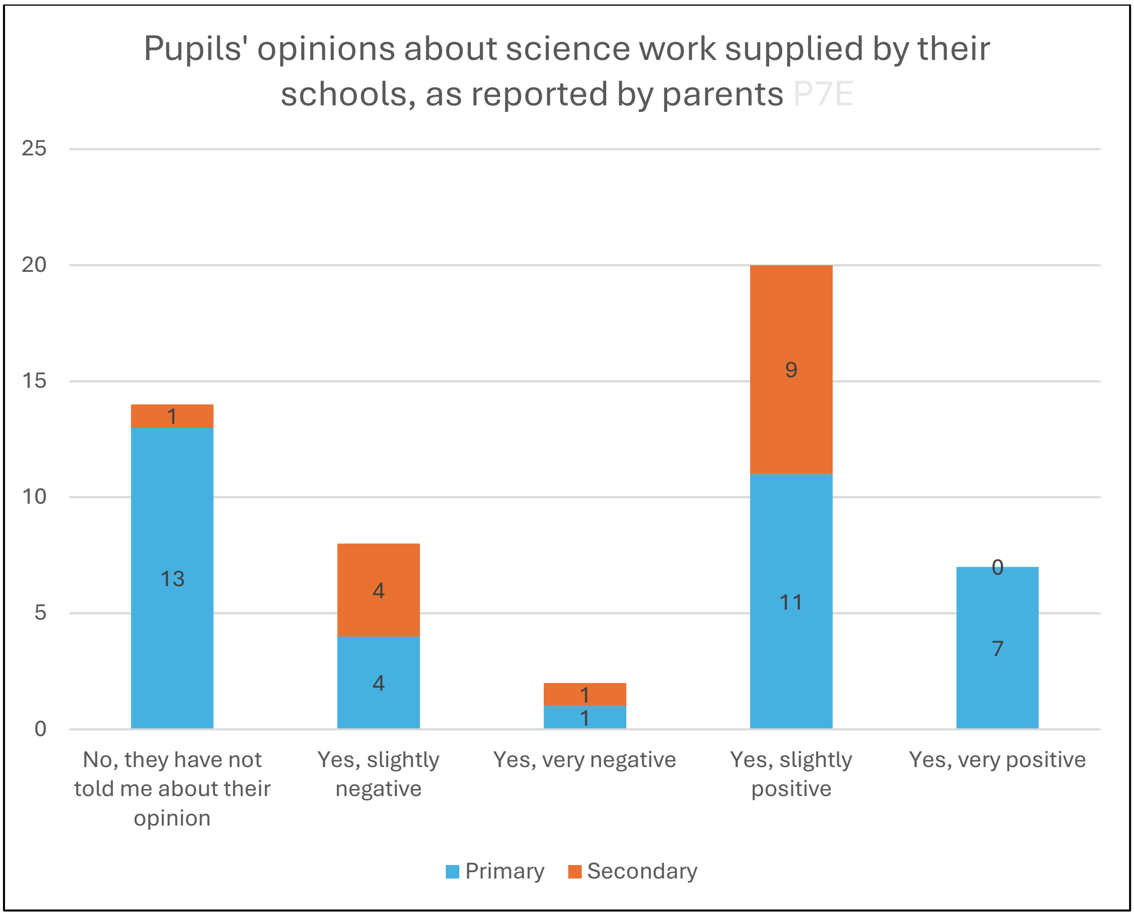


Figure 38: Responses to the question, "Has your child/children expressed any opinion about the science work provided by the school?" Columns are labelled with raw numbers of responses received. N = 51.

Figure 38 shows that most parents reported their children had positive views of science work their schools had sent them: positive opinions outnumber all other responses combined.

Evidence suggests that some pupils had preferred learning science differently, away from classroom settings and in the comfort of their own home. Pat, whose son was in year 11, explained that her son's previous school experience of learning science involved being *"just sat in a classroom writing a lot of stuff".* She thought lockdown had been an improvement for him.

It is not possible to tell whether pupils' views were influenced by a consideration of lockdown; whether, for instance, expectations had been lowered to take account of the straitened circumstances schools were working in. In addition, data do not show how pupils' opinions of lockdown science differed from their views of school science in normal conditions. The positive views are a validation of teachers' efforts during lockdown, but contrast somewhat with views expressed by teachers themselves, who mostly rated their efforts as sub-standard. This contrast is discussed further in section 6.5.

6.3.5 Children learning science without schools providing work

Six parents of primary school pupils indicated their children received no science work from school during lockdown. Most thought their children had learnt some science anyway, and chose several examples from a list of options to describe things they thought had helped, including:

- Observing nature (e.g. life in the garden, the weather etc),
- Doing practical things at home (e.g. cooking, gardening etc),
- Watching TV,
- Looking at books,
- Going for walks outside.

It was commonest for these parents to cite 'observing nature' as the most important factor helping their children to learn about science. None of these parents were interviewed, so any conclusions are highly inferential. Evidence suggests children could learn science with no school provision, but there are no data about the quality of this learning. However, it reinforces the potential for science to be learned away from school, for primary school children at least. Observing nature was probably highly variable, dependent on location and parental influence to draw children's attention to specific phenomena. It was probably also favoured by the time of year, with more opportunities for observing living things during the spring and summer months of the first lockdown.

6.4 Parents' observations of their children during lockdown

This section examines parental responses regarding their children's behaviour during lockdown, including questions specifically related to science education and others of a more general nature.

6.4.1 Changes in children's motivation

Most parents reported their children becoming less motivated to do schoolwork over the course of lockdown. Only three parents, all of primary pupils, reported their children becoming more motivated, while fifteen thought there had been no change. These data are shown in table 9.

	Primary pupils	Secondary pupils
Motivation hasn't really changed	11	4
They have become less motivated	29	11
They have become more motivated	3	0

Table 9: Responses to the question, "How, if at all, has your child's/children's motivation for doing schoolwork changed during lock-down?"

Reasons for children's changing motivation were not explored in the survey, but limited inferences are possible from responses to other questions. One question asked parents whether their children had been looking forward to returning to school. Most who reported decreasing motivation said their children were looking forward to returning to school. By contrast, the three reporting their children became more motivated all stated they had *not* been looking forward to returning to school. This reinforces the suggestion, raised at the end of section

6.3.4, that some children had begun to prefer education in lockdown conditions. One of these parents was Kieran. He explained that he and his wife had decided, because of lockdown, to continue home-educating their two youngest children:

"We were considering moving them, anyway, to a different primary school, and we got to find out about home education…and we kind of got more and more into it and realised …I think we could do this. We could do this ourselves, and especially my daughter… she'd say to her mum, like, "I really enjoy this," or "I've learned so much," or "I really understand this now and I never did before." Kind of gave us that motivation to do it - that we could *do it… it gave us that courage to do it."*

Kieran and his wife's decision had been influenced by their children's views, and by recognising tasks sent by the primary school during lockdown were similar to what they already did, as a family, on weekends and evenings.

Although most interviewees indicated their children's motivation decreasing over lockdown, it was apparent from Jim's account that motivation had fluctuated on a day-by-day basis, and was hard to predict. Unlike in the survey, interviewees could elaborate a range of reasons for their children's declining motivation. These drew on factors associated with the school, with their own actions as parents, and with their children as individuals. Although science was occasionally mentioned, changes in children's motivation were usually attributed to more general causes rather than specific subjects. Karen, for example, thought her daughter's motivation declined because her secondary school had not given much feedback during lockdown:

"She did a load of DT work, for instance… and then she got emails back from the head of department saying, "well done", and that was a real boost. But there was no feedback for maths, no feedback for English, no feedback for science, despite the fact there was an awful lot of work…you are doing all of that work and then getting no feedback…as an adult your motivation would go, let alone an 11 year old."

Karen said she wasn't sure how she would motivate her daughter again in the event of a second lockdown. Pat, on the other hand, thought her son had appreciated what his teachers had done, but had simply grown tired of lockdown:

"I think it was just the monotony - of just getting up, not going anywhere…another week of this, you know, and he did actually talk to me about missing the teachers."

She thought her son's relationships with teachers had changed. He began to recognise teachers he had previously disliked were doing a lot of work, causing his views to change. Kelly described a similar change for her daughter, who was in year 6. She thought it had made her realise how much she liked school, with its routines and boundaries.

As discussed in section 6.2.3, some primary schools limited schoolwork expectations for pupils. Kelly and Lily had both appreciated this had removed pressure for children, but Kelly commented on how it had resulted in her daughter becoming disengaged:

“There was no expectation from the school that your child had to do anything … I think there was more peer pressure actually to do things than there was from the school…so her response to that was, “Well I don't have to do it!””

Kelly’s comments suggest structures and boundaries, ordinarily supplied by school, contributed to her daughter’s motivation under normal conditions.

Evidence about children’s motivation suggests most were missing school in some way by the end of lockdown. Significantly, evidence also suggests children were affected by the way remote education was provided and managed, with communication, feedback, variety and expectations all contributing to their engagement in the process.

6.4.2 How children’s interest in science was affected by pandemic events

A survey question asked parents how they thought their child’s interest in science had been affected by the global pandemic. This aimed to investigate whether the heightened media profile of science and scientists due to the pandemic had influenced children’s interest in scientific subjects. Figure 39 presents these data.

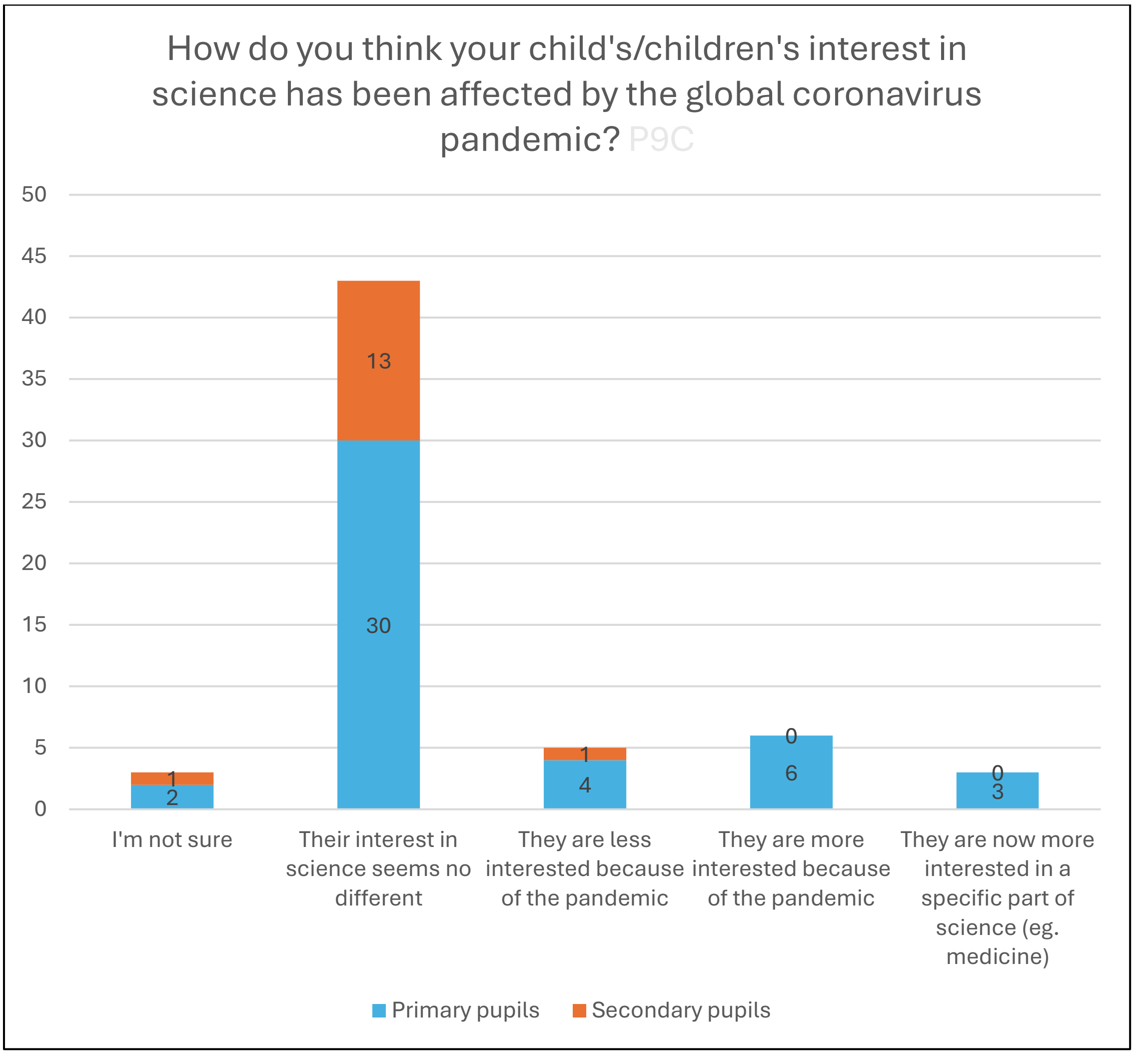


Figure 39: Responses to the question, "How do you think your child's/children's interest in science has been affected by the global coronavirus pandemic?" Columns are labelled with the raw numbers of responses received. Multiple options could be selected. N = 58.

Data in Figure 39 are unambiguous: a large majority of parents thought their children's interest in science was unchanged by the global pandemic. Despite science and scientists being in the media spotlight during lockdown, most children were neither more nor less interested in science as a result; at least not sufficiently to be noticed by their parents. It is not possible to attribute any causes to this, from these data at least. It is conceivable that since most children were of primary school age they had limited exposure to mainstream media and reporting about the pandemic. Although suggestions for pandemic-related activities appeared in science education publications (E.g. Gibbs, 2020b; Harris, 2020; Taylor, 2020), no data were gathered to indicate whether schools had used the pandemic as a teaching context during lockdown.

The children whose parents reported they became more interested were all at primary school. Three reported an increased interest in a specific area of science. One of these was Jim, but during his interview it emerged his children's interest might not have been explicitly influenced by the pandemic but by coincidental events, such as the Space-X rocket launches happening during lockdown. Whether a change in interest had occurred was also uncertain, as Jim stated lockdown had given him more opportunities to discuss things with his children, possibly making him aware of pre-existing interests that had previously escaped his attention. Dominic gave a clearer sense of his children's interest being stimulated by the pandemic itself:

"They'll come across, you know, talking of the pandemic on the television. They'll hear it on the news. If myself, my wife, talking - they'll hear that conversation and then they'll start asking questions. So that's…interested them, and they want to know has this sort of thing happened before, and how bad is it, and, you know, what causes it, is there going to be a treatment for it…Before the pandemic we'd never had a conversation about vaccines…they're a bit more intrigued I think about science."

Dominic's account confirms the plausibility of some children becoming more interested in science specifically because of the pandemic, but evidence suggests that this was not observable in most children at the time of the survey.

6.4.3 Children's worries or depression during lockdown

In the survey parents were asked whether their children had appeared more worried or depressed about anything because of the pandemic. Half of the sample thought they had, and were asked to specify reasons. These data are shown in Figure 40.

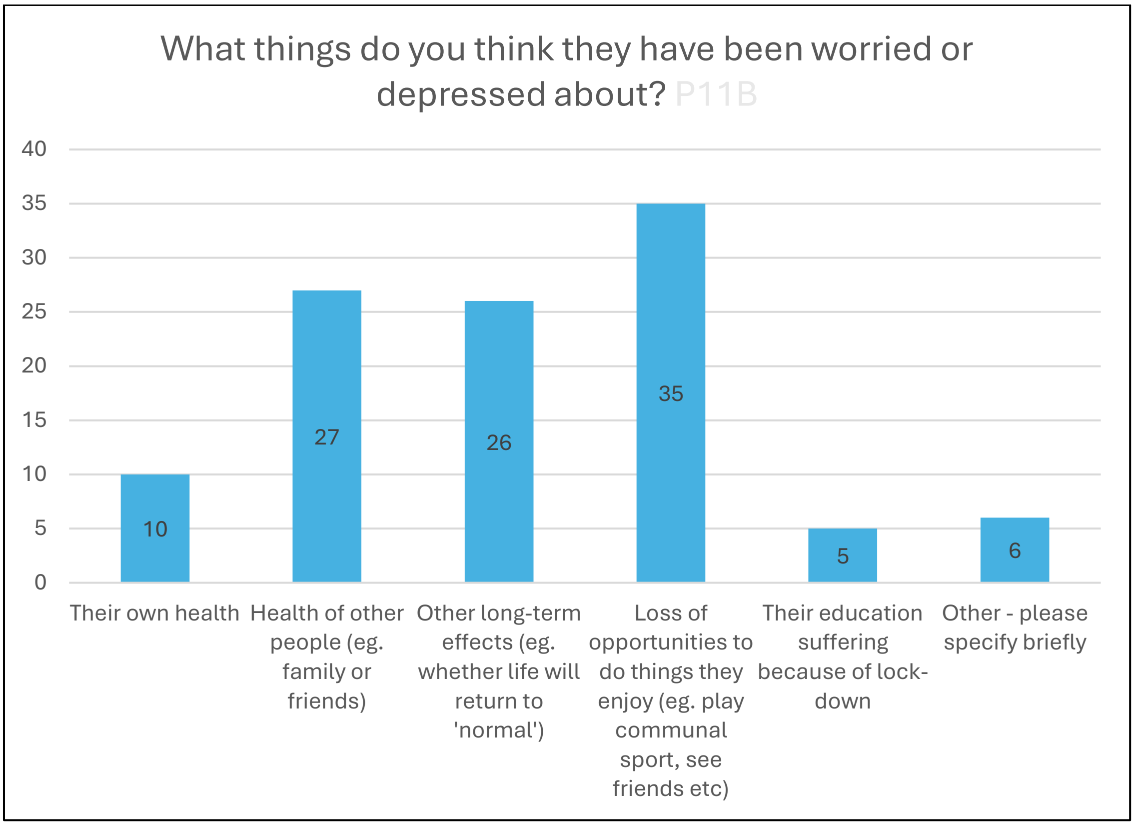


Figure 40: Responses from parents indicating why they thought their children had been more worried or depressed because of the pandemic. Multiple options could be selected. N = 38.

As Figure 40 shows, the commonest reason given for children being worried or depressed was loss of opportunity to do things they enjoyed. Almost all 38 parents selected this option. Second commonest was concerns for other people's health; this was much more common than concerns for their own health, although just over a quarter of parents indicated this too. Least common, from the options available, was that their education would suffer because of lockdown. Although this could suggest children were content with their education during lockdown, data cannot confirm this. Other plausible explanations could have caused the low number of responses for this option, including failure of the question wording to capture other relevant concerns around schoolwork. Dominic, for instance, did not select this option but described his son needing reassurance with science work, suggesting he might have experienced some anxiety about it.

Six parents selecting the ‘Other’ option gave details illustrating the diversity of lockdown experiences. One parent stated that lack of opportunity to travel had been a cause of worry or depression for their child, whilst another stated it had been loneliness, caused by being an only child. One parent, unusually, stated *“Government incompetence”* as a cause of worry or depression; their child was older than 16 so such concerns are conceivable, possibly based on what they perceived in the media. Another parent’s response revealed that their child had received very little from school. They stated:

“They have very much suffered from the lack of normality to their day, their independence and any control in their decisions. School closed and seemingly forgot they existed. Their online Google classroom started up in July.”

As lockdown for schools started in mid-March, this parent’s response implies their child had had little educational input from school for over 3 months.

Amongst interviewees there was a 50:50 split between those stating their children did appear more worried or depressed and those whose children did not. Accounts suggest family circumstances and children’s individual personalities played a significant part. They also suggest parents’ own judgements about their children’s behaviour could vary somewhat. Kelly had indicated her daughter had *not* been worried or depressed, but when asked whether the school's lack of expectations, discussed earlier, had affected her wellbeing, she was quite clear it had:

"Definitely. I mean even, like, at weekends for example, if we've got nothing to focus on she's sort of mooching around the house, and then she doesn't want to do anything…then when we'd get the books out …she really enjoyed it and I could see a difference, and she came alive again, and she was interested and she'd tell me what she'd found… she just needed some sort of consistency and some focus."

Kelly did not attribute her daughter's behaviour to worry or depression, but her comments imply mood changes brought on by aspects of lockdown. A change in the survey question wording might have captured a wider range of children's behavioural changes, therefore.

Pat thought there were several reasons her son had not been noticeably affected. As mentioned in section 6.2.1, he had played computer games regularly. She thought this hobby had enabled some boys to avoid becoming too depressed:

"It seems that the girls have struggled more in the family, because the boys have just sort of carried on if they've got an Xbox in the house. They can chat to their friends, they can communicate, almost carrying on as normal, and almost like "Wahey! We're at home! There's no school! We can spend all day on this!""

She thought her son's anaphylaxis had helped him feel safer during the enforced isolation of lockdown, and mentioned going outside into their garden as a factor in maintaining her son's wellbeing. Kelly also thought the outdoors had had a role in preventing minor anxieties becoming overwhelming for her children:

“We used to go out for walks and things, and we were playing games that we've not played before. I mean there were tensions in the house and that, because obviously you’re all under each other’s feet. So some days were harder than others, but…I don't think we've been too anxious.”

Kelly believed openness in talking as a family had helped her daughters. Similarly, Dominic attributed his children’s wellbeing during lockdown to the reassurances he and his wife gave about the risks of COVID-19:

“We talk about the fact that children are less likely to develop symptoms, or serious symptoms, so they haven't really considered that…When my wife started coughing… in the middle of the lockdown, my daughter did ask a couple of times, “You are okay, mummy, you are okay?” So she was worried, you know, in that respect because she knows …it could potentially have been serious.”

Changes in attitudes to school were another lockdown outcome for some children, manifesting as increased anxiety about returning when lockdown finished. Lily described this in her youngest son, who refused to return, while Karen explained her daughter had wanted to continue being home-educated:

“At one point she did decide that she was never going back to school, and actually this home learning is really good because you don't have to talk to people. So I was in touch with the SENCO of her school… and they organised for her to go in for extra days. So they've got a bit of a better relationship with her now that wouldn't have occurred if it hadn't been for COVID... she now

thinks "I've home schooled before, that's something I can carry on doing," and she seems to think that that's an option."

Survey data and experiences recounted by parents show that while some children experienced worries or depression because of the pandemic or lockdown, others did not. Evidence suggests that although parents knew their children well, in terms of recognising predispositions to worrying or depression, it was difficult to predict how this would be manifested for an individual child as contributory factors varied so much, and were themselves unpredictable.

6.5 Discussion

As in the previous two chapters, this section critically considers key findings and their contribution to the field. Parents' experiences feature far less frequently than experiences of teachers or learners in most educational lockdown literature, even among those sources with a school, rather than HE, focus. Some sources focus solely on parents (e.g. Andrew, Cattan, Costa-Dias et al., 2020; Villadsen et al., 2020); some combine parent and child experiences (e.g. Child Poverty Action Group, 2020); and several combine parent and educator experiences (e.g. Allen et al., 2021; Brink et al., 2020; Lucas et al., 2020). My study is comparable to this latter group, therefore, in terms of its evidence base, but methodologically it is different. Findings in these studies tend to focus on the 'what' of experiences, rather than questions of 'why' and 'how', reflecting a reliance on quantitative data. Unlike in my study, explanatory narratives and diverse detail, from parents' qualitative interviews, are mostly absent.

The following sub-sections discuss how triangulation of parent and teacher data contributes to this study's findings, and how this chapter's evidence both complements and enhances extant literature.

As mentioned in chapter 4, triangulation is possible between teachers' and parents' data, with four distinct outcomes resulting from such comparisons:

- Revealing the degree to which teachers' and parents' experiences correspond, describing a similar picture.
- Showing where evidence from teachers and parents diverges, raising questions.
- Illustrating how teachers' data are complemented and enhanced by insights arising from parents' different perspective.
- Highlighting instances of unique detail supplied by parents that teachers were either unable to give, or were not asked about.

These outcomes are discussed below.

6.5.1 Correspondence between teachers' and parents' evidence

In summary, the main findings representing correspondence between parents' and teachers' evidence are as follows:

- Methods used by teachers to communicate learning tasks to children generally correspond with parents' perceptions.
- The type and variety of learning tasks teachers reported they had set generally correspond with parents' perceptions.
- Proportions of parents reporting their child had received science learning tasks reflect those of teachers reporting the setting of science tasks.
- Primary teachers' accounts of the lower priority of science, compared to English and Maths, correspond with parents' perceptions.
- Parents' perceptions of LRT's effectiveness broadly reflect those of teachers.

Parental and teacher interviews highlight, more than survey responses, that the first three bullet points, relating to science learning tasks, reflect a dynamic, evolving situation. Not only did teachers change the type of tasks they set for pupils over the course of lockdown (by incorporating LRT for example), but in some cases they changed the way they communicated these tasks, reflecting both growing awareness of online education tools and an organic, quasi-experimental approach. Parents' interview evidence, discussed in section 6.3, illustrates how they and their children experienced tasks and communication from schools, and highlights differences in experience between primary and secondary pupils: primary pupils appear to have received less structured science tasks than secondary pupils. Coupled with the greater levels of adult supervision required for younger children, this led to more parental involvement for primary pupils' remote science education than for secondary pupils. This reflects evidence from primary teachers who describe struggling to maintain meaningful remote learning tasks in science over the duration of lockdown (see section 4.3.3).

In terms of the priority of science compared to English and Maths, this reflects a pre-existing and longstanding situation reported in literature (Harlen & Holroyd, 1997; Jarvis & Pell, 2004; Murphy et al., 2007). The suggestion by some teachers (see section 4.4.2) that parents themselves held English and maths in higher regard than science is not substantiated by parents' evidence; no parents explicitly stated this, and some parents specifically expressed the view that science was a high priority.

Although literature has no direct evidence about learning gains from different online education methods during lockdown, the large-scale exploratory study by

Allen (2021) reports most parents favouring LRT over other online teaching methods. In my study, parents who experienced LRT were a minority of the sample, like teachers. As discussed in section 6.3.3.1, this online education method scored noticeably higher than other online methods when parents ranked its effectiveness for their child's learning, though the number of parents was small (8), roughly 20% of the sample who responded to the question. Consequently, as most parents did not experience LRT, it is not possible to categorically state that parents preferred this approach over others. The finding does resonate with Allen (2021), however, whose large-scale exploratory study finds parents preferring LRT to other online methods, and lends some justification to the views of teachers who thought LRT should have been started earlier (section 5.3.4) or those parents stating they would have welcomed more LRT. While teachers were not directly asked to rank the teaching effectiveness of different online approaches, evidence suggests most who used LRT thought it was more effective than alternatives they had used (see section 5.4.4).

6.5.2 Divergence between teachers' and parents' evidence

Two instances of divergence between teachers' and parents' data are noteworthy, one relating to evaluations of science education quality during lockdown, and the other regarding the provision of home practical tasks.

Findings discussed in chapter 4 (section 4.4.1) illustrate that most teachers thought the quality of teaching they had provided during lockdown had been worse than their normal lesson quality, with a substantial number considering it 'a lot worse'. Parents' reports of the views their children had expressed about their remote science education were predominantly positive, however. Given that teachers and pupils were in different places, under different conditions, usually with limited direct contact, differing perceptions might be expected to some degree. However, such a contrast is suggestive of some other influencing factor. As discussed in chapter 4, teachers expressing more positive views were more likely to have received feedback about their work, for example from parents or pupils. With evidence in chapter 5 showing teachers who used LRT judged the quality of their educational provision more favourably, it is plausible that LRT provided a more tangible sense that remote education experiences were comparable to normal schooling than other online methods where no real-time contact with pupils occurred. This combined evidence from teachers and parents suggests that most teachers were probably judging their efforts too harshly, and that learning-focused contact between teachers and pupils or their parents helped those teachers who received it to moderate their self-assessment. Given a paucity of literature generally, as well as in relation to lockdown, examining the effect of feedback or real-time contact on teachers' calibration of their teaching effectiveness, this finding has some significance. It is also possible that communication between teachers and pupils, or their parents, boosted teacher morale, affecting their outlook and opinions of their lockdown teaching. A small amount of literature justifies this suggestion (e.g. Hargreaves, 2021; Kim & Asbury, 2020); more commonly, however, literature observes diminished teacher morale due to various lockdown-related causes (e.g. Kraft et al., 2021; Robinson et al., 2023).

Although more than half of primary and secondary teachers said they had provided home-based hands-on science tasks to compensate for the absence of school practical work, with plenty of specific examples being given (see section 4.5.2), parental evidence does not confirm that children performed the practical tasks set by their teachers. Interviews about home-based practical tasks, especially with parents of primary pupils, feature home-grown efforts at the forefront of their recollections, suggesting parents were initiating many practical tasks independently of school. Apart from instances where teachers used practical tasks during LRT, it is only possible to speculate the extent to which the setting of home-based practical tasks by teachers translated into those tasks being carried out. At best, parents' evidence demonstrates that children did perform some practical tasks, and that most parents thought these were beneficial for helping them learn science.

6.5.3 Parental perspective enhancing teachers' evidence

During the first lockdown, when most teaching activity did not involve LRT, teachers had little contact with pupils. Evidence they could share about lockdown science teaching is limited because they could not easily perceive impacts of the tasks they were setting. By being locked down with their children, parents were able to observe effects of remote education that teachers were unable to. Their data has enabled more light to be shed on the limited picture from teachers' evidence alone. Key findings are as follows:

- Parents' evidence constitutes authentic experiences illustrating various ways technology access difficulties were manifested. While teachers had general awareness of likely difficulties at home in terms of access to digital devices or the internet, they lacked accurate knowledge, impairing their ability to set appropriate tasks.
- Teachers who set asynchronous learning tasks had little control over how pupils would organise their time or attempt the tasks. Parents' evidence illustrates how they contributed to the organisation of their children's

remote education through daily routines, and the difficulties ensuing from juggling this with their own work commitments.

- Parents' evidence reveals impacts of the methods and instructions teachers provided for remote science education, showing how parents provided compensatory support when children were struggling. It illustrates benefits and drawbacks of online platforms, and the value of parents' own teaching and supervision, for primary school pupils especially.
- As discussed in section 6.5.2, parents' evidence gives a more detailed picture of home-based practical work by providing actual examples of hands-on tasks that were performed, and revealing that in many cases these were initiated by parents.
- Parents of primary school children, especially, contributed to their science learning in various deliberate ways (including practical tasks), supplementing and extending the tasks provided by school. Their evidence highlights how valuable parental input was.

Parents' evidence about struggles to provide adequate technology access for their children's remote learning feeds into the wider issue of inequality in remote learning during lockdown (Goudeau et al., 2021; Liu, 2021; Winter et al., 2021). Although educational background data about the parent sample in this study suggest the likelihood of lower levels of social deprivation than across the whole parent population, qualitative accounts illustrate that technology access caused issues for these families too. While demonstrating that the minutiae of home circumstances would have been beyond reasonable expectations of teachers' capacities to cater for (for example, teachers could not be expected to predict how parents' own computer access needs might limit their children's remote learning), parents' evidence reinforces that teachers and their schools lacked accurate knowledge about things such as what device an individual child might be using to participate in remote learning, whether it was shared, and whether homes had Wi-Fi. This reflects the evidence discussed in section 4.2.3. Teachers were aware of the *likelihood* of these issues, but lacked specific knowledge of which children would be affected, and how. They invariably became aware of specific cases only after issues had come to light. In view of a shortage of research into this issue as a barrier to effective remote learning, this finding is significant.

Evidence about parents providing routines for children during lockdown is a prime example of how the parental perspective fills gaps in the picture of lockdown science education provided by teachers, compensating for what teachers were unable to provide information about. In the period when most schools were not using LRT to provide remote education, and children had to learn much more independently, parental evidence is especially valuable. Most literature about parents' experiences of education during lockdown is based on quantitative data from large-scale surveys (e.g. Andrew, Cattan, Costa-Dias et al., 2020; Bonal & González, 2020). Consequently, these sources predominantly focus on issues like time spent on remote education, educational activities and resources, and analysis according to social class. The smaller number of qualitative studies (e.g. Kallitsoglou & Topalli, 2024; Khan, 2022; Shum et al., 2023) better reflect the experiential accounts of parents in my study: descriptions of stress, juggling roles, conflict and trying to establish routines which are elaborated in this chapter all align with these studies.

My data are insufficient to confirm the consistent finding from literature demonstrating that mothers bore the primary burden of educational assistance during lockdown (Dunatchik et al., 2021; Khan, 2022; Petts et al., 2021), but they do point to another possibility. This is that parents who were themselves teachers were, by experience, better equipped to instigate routines and apply pedagogical skill to help their children with learning during lockdown. Not being a line of enquiry that was pursued, more data would be required for confirmation, but this would be valuable: this is an under-researched area, with no literature.

As a proxy for children's experiences of online education (discussed in section 3.5.2.2), parents' evidence is valuable for understanding how online education worked in practice, from the learner perspective. Where they had children of different ages, some parents were aware of their youngest child's greater needs, reflecting literature identifying developmental differences that afforded older children more autonomy and self-regulation (e.g. Gehrer et al., 2022; Rousoulioti et al., 2022; Zaccoletti et al., 2020). However, as already mentioned above (section 6.5.1), children at primary school often received less structured science tasks than secondary school children, adding a further difficulty for them and compounding the burden on parents. This may explain why the more detailed examples of science assistance parents gave in interviews tended to be from parents of primary rather than secondary school pupils. Primary school pupils were doubly disadvantaged: not only were they developmentally less suited to independent learning, but they also received less guidance about science from their teachers, requiring more input from parents as a result. Using data from this study, it is not possible to confirm whether the science guidance primary school teachers provided was less structured than that they provided for other subjects, but limited literature supports this possibility, particularly in comparison with English and Maths (e.g. Derby, 2022).

Parents in this study expressed positive views about online platforms, resonating with Lucas et al. (2020) who suggest pupils were more engaged in schools using a VLE as the means of communicating learning tasks. However, evidence discussed in section 6.2.3 provides additional detail that suggests using online platforms such as VLEs was not, in itself, sufficient for children to be successfully engaged with learning tasks. As well as performing online functions effectively, platforms had to reflect pedagogical principles such as clear and consistent communication from teachers. Relatively simple oversights could cause problems: a lack of clarity in instructions, uploading of too many tasks at once, children not knowing when to expect tasks, or unfamiliarity with the teacher posting the tasks; all could counteract benefits otherwise inherent in the platform. These points reinforce the need for online learning to be focused predominantly on pedagogy rather than technology (Peimani & Kamalipour, 2021; Rodríguez et al., 2021; Yates et al., 2021).

6.5.4 Evidence unique to parents

Although some of the questions in each survey enquired about similar things, each group's distinctive perspective meant parents and teachers were also asked about different things to each other; a process continued in interviews. Hence, numerous new insights, not possible to obtain from teachers, are apparent from parental evidence. Key findings are as follows:

- Children in both primary and secondary schools maintained informal communications with their friends during lockdown. Sometimes these combined recreational activities, such as online gaming, with discussion of schoolwork. Parents who commented on these communications thought they were beneficial both for their children's education and wellbeing.

- Family dynamics, technology and home logistics featured in parents' accounts of the difficulties they experienced in facilitating remote learning. Causes of difficulties were often idiosyncratic, dependent on each family's unique circumstances.
- Most parents did not find it difficult to help their children with science. When asked what they had had to learn to fulfil this role, most identified subject material or curriculum knowledge, with few mentioning teaching skills. Retrospectively, however, it was clear their experiences had included pedagogical learning, suggesting they had not been aware they lacked pedagogical skills.
- A large majority of parents did not perceive any change in their children's level of interest in science because of the pandemic.

Literature documenting children's informal communication through social media and other electronic means during lockdown identifies benefits of online gaming for maintaining social connections and relieving stress (Nilsson et al., 2022; Widnall et al., 2022; Wiederhold, 2021). However, the use of online gaming as a medium through which children also informally discussed their schoolwork does not feature. The reported instances of this in my study (see section 6.2.1) represent a novel and interesting phenomenon, therefore, though data are limited and more research would be necessary to improve understanding.

Causes of parents' stress and difficulties, such as the conflict between home-schooling and parents' own work priorities reported in section 6.2.3, are reflected in other literature (e.g. Allen et al., 2021; Cambridge Partnership for Education, 2020). Qualitative evidence from interviewees in my study supplements existing research by illustrating the complex manifestation of factors such as family dynamics, technology and the home environment. These factors were often compounded, adding to the diversity of parents' experiences. For example, some parents with more than one child reported the need to keep them separate during remote learning, but this limited the supervision and guidance they could then give each child.

The lack of preparedness for teaching observed in many parents' qualitative evidence in this study is reflected in literature, which also recognises parental stress caused by concerns about the quality of their teaching (Garbe et al., 2020; Nilsson et al., 2022). Literature suggests parents overwhelmingly found it difficult to help their children with remote learning (Garbe et al., 2020; Misirli & Ergulec, 2021), but this contrasts markedly with quantitative data in my study (see section 6.2.4), in which most parents stated it had been either 'very easy' or 'quite easy' to help their children with science learning. This is additionally unusual, given over half the sample had no higher academic qualification in science than GCSE. As most were responding to the survey in their capacity as parents of primary school pupils, it is possible the lower demands primary schools generally placed on pupils for remote science learning alleviated demands on parents, or that the cognitive demand of the science was relatively low. Evidence discussed in section 6.3.3 tends to suggest, however, that lack of clear school guidance could be a source of frustration for parents, potentially placing a greater burden on them to compensate. Hence, it is possible that being asked specifically about science invoked some other factors in parents' assessment of the ease or difficulty of their experiences; comparisons to other school subjects which had caused them or their children more difficulty, for example. Qualitative evidence demonstrates several parents being motivated by their children's science learning, buying equipment online for carrying out practical tasks, for instance. The possibility that their perception of difficulty was influenced by their own personal fulfilment and enjoyment from participating in science activities cannot be ruled out.

Further insights into parents' teaching preparedness and skills are observable from comparing quantitative evidence about what parents stated they had had to learn to help their children in science, and qualitative reflections about their experiences. In the survey, parents mostly stated they had had to learn facts about science or the curriculum, with few identifying that learning skills for teaching had been necessary. However, reflective comments revealed that their more profound and memorable experiences had been pedagogical in nature, rather than related to the subject of science: recognising how their child related to them in a teaching role, establishing trust, providing motivation and fostering curiosity, for example. These parental insights reflect Bubb and Jones (2020), whose mixed methods study in a Norwegian municipality found that during lockdown parents had gained better understanding of how their children were learning, and their academic strengths and weaknesses. Supplementing this, the evidence in my study demonstrates that despite their experiences demonstrating the importance of pedagogical skills, survey responses suggest parents had not been aware they would need these. This raises the possibility that while most parents had prioritised their subject knowledge learning, they were unaware of the range or nature of other skills involved in teaching. Essentially, they did not know what they did not know. The existing field of literature about parental involvement in children’s education focuses mainly on school-settings (Garbe et al., 2020), involving supervision, encouragement and participation (Castro et al., 2015) rather than pedagogy. The requirements of lockdown stretched parental involvement well beyond its previous scope.

The apparent lack of influence of the COVID-19 pandemic on children’s interest in science is a finding not specifically reported in literature, though some research does investigate science subject interest, mainly in older students. Wu and Teets’s (2021) mixed methods study of students on a university general chemistry course reports a decline in learners’ emotional engagement with their specific course and a lack of interest in chemistry against the backdrop of the pandemic, but these outcomes are attributed more to lockdown conditions than the pandemic itself. Similarly, effects on learners in the mixed methods study of science teachers across US states by Macias et al. (2022) are attributable to effects of lockdown, not the pandemic, even though findings suggest science often engaged learners more readily than other subjects. In contrast, Wester et al.’s (2024) qualitative study of undergraduates across 13 academic institutions finds effects more closely connected to the pandemic, rather than lockdown and remote education. They suggest learners experienced ‘science fatigue’, a phenomenon in which desensitisation or disinterest in science occurred due to the overwhelming volume and complexity of information about the pandemic, for example in media updates. Conversely, Fong (2022), while acknowledging a complex picture, suggests some university students experienced renewed interest in STEM subjects, particularly medicine, by perceiving its value during the pandemic. The findings of Wester et al. (2024) and Fong (2022) confirm the plausibility that the pandemic might have affected how children felt about science, but my research reveals no significant effects at the time of data collection. The use of parental evidence as a proxy for children's experiences represents a potential limitation in this finding, and longer term effects cannot be excluded.

6.5.5 Summary of original findings

While the absence of subject-specific foci in the extant literature about parents' roles during lockdown education lends generic originality to my study, the following list specifies the main original findings, summarised from the previous four sub-sections:

- Science learning tasks set by primary school teachers were less structured than those from secondary school teachers, compounding the disadvantage younger children faced due to their developmental capacities making them less suited to independent learning. Consequently, parents of primary school pupils were required to contribute more time and effort into remote science education than parents of secondary school pupils.
- Parents' reports of their children's views of the quality of remote science education were mostly positive. In conjunction with teachers' evidence, this supports a conclusion that teachers gauged their teaching efforts more harshly than they would normally have done.
- Practical science tasks were enthusiastically embraced by many parents, with some parents of primary school pupils providing activities

themselves, independently of what teachers suggested. Nevertheless, parents' evidence cannot confirm the extent to which practical tasks set by teachers were actually carried out at home.

- Parents' evidence confirms that, though teachers were aware some families would struggle with technology access for online education, they lacked accurate information about the nature of these issues for specific children.
- Parents' accounts of challenges experienced while helping their children learn science during lockdown were predominantly pedagogical, rather than subject based. However, when asked about what they had needed to learn to help their children, responses mostly referred to subject or curriculum knowledge, suggesting they lacked awareness of the need for teaching skills.
- Learning platforms were regarded favourably by most parents who experienced them, but their benefits were undermined if basic pedagogical principles such as clear communication and appropriate timing were not used by schools.

Chapter 7: Conclusions

This chapter initially considers limitations in my research, before presenting a synthesis of the significant findings with associated implications and recommendations for further research or stakeholder action. Finally, it summarises the contribution to knowledge of the study.

7.1 Limitations

Chief limitations of this research are around sampling. While generalising from results was not an aim of the study, it is relevant to acknowledge that the relatively small convenience samples of 139 teachers and 78 parents present a risk for skewing data and introducing bias into conclusions, compared to carefully controlled representative samples. As has been discussed in chapter 3, the primary-secondary split was not even in either sample, with the teacher sample comprising an excess of secondary perspectives, and the parent sample an excess of primary perspectives. While this imbalance has potentially limited some comparative analyses, it has proved fortuitous in other ways: as data in my study have shown, secondary teachers were more active in the various methods of science teaching during lockdown than were primary teachers, who focused efforts more on English and maths. Hence, it is arguable that secondary teachers were able to supply a greater quantity of data relevant to the study's aims than primary teachers. Similarly, my data suggest the converse to be the case for parents: it was mostly the case that parents of primary school pupils were more involved in their children's remote science education, and hence they were arguably able to provide detail more relevant to the study than parents of secondary school pupils. The biases in the composition of each sample were more favourable to the study's aims, therefore, than if they had been reversed, with more primary teachers and more secondary parents.

While the teacher sample showed variation across several criteria (e.g. age, teaching experience, inspection rating of school etc) that may have given some appearance of representativeness, for parents their average level of education placed the sample well above that of their respective population. A broader sample could therefore have captured a wider range of experiences, including parents who found providing educational assistance more challenging. This reflects some of the difficulties in recruitment of parents, compared to teachers.

The study design imposed some limitations which reflect the conditions of the first Covid lockdown. While lockdown travel restrictions and social distancing requirements limited data collection methods to online approaches, this only affected the interview process (surveys would still have been conducted online) and in view of literature about the benefits of online interviewing (e.g. Gray et al., 2020), differences in data quality compared to face-to-face interviewing were probably minimal. However, the imperative to collect data while teachers and parents remained in lockdown, or retained fresh memories of events, were limiting conditions. Removing this time restriction could have facilitated a longer period of recruitment, improving sample diversity and generating richer data. More control of samples could have achieved a higher degree of data triangulation by recruitment that focused on participants having the same schools in common. This would have been hard to achieve under lockdown conditions and given the time constraints mentioned. Pupils' evidence could have been added to provide a third perspective. While the pupil perspective is largely absent from my study, some parental evidence is proxy data on behalf of their children – questions about what their children were concerned about, or their motivation, for instance. As has been discussed in chapter 3, while this is itself a limitation, literature about parental proxy data in education (e.g. Wittrock et al., 2017) would suggest parents in my study probably provided more accurate proxy data than a sample with lower levels of education.

Like any research, this study is also inherently constrained by the ontological and epistemological limitations of its methods. Though steps have been taken to reduce ambiguity in data, for example by careful wording of questions, conclusions are inevitably dependent on some assumptions. It is assumed that participants have understood questions as I have intended, and have responded honestly, for instance. Due to the methods used, data are inevitably subjective interpretations, made at specific times and places. As the product of a single researcher, there is always potential for researcher positionality to exert undue influence, skewing interpretations and conclusions. This has been approached, throughout, by a reflexive orientation to research activities, and an iterative process of checking by supervisors.

Wherever possible, steps have been taken to ensure limitations such as those described above have not affected the trustworthiness of this research. Conclusions have not been generalised, avoiding any implication of applicability beyond the samples of participants involved. In recognition of methodological limitations, they are intended as tentative suggestions justifiable by arguments based on available data, rather than definitive statements of discovered ‘fact’. Reasonable doubts or alternative interpretations have been stated where appropriate.

7.2 Summary of research findings, implications and recommendations

Each data chapter, 4-6, has critically considered how evidence generated reflects similar findings in other literature, and has added to this body of knowledge through novel findings or enhanced detail. Overall, this study provides comprehensive evidence of how, with no contingency planning, processes of science education for schoolchildren were disrupted by a major emergency, and how teachers and parents responded. Implications are raised both by the challenges experienced and through the potential for new practices to be incorporated into mainstream teaching. These points are developed in the following sub-sections. Distilled from chapters 4-6, the key findings that follow have been prioritised by considering their potential for generating important and actionable recommendations. While it is recognised that any judgement of importance is subjective, the legitimacy and accountability of the recommendations is strengthened by their derivation from accounts of lived experiences (Sandhu, 2017). Each sub-section uses a headline statement as a descriptive heading prefacing more detailed discussion. Figure 41 presents an overview of these syntheses of findings, implications and recommendations.

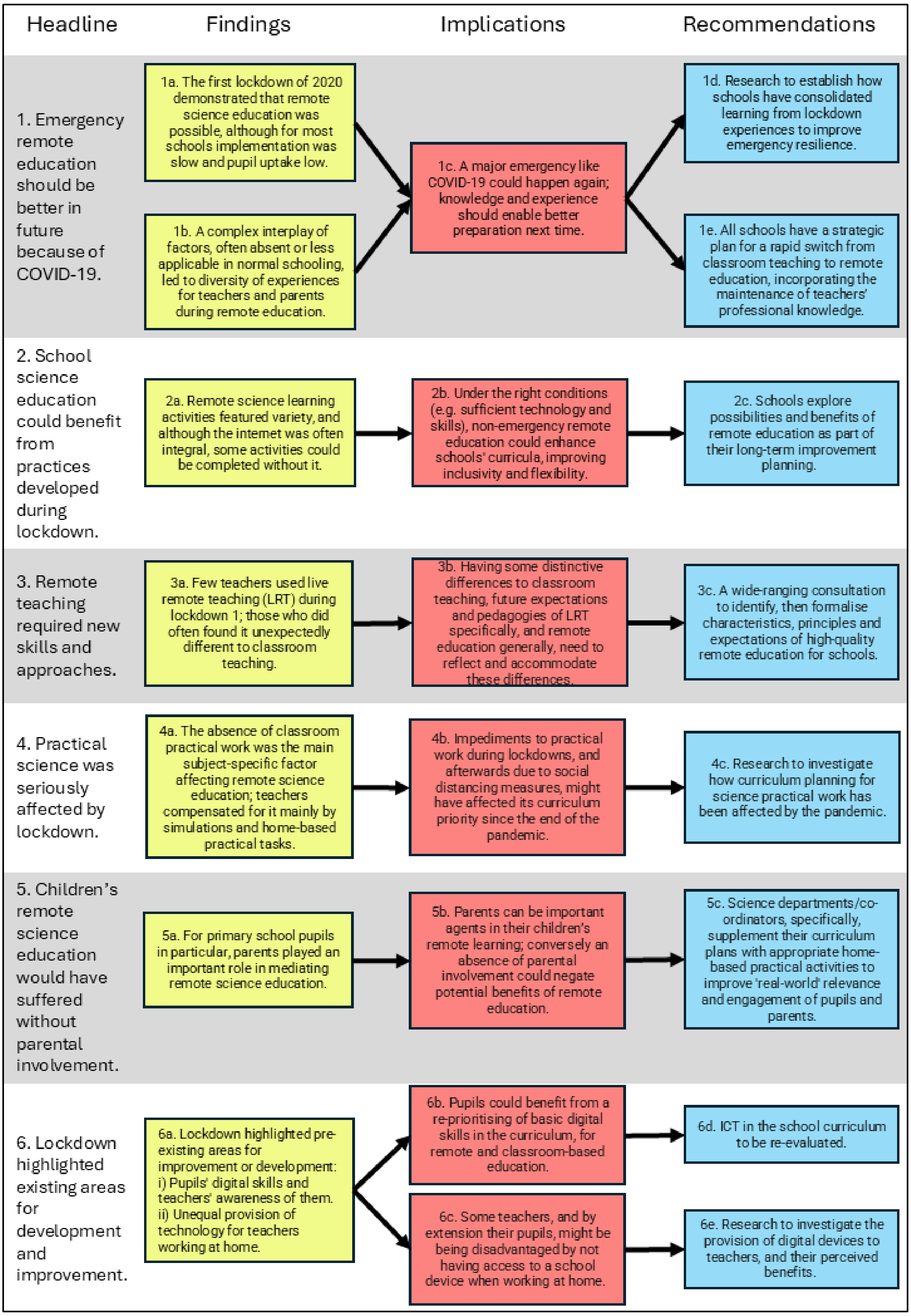


Figure 41: Summary diagram showing research findings, corresponding implications and recommendations. Headline statements capture a key element of each horizontal layer.

Each sub-section below relates to a single horizontal section of Figure 41.

7.2.1 Headline 1: Emergency remote education should be better in future, because of COVID-19

Research Finding 1a: The first lockdown of 2020 demonstrated that remote science education was possible, although for most schools, implementation was slow and pupil uptake low.

The remote education practice of most teachers in this study evolved over weeks or months for various reasons, not all of which are attributable to the unpredictability of lockdown: transition to functioning and effective remote education might have been swifter and less problematic had school conditions been different before the pandemic. Technology-related examples substantiate this assertion: pupils' familiarity and skills in using digital technology were often mismatched with task expectations, and schools had patchy knowledge of pupils' home access to digital technology. Consequently, although most remote education required the internet, teachers often set learning tasks with limited knowledge of pupils' capacities to access and complete them. This challenge was most pronounced for schools serving economically disadvantaged communities due to inferior access to requisite technology.

Most teachers received communication from half or fewer of their pupils during this first lockdown. Many pupils neither returned learning activities nor responded to emails, leaving teachers uncertain whether they were not receiving tasks, receiving but attempting them without returning work, or receiving them and not attempting them. Perceptions about lack of engagement exceed those reported by Sibieta and Cottell (2020), but limited contact suggests teachers' judgements were probably speculative, reflecting literature on learning loss where predictions were more prevalent than empirical evidence (Donnelly & Patrinos, 2021). However, the delays recounted above provide plausible explanations for potential learning loss.

Teachers could not anticipate numerous communication and logistical challenges caused by loss of face-to-face pupil contact, frequently responding reactively to emerging problems rather than proactively planning preventive measures. Calibrating how much work to set pupils proved difficult given limited feedback and communication barriers. Task-setting difficulties probably led to some pupils doing little or no science learning for prolonged periods.

Despite widespread challenges, some schools implemented more effective online education from an early stage, demonstrating its feasibility. However, success depended on specific conditions: within this study, independent schools achieved this considerably earlier than state schools, corroborating the findings of Cullinane and Montacute (2020). Independent school teachers reported their pupils having good access to their own technology at home, consistent with Green (2021), but contrasting with many state school teachers who described pupils struggling to access technology for online learning.

Research finding 1b: A complex interplay of factors, often absent or less applicable in normal schooling, led to diversity of experiences for teachers and parents during remote education.

The wide diversity of experience reported in other literature (e.g. Breslin, 2021; Howard et al., 2021; Villadsen et al., 2020) is evident in teachers' and parents' accounts in this study. Consistent with Andrew et al. (2020), inequalities that school attendance typically mitigates, such as internet access, became more pronounced with homes serving as primary sites of learning. Variables normally less relevant to education, such as family dynamics and the home environment, tended to be magnified.

Teachers’ lack of prior experience and an initial absence of relevant guidance meant they had to effectively invent emergency remote education independently, resulting in variations between individual schools’ approaches and expectations. Not knowing how long lockdown would last hampered curriculum planning; some schools maintained existing curricula, while others focused on pupils revising previous material. Some primary schools prioritised English and Mathematics over science, meaning some younger pupils potentially missed specific science learning that would not be encountered again, even at secondary school.

Initially many teachers based remote education on trial-and-error, adapting classroom-based resources. As Howard et al. (2021) also reported, such resources were often ineffective in remote education contexts and when pupils were working independently.

Some schools were better equipped for remote education than others because of existing technology or systems. Although suggested as advantageous (e.g. Bubb & Jones, 2020; Hodgen et al., 2020; Lucas et al., 2020) evidence in this study demonstrates these advantages could be undermined if, for instance, pupils or parents lacked prior familiarity with them. However, in some cases lockdown did provide opportunities for schools’ under-utilised digital technology to have its potential realised more fully.

The diversity and complexity of teachers' and parents' remote education experiences constitute critical observations for understanding its practical implementation. Whether remote education is required for future emergencies, or whether it is developed as part of a hybridised approach to schooling, understanding the multiple factors affecting its successful implementation will be essential.

Implication 1c: A major emergency like COVID-19 could happen again; knowledge and experience should enable better preparation next time.

Remote education cannot be ruled out as a future emergency requirement, and the COVID-19 experience should enable substantially improved preparation. As Williams et al. (2023) state, risks from emerging infectious disease pandemics are increasing; they suggest maintaining the preparedness momentum achieved during the pandemic.

Schools were not the only educational stakeholders during the COVID-19 pandemic: system-wide actors, such as exam boards, also had significant roles in how remote education during COVID-19 unfolded. Schools cannot be expected to bear the burden of emergency remote education alone; they should be empowered to make key decisions about provision, but with appropriate support. Consequently, this implication holds relevance for multiple stakeholders, from individual schools to governments. Just as schools maintain perpetual readiness for fires, *proportionate* preparedness for another COVID-scale emergency appears prudent. The events of 2020 abundantly demonstrate the cost of unpreparedness.

Recommendation 1d: Research to establish how schools have consolidated learning from lockdown experiences to improve emergency resilience.

Academic research could investigate what a representative sample of schools have done or are doing to ensure they are prepared for a rapid switch to high quality remote education in an emergency. The research would assess general sector-wide preparedness for future COVID-scale emergencies, and evaluate potential consistency of responses. This research would need conducting to gauge the urgency of the recommendation below.

Recommendation 1e: All schools have a strategic plan for a rapid switch from classroom teaching to remote education, incorporating the maintenance of teachers' professional knowledge.

The existence of large quantities of literature about education during COVID-19 will not prevent recurrence of the sort of difficult experiences reported in this study: in practical terms a future emergency would require academic knowledge to have been transformed into usable policies and practices for schools and teachers to implement at short notice. As the events of March 2020 showed, a swift transition to remote education might be necessary, making rapidly implementable contingency plans essential. Hence the proportionate standby referred to in implication 1c, above.

Some requirements for strategic plans, such as accurate information about pupils' home internet access and effective communication strategies, are apparent from this study. However, an emergency switch to remote education would also need teachers to possess current, practical knowledge of remote education. If only needed in a real emergency, perhaps decades hence, by individuals without personal experience or whose knowledge has not kept pace with technological developments, rapid transition could prove as problematic as in 2020. Post-COVID, videoconferencing use has been maintained for several purposes within education, but the extent to which best practices from lockdowns have been formalised or disseminated, even within individual schools, is not clear. With schools reverted to face-to-face education, a lack of ongoing exposure to developments in remote education is possible, risking erosion of knowledge gained during lockdowns. Hence, a compelling argument exists for maintaining minimum levels of knowledge. Periodically refreshing and developing teachers' skills, and including pedagogies of remote education in Initial Teacher Education (ITE) are possibilities. Alternatively, schools could prioritise integration of elements of remote education into their curricula as an ongoing developmental process. These ideas reflect suggestions from Guddmundsdottir and Hathaway (2020), and could maintain and develop knowledge and skills for both teachers and pupils; a proposal developed in recommendation 2c.

These suggestions do not underestimate the scale of this challenge, but it is arguably a smaller challenge than dealing with a future COVID-scale emergency from a state of unreadiness. Rather than leaving this for individual schools to manage alone, this kind of planning could be overseen at the level of local authorities or multi-academy trusts, ensuring, for example, regular reviews of plans as circumstances change. The outcome of implementing this recommendation would be to shift schools' orientation towards large-scale emergencies from reactive to proactive.

7.2.2 Headline 2: School science education could benefit from practices developed during lockdown

Research finding 2a: Remote science learning activities featured variety, and although the internet was often integral, some activities could be completed without it.

Most teachers in this study used several different approaches and activity types for teaching science remotely, reflecting findings of Müller and Goldenberg (2021). The internet and associated digital technologies were usually integral either because content was hosted online, or simply because activities were sent via the internet and pupils were expected to return them the same way. LRT was used by a minority of schools, as also found by Cullinane and Montacute (2020) but became more widespread, while email was the commonest communication method between teachers and pupils or their parents.

Teachers developed various remote education pedagogies by realising affordances of digital technology, such as pre-recording themselves giving explanations. The repeated availability of such material, at pupils' convenience, reflect potential suggested by Kearney et al. (2012) in discussions of mobile learning, and highlight teachers' innovations during lockdown.

Although the internet was central to communication, learning tasks themselves did not always require the internet, nor digital devices. Teachers deliberately set tasks of this type because of worries about pupils' screen-time and another commonly reported concern - the loss of science practical work. Hence, remote science education did not revolve solely around technology, and a varied diet, in which pupils were not just learning from screens, was possible.

Implication 2b: Under the right conditions (e.g. sufficient technology and skills), non-emergency remote education could enhance schools' curricula, improving inclusivity and flexibility.

As discussed in the introductory chapter (section 1.4), an emergency perspective is one way to contemplate future uses of remote education by schools, but potentially just as significant is how it might improve schools' educational practices in the longer term. As this study has shown, using the internet as the medium for providing remote education was possible; sometimes advantages over face-to-face modes of instruction were demonstrable.

Although activities involving specialist equipment, as might be found in a science laboratory, do not transfer readily to an online format, some other types of teaching and learning could, in time, be supplemented by remote provision. Reflecting Peimani and Kamalipour's suggestions (2021), this could improve inclusivity, flexibility and educational benefits, for instance for pupils unable to participate in classroom learning. A gradual transformation to more hybridised, flexible forms of schooling is therefore conceivable, without invoking the sort of revolutionary disruption of COVID-19. This could initially, for instance, be conceived as an evolution of existing notions of homework, or exam revision.

Scaling such visions of hybridised school/remote education is not without obstacles, such as social inequality reported widely in literature (e.g. Anders et al., 2020; Andrew, Cattan, Costa Dias et al., 2020; Children's Commissioner, 2020; Menzies, 2020) and recounted by teachers in this study. As COVID-19 highlighted, issues like this were beyond the scope of schools alone to solve, and hence would require time, financial investment and political will.

As teachers and parents' evidence illustrated, remote education experiences could also be beset by complexity absent from school-based education, but in visualising possible futures that embrace technological breakthroughs and social change, it would be logical to re-examine the concepts of place, time and personalisation that physical school buildings restrict, but remote education does not.

Recommendation 2c: Schools explore possibilities and benefits of remote education as part of their long-term improvement planning.

The possibilities for remote education to enhance schools' practice are considerable, exemplified by the hosting of pre-recorded content online. Considering the experiences of remote education and teachers' stated intentions to change aspects of practice (see chapter 4, section 4.8), many relating to features of remote education, this recommendation is about formalising a mechanism for operationalising this development. Deliberations around curriculum and inclusivity, for instance during school improvement planning cycles, could begin to incorporate aspects of remote education.

7.2.3 Headline 3: Remote teaching required new skills and approaches

Research finding 3a: Few teachers used live remote teaching (LRT) during lockdown 1; those who did often found it unexpectedly different to classroom teaching.

With only around a quarter of surveyed teachers in this study using LRT during the first lockdown, usually later rather than earlier on, most were unaware either of the potential for teaching via videoconference, or how to do it. Awareness grew as teachers were exposed to videoconferencing through staff meetings and professional development courses. Despite the relatively low proportion using LRT for teaching, by the end of the first lockdown it had nevertheless become established as a benchmark for remote education in subsequent lockdowns, albeit with limited evidence of effectiveness.

Although the synchronous presence of teachers and pupils lent it a superficial similarity to the classroom, it became clear that LRT was not just classroom teaching via videoconference. Teachers' descriptions were of a distinctly different experience, though often compared with classroom teaching. Real-time contact between teachers and pupils was perceived positively, representing more tangible evidence of pupil engagement than other remote education methods, but pupils were often more reluctant to contribute orally than in the classroom. LRT lessons were thus dominated by teacher monologue, and the dominant pedagogy was verbal transmission of information with supporting visual aids such as PowerPoint presentations, like how many teachers stated they used digital technology in their classrooms. Nevertheless, teachers using LRT gave higher ratings overall for the quality of remote education they had provided than those who had not.

Aural differences between LRT and classroom-based lessons were accompanied by marked visual differences. Teachers dwelt on whether pupils' cameras were switched on, and the reluctance of pupils to show their faces. Teachers' computer screens frequently showed only names rather than a live video-stream of pupils' faces, so although LRT was teaching in real-time, they sometimes had doubts about pupils' presence or attention. Moreover, using facial expressions to monitor attention or comprehension, which they were accustomed to doing in classrooms, was not possible when cameras were switched off. Teachers realised that planning effective LRT lessons was therefore unlike planning classroom-based lessons, largely because the human interaction was very different. With practice they became more familiar with tools such as the chat function and break-out rooms and began to exploit opportunities that LRT presented.

The emergence of LRT and widespread use of videoconferencing for meetings and professional development are two of the more significant outcomes of remote education in lockdown. Teachers and parents judged LRT favourably, usually more so than other the common approaches in which no real-time contact between pupils and teachers occurred, which could plausibly explain its prevalence in subsequent lockdowns. It seems likely it will have an important role in any planned remote education for the foreseeable future.

Implication 3b: Having some distinctive differences to classroom teaching, the expectations and pedagogies of LRT specifically, and remote education generally, need to reflect and accommodate these differences.

Differences between online and face-to-face modes of education are highlighted in literature (e.g. Wisanti et al., 2021; Yandell, 2020), as well as being observed in this study. Teachers' evidence suggests successful remote education practices resulted from changing classroom approaches and resources to embrace limitations and exploit affordances of changed conditions. In LRT, for example, familiar classroom techniques such as questioning sometimes needed adapting. However, remote education entailed more than just adapting pedagogy; teachers had to amend expectations about lesson timings, communication and pupils' independent working capabilities. For primary pupils, parents were necessary as mediators. The implication is that for remote education to be planned, whether for an emergency or not, it needs to reflect and incorporate these distinctive differences.

Recommendation 3c: A wide-ranging consultation to identify, then formalise characteristics, principles and expectations of high-quality remote education for schools.

An important part of preparation for another emergency like COVID-19 would be quality assurance of planning for remote education, ensuring consistent educational standards and working conditions. This recommendation proposes a consultation to gather information and distil out best practices and principles for subsequent implementation by teachers and schools when needed. Consultation would need to be wide-ranging to cover diverse aspects such as technology infrastructure and differences between primary and secondary contexts. A consolidation of findings, as advisory standards, analogous to the Education Endowment Foundation’s guidance on improving school science (Holman & Yeomans, 2018), could enhance both schools' emergency resilience and remote education capabilities. A parallel strand of this consultation, potentially undertaken in conjunction with professional associations and unions, would explore suitable working conditions for teachers teaching remotely from home, to ensure this important aspect is not overlooked: as some teachers in this study reported, remote education led to various health-related problems.

7.2.4 Headline 4: Practical Science was seriously affected by lockdown

Finding 4a: The absence of classroom practical work was the main subject-specific factor affecting remote science education; teachers compensated for it mainly by home-based practical tasks and simulations.

The inability to undertake class practical work was a conspicuous setback affecting remote science education specifically. As compensation, many teachers set simple practical activities for pupils to perform independently, often using common household objects. Various imaginative practical activities were described by teachers, some highlighting the fortunate circumstance of the first lockdown occurring during spring and summer months when outdoor activities, such as ‘bug hunts’, were viable. Parents had a positive view of home-based practical activities and were motivated to get involved themselves, describing specific examples of practical science activities they had initiated. Many thought these activities had helped children learn science, often more than other lockdown learning activities, although evidence to confirm this view was limited. Some teachers performed simple science demonstrations on webcam during LRT; logistical challenges and health and safety tended to privilege physics over chemistry or biology for this.

Online simulations were also cited as a substitution for classroom practical activities by teachers, but views on these varied. Drawbacks, such as the generation of unrealistically uniform data, were identified. As well as presenting topic-specific content, simulations were sometimes considered helpful for developing pupils’ ‘Working scientifically’ knowledge.

Implication 4b: Impediments to practical work during lockdowns and afterwards due to social distancing measures might have affected its curriculum priority since the end of the pandemic.

A long-standing focus within the science education community (E.g. Abrahams & Millar, 2008; Millar, R. & Abrahams, 2009; Osborne & Millar, 1998; Wellington, 1998) practical science has probably never been subject to disruption like COVID-19. This warrants concern for the state of practical science post-pandemic, if only to carry out a 'health-check'. Practical science is a costly, highly specialised endeavour for schools. It is conceivable, therefore, that following the challenges of COVID-19 practical science has not 'bounced back', possibly because non-practical alternatives like those used during the pandemic have been deemed sufficient instead, either by teachers or school leaders. Recent research has suggested changes in school science practical work, with shifts away from hands-on experience and increases in teachers showing videos of experimental procedures (Hamlyn et al., 2024). The same authors also suggest the possibility, raised above, that digital substitutes used during lockdowns have become embedded.

Recommendation 4c: Research to investigate how curriculum planning for science practical work has been affected by the pandemic.

Before COVID-19, concerns in practical school science had been identified over several years (E.g. Holman, 2017; House of Commons Science and Technology Committee, 2011; House of Lords Science and Technology Committee, 2006; Science Community Representing Education, 2008). None of this literature foresaw a global pandemic that would close schools for months, disrupting how teaching and learning happened. Practical science effectively took a major ‘hit’: as outlined above, this recommendation is for a much-needed ‘health-check’.

This recommendation would be carried out by academic researchers, but the results would have relevance to various stakeholders, including government.

7.2.5 Headline 5: Children’s remote science education would have suffered without parental involvement

Finding 5a: For primary school pupils in particular, parents played an important role in mediating remote science education.

As children did not always understand teachers’ instructions, or struggled to learn independently, parents were often compelled to act as intermediaries during remote education. For primary school pupils, especially, it was frequently necessary for parents to act as surrogate teachers, partly because teachers’ communications were often aimed at parents anyway and, for science, could be suggestions rather than specific instructions. Parents thus described planning activities for their children to keep them meaningfully occupied. For primary pupils, concentrating for extended periods could be difficult; they needed human interaction and encouragement.

Few of the primary teachers were science specialists and primary schools often placed a lower priority on science and other subjects: English and Mathematics were a much bigger focus. Despite a lower profile, parents sometimes provided practical science activities of their own, and their evidence suggests it was their own enthusiasm and interest that led them to go beyond the tasks that teachers had set. This closer involvement meant parents gained insights, both into their children’s personalities, and into educational practice. Some said that it helped them appreciate the work of teachers better. Concerns and stresses were revealed, however, reflecting other literature (e.g. Allen et al., 2020b; Cambridge Partnership for Education, 2020). Some worried about whether they were doing things 'right', or whether their actions might have longer term repercussions for their children's education. Just under half of parents stated that they had had to learn things to help their children, usually related to science subject knowledge.

Overall, parents had an important role in children's education during lockdown, and those interviewed for this study probably exceeded what they would normally do by a substantial margin. It is through the lens of future remote education that their contribution is significant, whether in an emergency or during more planned integration.

Implication 5b: Parents can be important agents in their children's remote learning; conversely an absence of parental involvement could negate potential benefits of remote education.

Without parents' help, pupils would have been more disadvantaged. Their support, supervision and physical presence probably mitigated learning losses. In planning for remote education, therefore, schools would need to factor in parental influence, or the lack of it.

This implication is relevant to remote education, but evidence in this study also shows the potential for parents to become more actively engaged, enhancing their children's science learning through their own input and ideas. There is relevance therefore, in recognising that schools could have a potentially under-utilised resource, through parents, for enhancing pupils' science education. This implication has relevance to the existing field of study into informal STEM education (e.g. Zucker et al., 2021), and reflects Gülhan's suggestion (2023) that parental involvement has been under-represented within this field.

Recommendation 5c: Science departments/co-ordinators, specifically, supplement their curriculum plans with appropriate home-based practical activities to improve 'real-world' relevance and engagement of pupils and parents.

This recommendation is a response to the preceding implication, also reflecting finding 2a about home-based practical science. Effectively, this recommendation seeks to exploit home-based practical work and parental enthusiasm for practical science, both demonstrated in this study. It is, therefore, about continuing and extending innovations which had a perceived impact on learning and engagement, sharing and incorporating these into schemes of learning.

This recommendation is clearly relevant to teachers in schools, but some impetus could be generated by subject associations through articles and professional development.

7.2.6 Headline 6: Lockdown highlighted existing areas for development and improvement

Finding 6a: Lockdown highlighted pre-existing areas for improvement or development:

i) **Pupils' digital skills and teachers' awareness of them.**
ii) **Unequal provision of technology for teachers working at home.**

Lockdown raised teachers' awareness of issues that had existed previously, but, due to different circumstances, had not been widely apparent. Pupils struggled to complete learning tasks because their digital skills did not match teachers' expectations. The second issue, revealed by survey data, is unequal provision of devices such as laptops or tablets for teachers to use when working at home. These two points are discussed separately below.

i) Many teachers were unaware that pupils would not have sufficient computer-based skills or knowledge for completing remote learning tasks. Pupils needed familiarity with software suites such as Microsoft Office, but basic functions like 'copy and paste' often caused problems. Some pupils did not know their credentials for logging on to school systems, a fundamental requirement for accessing email, the main method of communication schools used to contact home. However, even those who could access email did not always know how to use it. This situation clearly existed before the pandemic but was largely unknown.
ii) Although lockdown occurred almost two decades after the first government-backed scheme to provide teachers with laptops (Cunningham et al., 2003), around a third of the teachers who participated in the survey stated they had to use their own device when working at home. Some teachers had to buy a laptop or computer during lockdown to be able to work from home.

Implication 6b: Pupils could benefit from a re-prioritising of basic digital skills in the curriculum, for remote and classroom-based education.

Teachers' descriptions of skills pupils lacked usually corresponded to what would have been commonly called 'ICT' several years ago. The implication is that pupils had not received much teaching of these skills before lockdown and could benefit from this being rectified, both generally, and specifically for future instances of remote education.

This implication raises questions about assumptions: secondary teachers, for instance, might have thought the skills were being taught somewhere else in the curriculum, when they were not. A further question is how the situation escaped attention prior to lockdown. Considering the evidence, discussed in section 4.8.2 of chapter 4, where most instances of teachers using digital technology for teaching science involved them, rather than pupils, controlling the technology, this may reflect low levels of technology integration in school, possibly because of barriers (E.g. Bingimlas, 2009; Francom, 2020; Tosuntaş et al., 2019).

Implication 6c: Some teachers, and by extension their pupils, might be being disadvantaged by not having access to a school device when working at home.

There are issues of fairness around the lack of parity in teachers' access to school-supplied devices such as laptops. Teachers without a school laptop (or equivalent device) have recourse to two options. Buying their own would impose a financial burden that could see the device shared with family members, not covered by school technical support, and potentially a lower specification than a school device. Alternatively, they could manage without. Either of these options is disadvantageous compared to having a device supplied by school, as fulfilment of key professional duties such as lesson planning are negatively impacted, ultimately affecting pupils. In the context of remote education, the quality assurance referred to in recommendation 4 would be hard to achieve without the necessary hardware itself being quality assured.

Recommendation 6d: ICT in the school curriculum to be re-evaluated.

This recommendation is aimed at stakeholders such as the Department of Education. ICT was superseded by Computing in 2014 (Department for Education, 2014), a transition influencing educational research by a change of focus towards teaching programming and algorithmic thinking (e.g. Royal Society, 2017; Sentance & Csizmadia, 2017). A re-evaluation of ICT, for example by a study of the extent to which computing is teaching basic digital skills, is justified specifically because of findings about pupils' skills outlined above.

Recommendation 6e: Research to investigate the provision of digital devices to teachers, and their perceived benefits.

Implication 6c, above, suggests disadvantages caused by teachers not having laptops provided by their school. This cannot be assumed, which is why this recommendation for academic research would involve investigating benefits teachers perceive when they do have a school laptop. It is possible, for example, that some teachers prefer to buy their own device. However, a further purpose of the research would be to obtain a national picture of provision, to draw attention, where necessary, to any lack of parity across the teaching profession.

7.3 Contribution to knowledge

This study has a distinctive contribution to the field of lockdown education. Literature relevant to the study's aims was very limited at the beginning of the UK's first lockdown. Although, at the time, literature pertaining to pre-COVID remote education was extensive, most had a higher education focus.

Furthermore, literature about education in serious emergencies was mainly oriented towards conflict, not pandemics. While school closures for pandemics had occurred before, for example in the 1918 influenza pandemic, these were local or regional, rather than national or international (Ager et al., 2020; Stern et al., 2009); the scale of educational disruption caused by COVID-19 dwarfs that of any previous event, affecting almost 1.6 billion learners in over 190 countries (United Nations, 2020). Fundamentally Covid-19 was different to any other natural disaster, conflict or disease outbreak because it was a global, simultaneous disruption, affecting nearly every country at the same time. Hence, no extant literature had examined education under conditions like those created by COVID-19, because it was unprecedented.

The conventional practice of reviewing literature before data collection commenced, to identify gaps in the field, could not be undertaken in the circumstances of COVID-19: gaps emerged during and after data collection. Most studies feature non-subject perspectives and rely exclusively on quantitative data, while my study contributes new perspectives through the use of mixed methods to investigate science education for school-age children. Mixing methods of quantitative surveys and qualitative interviews has additionally lent a high degree of rigour to this research.

The research questions informing this study were:

1. How have teachers responded to requirements for teaching science remotely in lockdown conditions, and with digital technology as the predominant means of delivery?

2. How is remote science teaching being experienced, mediated or supplemented by parents/guardians?

Looking initially at the first question, my study, including triangulation across different data sources, has revealed depth and diversity in teachers' experiences, addressing an acknowledged shortage of studies in which triangulation has been carried out (Bond, 2021). Although the shortage of comparable subject-specific literature limits cross-subject comparisons, this study's evidence suggests practical work was the most significantly affected aspect of science teaching during remote instruction. Evidence presented in chapters 4 and 5 illuminates both the challenges teachers encountered and the solutions they developed. Teachers' perspectives on various dimensions of remote education are systematically explored. The emergence of LRT, which became the predominant approach to remote education in subsequent lockdowns, is comprehensively documented.

In addressing the second question, parents' data have complemented and enhanced teachers' data, contributing to a more comprehensive understanding of remote science education provision during the first lockdown. Triangulation with teacher data has enhanced the validity of conclusions. Evidence highlights how important parents were for facilitating children's remote education generally, and how they contributed to science learning specifically.

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Appendices

List of appendices

Appendix 1: Brief summarised descriptions of teacher interviewees.

All teacher names are pseudonyms.

Teacher: **Alina**							
Secondary teacher	State sector	Female	10-15 years teaching experience	School location: York	500-1000 pupils on school roll	Ages taught: KS3-4	Interviewed on 22/7/20

- Her school was graded ‘Inadequate, serious weaknesses’ at the last inspection.
- At the time of the survey she was working from home all the time.
- School provides her with a laptop.
- Uses social media for personal and work purposes.
- Digital technology used at home, either for personal or work purposes, includes a smartphone and laptop.

Teacher: **Andrea**							
Secondary teacher	State sector	Female	Over 15 years teaching experience	School location: Cardiff	500-1000 pupils on school roll	Ages taught: KS3-4	Interviewed on 20/7/20

- Holder of a TLR2 post.
- Her school was graded ‘Requires Improvement’ at the last inspection.
- At the time of the survey she was working from home all the time.
- School provides her with a laptop.
- Uses social media for personal and work purposes.
- Digital technology used at home, either for personal or work purposes, includes a smartphone and laptop.

Teacher: **Anne**							
Secondary teacher	Independent sector	Female	10-15 years teaching experience	School location: Leicester	1000-1500 pupils on school roll	Ages taught: KS3-5	Interviewed on 28/7/20
• She did not know the grading of the last school inspection. • At the time of the survey she was working from home all the time. • School provides her with a laptop. • Uses social media for personal but not work purposes. • Digital technology used at home, either for personal or work purposes, includes a smartphone, tablet, laptop, pc, smart television, digital camera, and virtual assistant.							

Teacher: **Beatrice**							
Secondary teacher	State sector	Female	0-2 years teaching experience	School location: Bradford	500-1000 pupils on school roll	Ages taught: KS3-4	Interviewed on 24/7/20
• Trainee teacher (Teach First). • Her school was graded 'Outstanding' at the last inspection. • At the time of the survey she was working from home all the time. • School provides her with a laptop. • Uses social media for personal and work purposes. • Digital technology used at home, either for personal or work purposes, includes a smartphone and laptop.							

Teacher: **Celia**							
Primary teacher	State sector	Female	5-10 years teaching experience	School location: Reading	200-500 pupils on school roll	Ages taught: KS2	Interviewed on 16/9/20

- Science middle leader.
- Her school was graded ‘Good’ at the last inspection.
- At the time of the survey she was working from home all the time.
- School provides neither a laptop nor tablet.
- Uses social media for personal and work purposes.
- Digital technology used at home, either for personal or work purposes, includes a smartphone and laptop.

Teacher: **Eleanor**							
Secondary teacher	Independent sector	Female	10-15 years teaching experience	School location: Leicester	1000-1500 pupils on school roll	Ages taught: KS3-5	Interviewed on 29/7/20

- She did not know the grading of the last school inspection.
- At the time of the survey she was working from home all the time.
- School provides her with a laptop.
- Uses social media for personal but not work purposes.
- Digital technology used at home, either for personal or work purposes, includes a smartphone, tablet, laptop, smart television and digital camera.

Teacher: **Ella**							
Secondary teacher	State sector	Female	Over 15 years teaching experience	School location: Manchester	1000-1500 pupils on school roll	Ages taught: KS3-4	Interviewed on 27/7/20

- Her school was graded 'Outstanding' at the last inspection.
- At the time of the survey she was teaching in school occasionally.
- School provides her with a laptop.
- Uses social media for personal and work purposes.
- Digital technology used at home, either for personal or work purposes, includes a smartphone, tablet, laptop and smart television.

Teacher: **Elspeth**							
Primary teacher	State sector	Female	10-15 years teaching experience	School location: Newcastle - upon-Tyne	200-500 pupils on school roll	Ages taught: KS2	Interviewed on 10/9/20

- Her school was graded 'Good' at the last inspection.
- At the time of lockdown she was working from home all the time.
- School provides neither a laptop nor tablet.
- Uses social media for personal and work purposes.
- Digital technology used at home, either for personal or work purposes, includes a smartphone and laptop.

Teacher: **Hilda**							
Secondary teacher	State sector	Female	0-2 years teaching experience	School location: Wakefield	500-1000 pupils on school roll	Ages taught: KS3-4	Interviewed on 27/7/20

- Newly qualified teacher.
- Her school was graded ‘Good’ at the last inspection.
- At the time of the survey she was working from home all the time.
- School provides neither a laptop nor tablet.
- Uses social media for personal but not work purposes.
- Digital technology used at home, either for personal or work purposes, includes a smartphone, tablet, laptop and virtual assistant.

Teacher: **Jack**							
Secondary teacher	State sector	Male	Over 15 years teaching experience	School location: Sheffield	1500-2000 pupils on school roll	Ages taught: KS3-4	Interviewed on 28/7/20

- Deputy subject leader for science.
- His school was graded ‘Good’ at the last inspection.
- At the time of the survey he was working from home all the time.
- School provides him with a laptop.
- Does not use social media for personal nor work purposes.
- Digital technology used at home, either for personal or work purposes, includes a smartphone, tablet, PC and virtual assistant.

Teacher: **Joelle**							
Primary teacher	State sector	Female	Over 15 years teaching experience	School location: Sheffield	200-500 pupils on school roll	Ages taught: KS2	Interviewed on 14/9/20

- Holder of a curriculum lead TLR.
- Her school was graded ‘Good’ at the last inspection.
- At the time of the survey she was teaching at school on most or all her usual working days.
- School provides her with a laptop.
- Uses social media for personal and work purposes.
- Digital technology used at home, either for personal or work purposes, includes a smartphone and laptop.

Teacher: **Josh**							
Secondary teacher	State sector	Male	Over 15 years teaching experience	School location: Leeds	1000-1500 pupils on school roll	Ages taught: KS4-5	Interviewed on 22/7/20

- His school was graded ‘Good’ at the last inspection.
- At the time of the survey he was working at home all the time.
- School provides him with a tablet.
- Uses social media for personal but not work purposes.
- Digital technology used at home, either for personal or work purposes, includes a smartphone, tablet, laptop and smart television.

Teacher: **Judy**							
Secondary teacher	Independent sector	Female	Over 15 years teaching experience	School location: Brussels	500-1000 pupils on school roll	Ages taught: KS5	Interviewed on 21/7/20
• Head of Science in a British school in Brussels. • She doesn't know the school's last inspection rating. • At the time of the survey she was working from home all the time. • School provides her with a laptop. • Uses social media for personal but not work purposes. • Digital technology used at home, either for personal or work purposes, includes a laptop, tablet and digital camera.							

Teacher: **Julia**							
Secondary teacher	State sector	Female	5-10 years teaching experience	School location: Southampton	500-1000 pupils on school roll	Ages taught: KS3-4	Interviewed on 21/7/20
• Her school was graded 'Good' at the last inspection. • During lockdown she was teaching in school occasionally. • School provides her with a laptop. • Uses social media for work but not personal purposes. • Digital technology used at home, either for personal or work purposes, includes a laptop.							

Teacher: **June**							
Secondary teacher	State sector	Female	Over 15 years teaching experience	School location: Sheffield	1500-2000 pupils on school roll	Ages taught: KS4-5	Interviewed on 23/7/20

- Her school was graded ‘Good’ at the last inspection.
- At the time of the survey she was working from home all the time.
- School provides neither a laptop nor tablet.
- Does not use social media for personal nor work purposes.
- Digital technology used at home, either for personal or work purposes, includes a smartphone, tablet and laptop.

Teacher: **Lisa**							
Secondary teacher	State sector	Female	5-10 years teaching experience	School location: Barnsley	500-1000 pupils on school roll	Ages taught: KS3-4	Interviewed on 29/7/20

- Assistant Head of Science, and lead practitioner.
- Her school was graded ‘Good’ at the last inspection.
- At the time of the survey she was working from home all the time.
- Uses social media for personal but not work purposes.
- Digital technology used at home, either for personal or work purposes, includes a smartphone, tablet and laptop.

Teacher: **Nick**							
Primary teacher	State sector	Male	10-15 years teaching experience	School location: Sheffield	200-500 pupils on school roll	Ages taught: KS2	Interviewed on 24/7/20
• He holds a TLR for Development of the Curriculum. • His school was graded ‘Good’ at the last inspection. • At the time of the survey he was teaching at school on most or all of his usual working days. • Uses social media for personal and work purposes. • Digital technology used at home, either for personal or work purposes, includes a smartphone, tablet and laptop.							

Teacher: **Nigel**							
Secondary teacher	State sector	Male	0-2 years teaching experience	School location: Sheffield	1500-2000 pupils on school roll	Ages taught: KS3	Interviewed on 20/7/20
• Newly qualified teacher. • His school was graded ‘Inadequate: requires special measures’ at the last inspection. • During lockdown he was teaching in school occasionally. • School provides neither a laptop nor tablet. • Does not use social media for personal nor work purposes. • Digital technology used at home, either for personal or work purposes, includes a laptop and PC.							

Teacher: **Rachel**							
Secondary teacher	State sector	Female	Over 15 years teaching experience	School location: Dorchester	500-1000 pupils on school roll	Ages taught: KS3-5	Interviewed on 17/9/20
• 2nd in science. • Her school was graded 'Good' at the last inspection. • At the time of the survey she was teaching in school occasionally. • She has a laptop provided by school. • Uses social media for personal but not work purposes. • Digital technology used at home, either for personal or work purposes, includes a smartphone and laptop.							

Teacher: **Sharon**							
Secondary teacher	State sector	Female	Over 15 years teaching experience	School location: Barnsley	500-1000 pupils on school roll	Ages taught: KS3-4	Interviewed on 24/7/20
• Head of Science. • Her school was graded 'Good' at the last inspection. • At the time of the survey she was working in school occasionally. • Uses social media for personal but not work purposes. • Digital technology used at home, either for personal or work purposes, includes a smartphone, laptop, PC and smart television.							

NB. A total of 21 teachers were interviewed; data from 20 were used for analysis due to one teacher's audio file being of insufficient quality for transcription.

Appendix 2: Brief summarised descriptions of parent interviewees.

All parent names are pseudonyms.

Children's school in bold indicates child selected for survey answers.

Parent: **Dominic**						
Age: 50+	Male	Lives in the Wakefield area	3 school aged children	Children's school: **Primary**, secondary	Own education: Masters degree. No science qualifications.	Interviewed on 17/9/20

- Dominic is a teacher.
- No children were due to take exams this year.
- Dominic's home has broadband and it is fast some of the time. There has been an occasional loss of speed or connection during lockdown.
- Dominic's children use Smartphone, Tablet, Laptop, Smart TV (or internet-enabled TV), Games console to access the internet at home.
- They can use the internet anywhere at home.
- Dominic allows access for a certain amount of time each day or at specified times, and uses parental controls on their device to control which websites they can access.
- Dominic's children don't appear to have been worried or depressed during lockdown, and have been looking forward to returning to school.

Parent: **Jim**						
Age: 40-49	Male	Lives in the Dewsbury area	2 school aged children	Children's school: **Primary**	Own education: HNC level 4 in science.	Interviewed on 10/9/20

- Nobody in the house has never been a teacher.
- No children were due to take exams this year.
- Jim's children use Tablet, Laptop, Smart TV (or internet-enabled TV), Games console to connect to the internet.
- They are allowed to use the internet whenever they want to.
- During lockdown the children have been more worried or depressed about most options on the list.
- They have become less motivated to do schoolwork during lockdown and have been looking forward to returning to school.

Parent: **Karen**						
Age: 50+	Female	Lives in the Woolwich area	1 school aged child	Children's school: **Secondary**	Own education: Masters degree in a science-related subject.	Interviewed on 9/9/20

- Nobody is a teacher or teaching assistant in the household, but someone has been in the past, though not a science teacher.
- Karen's child was not due to take exams this year.
- Her child uses Smartphone, Tablet, Laptop, PC, Games console to connect to the internet.
- She uses parental controls on their device to control which websites they can access, and they are not allowed to use the internet except in communal living areas.
- Karen's child has been more worried or depressed about several options on the list.
- They have become less motivated to do schoolwork during lockdown, and have not been looking forward to returning to school.

Parent: **Kelly**						
Age: 40-49	Female	Lives in the Sheffield area	2 school aged children	Children’s school: **Primary**, secondary	Own education: HNC level 4, GCSE in science.	Interviewed on 17/9/20

- Nobody in the house has never been a teacher.
- One child was due to take exams this year.
- Kelly has broadband at home, which is fast all or most of the time.
- Kelly’s children connect to the internet using Smartphone, Tablet, Laptop, Smart TV (or internet-enabled TV), Games console.
- They can use the internet anywhere at home.
- Kelly uses parental controls on their device to control which websites they can access.
- Kelly’s children have not been worried about anything because of lockdown.
- They have become less motivated to do schoolwork during lockdown.

Parent: **Kieran**						
Age: 40-49	Male	Lives in East Riding of Yorkshire	3+ school aged children	Children’s school: **Primary**, secondary	Own education: Bachelor’s degree in science or related subject.	Interviewed on 11/9/20

- Nobody in the house has ever been a teacher.
- No children were due to take exams this year.
- Kieran’s home has broadband which is fast all or most of the time.
- Kieran’s children use Smartphone, Tablet, Laptop, PC, Smart TV (or internet-enabled TV), Games console to connect to the internet at home.
- They can use the internet anywhere at home.
- Kieran allows access for a certain amount of time each day or at specified times, and uses parental controls on their device to control which websites they can access.
- Kieran’s children haven’t appeared worried or depressed about anything during lockdown and have become more motivated to do schoolwork during lockdown.

<table>
<tr><td colspan="7">Parent: Lily</td></tr>
<tr><td>Age: 40-49</td><td>Female</td><td>Lives in the Barnsley area</td><td>2 school aged children</td><td>Children’s school: Primary</td><td>Own education: Masters degree in a science-related subject.</td><td>Interviewed on 15/9/20</td></tr>
<tr><td colspan="7">
Nobody in the house has ever been a teacher.
No children were due to take exams this year.
Lily’s house has broadband, which is fast all or most of the time.
Her children use Tablet, Smart TV (or internet-enabled TV), Games console to connect to the internet.
Lily allows access for a certain amount of time each day or at specified times, and uses parental controls on their device to control which websites they can access.
They have been more worried or depressed about most options on the list.
Lily’s children have become less motivated to do schoolwork during lockdown and have been looking forward to returning to school.
</td></tr>
</table>

Parent: **Lucy**						
Age: 30-39	Female	Lives in the Portsmouth area	1 school aged child	Child is home-educated.	Own education: Honours degree or equivalent in a science or technology related discipline	Interviewed on 7/9/20

- Nobody in the house is a teacher, but someone has worked as a teacher in the past, though not a science teacher.
- Lucy's child was not due to take exams this year.
- Lucy's child uses a tablet and smart TV to connect to the internet at home.
- Screen time is limited but in a fairly relaxed way, and parental controls are used to control which websites are accessible.
- Lucy's child has been more worried or depressed about several options on the list.
- Lucy's child's motivation for doing work has not really changed during lockdown.

Parent: **Pat**						
Age: 50+	Female	Lives in the Sheffield area	1 school aged child	Children's school: **Secondary**	Own education: Masters degree, GCSE or equivalent in science.	Interviewed on 8/9/20

- Nobody is a teacher or teaching assistant in the household, but someone has been in the past, though not a science teacher.
- Pat's child was not due to take exams this year.
- Pat's child uses Smartphone, Tablet, Laptop, Games console to access the internet at home.
- They're allowed to use it whenever they want.
- They do not appear worried or depressed about anything as a result of the pandemic.
- They have become less motivated to do schoolwork during lockdown and have been looking forward to returning to school.

Appendix 3: Teacher survey questions and tabulated structure

Survey section 1: **About you and your school (Max. 24 questions)**

Q. No.	**Question wording**	**Answering** • Indicates options	**Notes**
1	What gender are you?	• Female • Male • Prefer not to say	
2	Which of the following items of technology do you use at home (for personal or work purposes)? (Please select all that apply)	• Laptop • PC • Tablet • Smartphone • Digital camera other than a phone camera • Smart TV • Virtual assistant • Other – please specify	Respondents select all options that apply.
3	Do you use social media for personal use?	• Yes • No	
4	Which of the following social media platforms do you use for personal use?	• Facebook • Twitter • Instagram • YouTube	Piped question from 'Yes' on question 3. Respondents select all options that apply.

		• WhatsApp • Messenger • WeChat • Tumblr • Snapchat • Other – please specify	
5	Please choose your teaching role	• Primary school or reception teacher • Secondary school teacher	Question to pipe respondents to later sections (below) relevant for primary or secondary teachers.
6	Please indicate how you are currently working.	• I am teaching at school occasionally • I am teaching at school on most or all my usual working days • I am working from home all the time	
7	Roughly how many pupils are on your school's roll?	• Fewer than 100 • 100-200 • 200-500 • Over 500	Options more relevant to primary schools.
8	What age range of pupils are you teaching this academic year?	• Reception • Key stage 1 • Key stage 2	Options relevant to primary schools.
9	Roughly how many pupils are on your school's roll?	• Fewer than 500 • 500-1000 • 1000-1500 • 1500-2000 • Over 2000	Options more relevant to secondary schools.
10	What age range of pupils are you teaching this academic year?	• Key stage 3 • Key stage 4	Options relevant to secondary schools.

		• Key stage 5	
11	How many years teaching experience do you have?	• 0-2 years • 2-5 years • 5-10 years • 10-15 years • Over 15 years	
12	Do you have a laptop or tablet provided by your school?	• Laptop • Tablet • Both • Neither	
13	Do you use your own personal device (e.g. laptop) to do schoolwork at home?	• Yes • No	Piped question from 'Neither' on question 12.
14	Do you use social media for work purposes?	• Yes • No	
15	Which of the following social media platforms do you use for work purposes?	• Facebook • Twitter • Instagram • YouTube • WhatsApp • Messenger • WeChat • Tumblr • Snapchat • Other – please specify	Piped question from 'Yes' on question 14. Respondents select all options that apply.
16	What things do you do when you use social media for work purposes?	• I follow specific individuals whose work or views I am interested in • I look at what other people are saying	Piped question from 'Yes' on question 14, following question 15. Respondents select all options that apply.

		• I share things already on social media that I think are important (e.g. re-tweeting) • I contribute my own ideas or views (e.g. about how to teach certain topics) • I share my own work for other teachers to see or use • I use it to communicate with a group of colleagues in my school about work issues • I use it to communicate with pupils • I use it to communicate with teachers who work in other schools • Other – please specify	
17	What is the first part of your school's postcode? (This is just to help give a rough location for your school - it does not identify your school)	Text entry.	
18	If you know your school's last inspection rating, please indicate it below:	• Outstanding • Good • Requires improvement • Inadequate: serious weaknesses • Inadequate: requires special measures • Don’t know	
19	If you hold a Teaching and Learning Responsibility (TLR), please indicate what it is here:	Text entry	

20	What is your awareness of internet access at home for the pupils you teach?	• I don't know much about this • Most homes have at least one internet-connected device other than a smartphone • Most pupils have a smartphone • Most pupils have access to their own PC, laptop or tablet • Pupils I teach are too young to go on the internet unsupervised • Most pupils will probably struggle to access the internet • Other - please specify	Respondents select all options that apply.
21	Do you feel that science has maintained its importance in your school's curriculum during lock-down?	• Yes • No • Probably not • I'm not sure	
22	Before lock-down which of the following things did you do frequently in your science teaching?	• Showed pupils things from the internet (e.g. YouTube videos) • Showed pupils presentations (e.g. PowerPoint) • Set homework that required pupils to use the internet (e.g. for research or to access tasks you'd set) • Set tasks in which pupils used technology in lessons to make digital content (e.g. presentations, videos etc)	Respondents select all options that apply.

		• Set tasks in which pupils used digital technology for experiments (e.g. data-loggers, digital microscopes etc) • Set tasks which required pupils to use the internet in lessons • None of the above	
23	Has the lock-down made you think about changing any aspects of your teaching in the future - for example, making more use of online tools or resources?	• Yes • No • I'm not sure	
24	Please indicate briefly what changes to your teaching you are thinking about as a result of the lock-down.	Text entry	Piped question from 'yes' on question 23.

Survey section 2: **Questions relevant for primary teachers only (piped according to question 5)**

Q. No.	Question wording	Answering • Indicates options	Notes
25	Have you provided any science education for pupils during lock-down? (E.g. remote science teaching, providing materials or instructions for pupils etc)	• Yes • No	
26	What sort of response have you had from pupils for the science education you've provided?	• About half have engaged with it • I can't really tell • Most have engaged with it • Fewer than half have engaged with it	Piped question from 'yes' on question 25.
27	How has this level of response from pupils varied during lock-down?	• It has stayed roughly the same • It has increased during lock-down • It has decreased during lock-down • I'm not sure how it's changed	Piped question from 'yes' on question 25, following question 26.
28	Please indicate the reason(s) you haven't provided any science for pupils during lock-down	• My school is prioritising other subjects • I'm a trainee teacher • A colleague is dealing with science for my pupils • I would need professional development • Technological reasons (please give brief details) • Other reasons (please explain briefly)	Piped question from 'no' on question 25.
29	Has the science education you have provided required pupils (or their parents) to use the internet?	• Yes • No	Piped question from 'yes' on question 25, following question 27.

30	Please describe briefly what things you have done, without the internet, to provide science for pupils.	Text entry	Piped question from ‘no’ on question 29.
31	Why haven't you asked pupils (or their parents) to use the internet for science during lock-down?	Text entry	Piped question from ‘no’ on question 29, following question 30.
32	Which of the following describe things you have done during lock-down that have required pupils or their parents to use the internet?	• I've emailed parents • I've emailed pupils • I've put work or instructions on the school website or social media • I've done 'live' teaching using a video conference tool (e.g. Zoom, Teams etc) • I've used social media messaging (e.g. WhatsApp, Twitter etc) • Other - please specify	Piped question from ‘yes’ on question 29. Respondents select all options that apply.
33	What sort of science work involving the internet have you asked pupils to do during lock-down?	• Go on specific websites (e.g. BBC Bitesize) • Watch science videos (e.g. on YouTube) • Complete tasks that you've set (e.g. worksheets) • Do online quizzes • Send digital content to you (e.g. completed tasks, photos or videos) • Other - please specify	Piped question from ‘yes’ on question 29, following question 32. Respondents select all options that apply.

34	Which video-conferencing platform(s) have you used?	• Zoom • Google Hangouts • ClickMeeting • GoToMeeting • Adobe Connect • Skype • WebEx • RingCentral Video • BigBlueButton • Microsoft Teams • Other – please specify	Piped question from selecting of LRT option on question 32, following question 33. Respondents select all options that apply.
35	Roughly what proportion of your pupils have you been able to use videoconferencing with?	• Fewer than a quarter • Fewer than half • About half • Between half and three quarters • Over three quarters	Piped question from selecting of LRT option on question 32, following question 34.
36	Compared to attending normal science lessons, how good do you think the science education your pupils have received during lock-down has been?	• Better • At least as good • Almost as good • A bit worse • A lot worse • No opinion • Don’t know	
37	What has influenced your view of the quality of the science education you've provided during lock-down?	• Pupil communication or feedback • Parent communication or feedback • Colleague communication or feedback	Respondents select all options that apply.

		• Senior leadership communication or feedback • Just my own opinion	
38	Have pupils and/or parents contacted you directly with science-related questions?	• Yes • No	
39	Have you had any requests for extra science work (i.e.. additional to work you have already set)?	• Yes • No	
40	Please indicate if you have used the websites of any of the following organisations to help you provide science education during lock-down, either for your own planning or for pupils to use. You can add others if you wish.	• BBC • National STEM Centre • Twinkl • TES (Times Educational Supplement) • ASE (Association for Science Education) • Wow Science • Ogden Trust • Centre for Industry Education Collaboration (CIEC) • Primary Science Teaching Trust • Other • I haven't used any of these	
41	Are there websites or online tools that you have found to be particularly useful, and which you would definitely recommend if lock-down conditions happen in future? If so please specify	Text entry	

	what they are. (This could include things that you, but not pupils, have used).		
42	Have you also asked children to do things for which they've not needed the internet? (E.g. home experiments, going outside to look for things etc)	• Yes • No	
43	What sort of things have you asked pupils to do that hasn't required them to use the internet?	Text entry	Piped question from 'yes' on question 42.
44	How easy has it been to continue providing science work for pupils during lock-down?	• It has become easier • It has become more difficult • It has been difficult throughout the whole of lock-down • It has become more difficult • The ease/difficulty has remained the same • It has been fairly easy throughout the whole of lock-down	Respondents select all options that apply.
45	What do you think would have improved the quality of the science education you have supplied during lock-down?	• If pupils had had better access to technology • If I'd had better knowledge of how to provide remote learning • If there had been better ways to communicate with pupils or parents • If I'd known about better resources for providing remote learning	Respondents select all options that apply.

		• If I'd had better access to technology (e.g. not having to share devices) • If I'd had better quality technology (e.g. better hardware, • If I'd been able to contact someone who could help me • I can't think of anything • Other - please specify	
46	Would you be prepared to participate in an interview to have a more in-depth discussion about some of the issues raised in this questionnaire?	• Yes – my email address is: • No	

Survey section 3: **Questions relevant for secondary teachers only (piped according to question 5)**

NB. Most questions are the same as for primary teachers; there are three extra questions, 50, 59 and 69, and some answering options differ slightly.

Q. No.	**Question wording**	**Answering** • Indicates options	**Notes**
47	Have you provided any science education for pupils during lock-down? (E.g. remote science teaching, providing materials or instructions for pupils etc)	• Yes • No	
48	What sort of response have you had from pupils for the science education you've provided?	• About half have engaged with it • I can't really tell • Most have engaged with it	Piped question from 'yes' on question 47.

		• Fewer than half have engaged with it	
49	How has this level of response from pupils varied during lock-down?	• It has stayed roughly the same • It has increased during lock-down • It has decreased during lock-down • I'm not sure how it's changed	Piped question from 'yes' on question 47, following question 48.
50	How has the level of engagement varied for different year groups?	• It has depended on the specific class, rather than age • It's been hard to tell • It's been similar for all groups • Older pupils have engaged more • Younger pupils have engaged more	Piped question from 'yes' on question 47, following question 49.
51	Please indicate the reason(s) you haven't provided any science for pupils during lock-down	Text entry	Piped question from 'no' on question 47.
52	Has the science education you have provided required pupils (or their parents) to use the internet?	• Yes • No	Piped question from 'yes' on question 47, following question 50.
53	Please describe briefly what things you have done, without the internet, to provide science for pupils.	Text entry	Piped question from 'no' on question 52.
54	Why haven't you asked pupils (or their parents) to use the internet for science during lock-down?	Text entry	Piped question from 'no' on question 52, following question 53.
55	Which of the following describe things you have done during lock-down that have required pupils or their parents to use the internet?	• I've emailed parents • I've emailed pupils • I've put work or instructions on the school website or social media	Piped question from 'yes' on question 52. Respondents select all options that apply.

		• I've used the school's Virtual Learning Environment (VLE) • I've done 'live' teaching using a video conference tool (e.g. Zoom, Teams etc) • I've used social media messaging (e.g. WhatsApp, Twitter etc) • Other - please specify	
56	What sort of science work involving the internet have you asked pupils to do during lock-down?	• Go on specific websites (e.g. BBC Bitesize) • Watch science videos (e.g. on YouTube) • Complete tasks that you've set (e.g. worksheets) • Do online quizzes • Send digital content to you (e.g. completed tasks, photos or videos) • Other - please specify	Piped question from 'yes' on question 52, following question 55. Respondents select all options that apply.
57	Which video-conferencing platform(s) have you used?	• Microsoft Teams • Zoom • Google (Hangouts, Meet, Classroom) • Skype • Adobe Connect • Others	Piped question from selecting of LRT option on question 55, following question 56. Respondents select all options that apply.
58	Roughly what proportion of your pupils have you been able to use videoconferencing with?	• Fewer than a quarter • Fewer than half • About half	Piped question from selecting of LRT option on question 55, following question 57.

		• Between half and three quarters • Over three quarters	
59	What was the state of readiness of the school's VLE for supporting remote learning in science?	• I don't know • It has required a lot of updating • It has required a moderate amount of updating • It required a little additional preparation • It was completely ready	Piped question from selecting of VLE option on question 55, following question 56 (and LRT questions if applicable).
60	Compared to attending normal science lessons, how good do you think the science education your pupils have received during lock-down has been?	• Better • At least as good • Almost as good • A bit worse • A lot worse • No opinion • Don’t know	
61	What has influenced your view of the quality of the science education you've provided during lock-down?	• Pupil communication or feedback • Parent communication or feedback • Colleague communication or feedback • Senior leadership communication or feedback • Just my own opinion	Respondents select all options that apply.
62	Have pupils and/or parents contacted you directly with science-related questions?	• Yes • No	

63	Have you had any requests for extra science work (i.e.. additional to work you have already set)?	• Yes • No	
64	Please indicate if you have used the websites of any of the following organisations to help you provide science education during lock-down, either for your own planning or for pupils to use. You can add others if you wish.	• ASE (Association for Science Education) • National STEM Centre • TES (Times Educational Supplement) • BBC • IoP (Institute of Physics) • RSC (Royal Society of Chemistry) • RSB (Royal Society of Biology) • AQA • OCR • Edexcel • Teachitscience • Twinkl • I haven't used any of these • Other – please specify	Respondents select all options that apply.
65	Are there websites or online tools that you have found to be particularly useful, and which you would definitely recommend if lock-down conditions happen in future? If so please specify what they are. (This could include things that you, but not pupils, have used).	Text entry	

66	Have you also asked children to do things for which they've not needed the internet? (E.g. home experiments, going outside to look for things etc)	• Yes • No	
67	What sort of things have you asked pupils to do that hasn't required them to use the internet?	Text entry	Piped question from 'yes' on question 66.
68	How easy has it been to continue providing science work for pupils during lock-down?	• It has become easier • It has become more difficult • It has been difficult throughout the whole of lock-down • It has become more difficult • The ease/difficulty has remained the same • It has been fairly easy throughout the whole of lock-down	Respondents select all options that apply.
69	How easy has it been to monitor pupils' science learning during lock-down?	• It has become easier • It has become more difficult • It has been difficult throughout the whole of lock-down • It has become more difficult • The ease/difficulty has remained the same • It has been fairly easy throughout the whole of lock-down	

70	What do you think would have improved the quality of the science education you have supplied during lock-down?	• If I'd had better quality technology • If I'd had better access to technology • If pupils had better access to technology • If I'd had better knowledge of how to provide remote education • If I'd known about better resources for providing remote learning • If there had been better ways to communicate with pupils or parents • If I'd been able to contact someone who could help me • I can't think of anything • Other – please specify	Respondents select all options that apply.
71	Would you be prepared to participate in an interview to have a more in-depth discussion about some of the issues raised in this questionnaire?	• Yes – my email address is: • No	

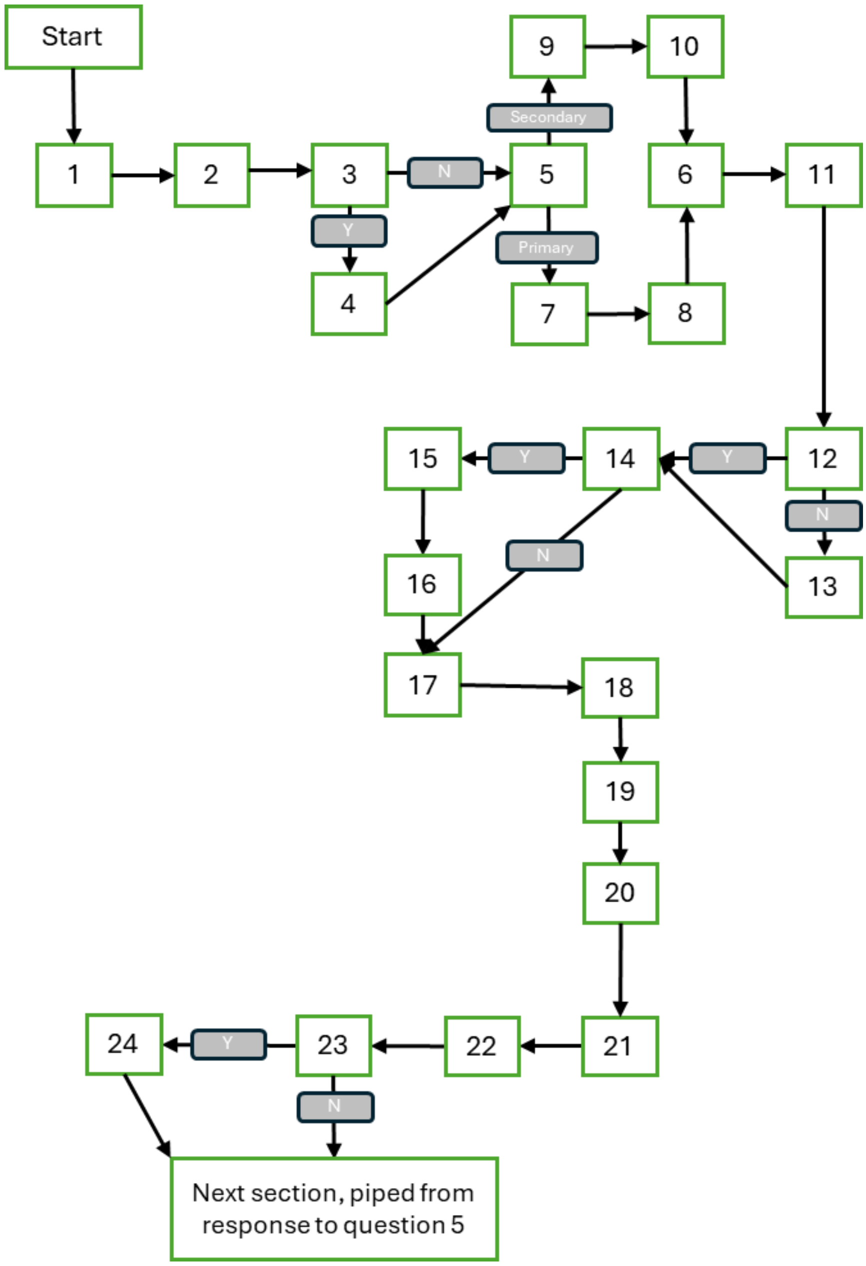
Appendix 4: Teacher survey flow diagrams

Numbers in boxes represent questions. Question wording can be found in appendix 3. ‘Y’ and ‘N’ show different pathways for ‘Yes’ and ‘No’ responses, respectively.

<u>Teacher survey section 1:</u>

About you and your school

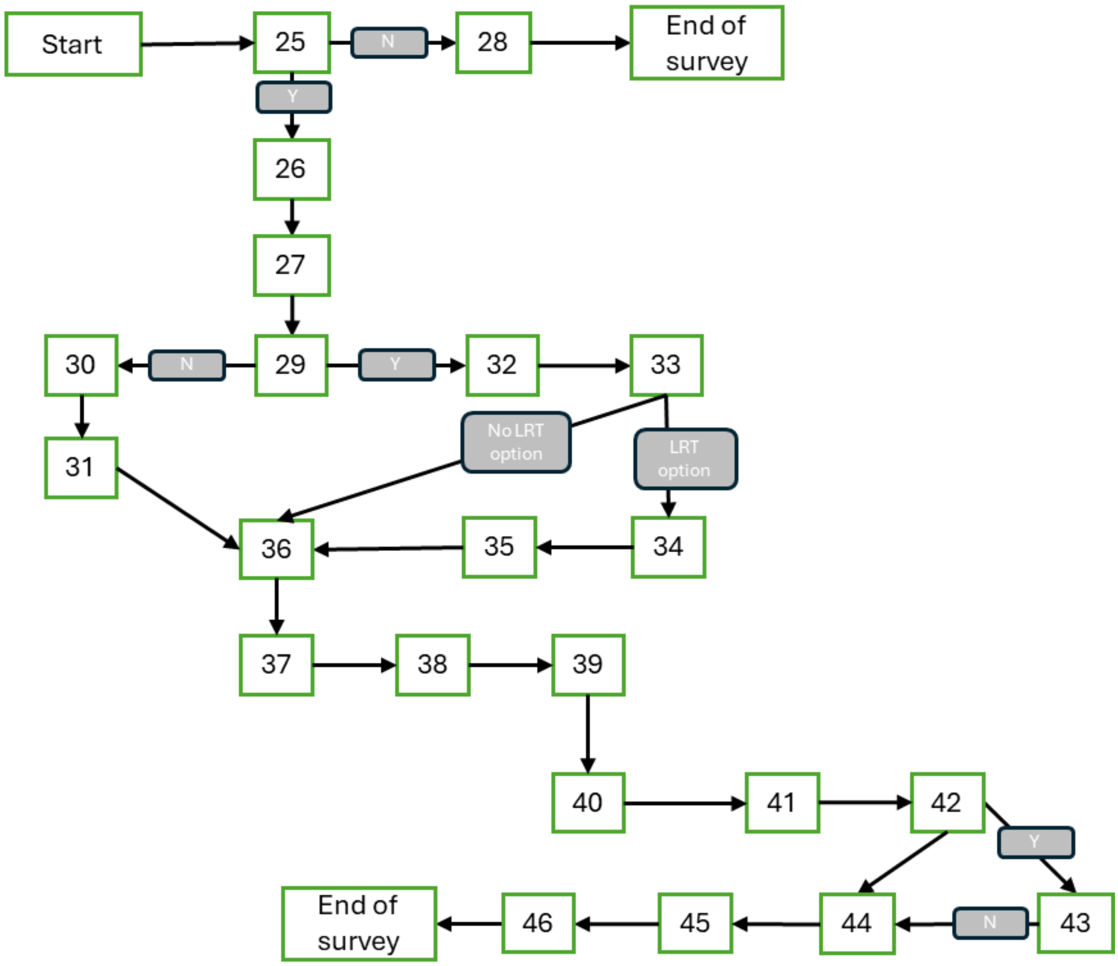
(Total 24 questions)



<u>Teacher survey section 2:</u>

Questions relevant for primary teachers only

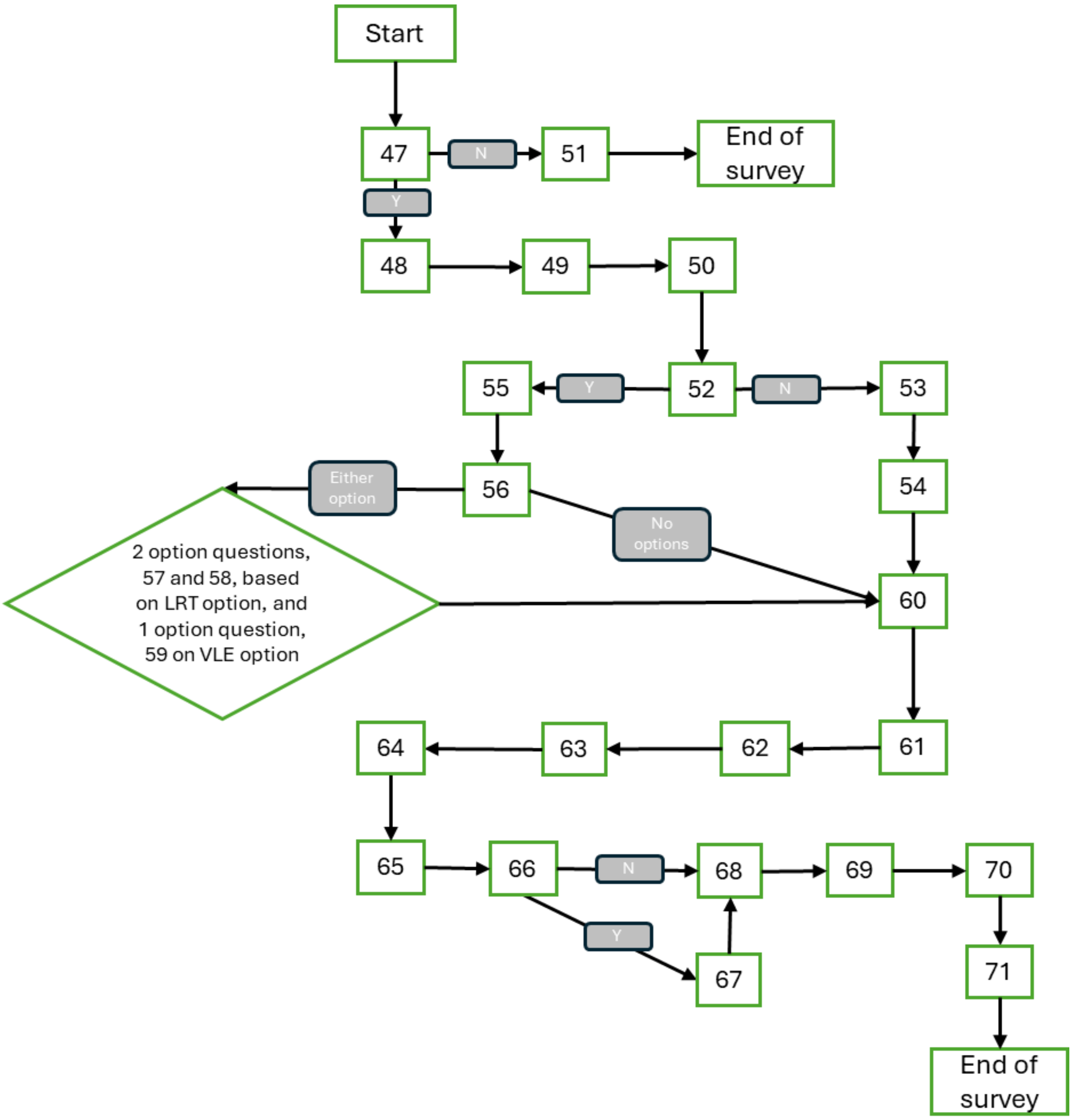
(Piped according to question 5 in section 1 - Total 22 questions)



<u>Teacher survey section 3:</u>

Questions relevant for secondary teachers only

(Piped according to question 5 in section 1 - Total 25 questions)



Appendix 5: Parent survey questions and tabulated structure

Survey section 1: **About you, your home and family (Total 24 questions)**

Q. No.	Question wording	Answering • Indicates options	Notes
1	What is your age?	• Under 25 • 25-29 • 30-39 • 40-49 • 50+ • Prefer not to say	
2	Do you class yourself as a single parent?	• Yes • No • Prefer not to say	
3	What is your gender?	• Female • Male • Other • Prefer not to say	
4	What is the first part of the postcode where you live? (This does not identify your house; it just gives an approximate location).	Text entry	
5	Does your home have broadband?	• Yes • No	
6	How would you describe the speed of your broadband connection?	• Slow • Fast some of the time	Piped question from 'Yes' on question 5.

		• Fast all of the time • I don't know	
7	What is your highest level of educational qualification in ANY subject?	• No educational qualifications • GCSE or equivalent (e.g. 'O' level) • 'A' level or equivalent (e.g. AS level, level 3 NVQ) • HNC or equivalent (e.g. level 4 NVQ) • Foundation degree or equivalent (e.g. HND or level 5 NVQ) • Honours degree or equivalent (e.g. graduate diploma or level 6 NVQ) • Masters degree or equivalent (e.g. postgraduate certificate) • Doctorate or equivalent (e.g. level 8 diploma)	
8	What is your highest level of qualification in a SCIENCE, SCIENCE-RELATED or TECHNICAL subject?	• None • GCSE or equivalent (e.g. 'O' level) • 'A' level or equivalent (e.g. AS level, level 3 NVQ) • HNC or equivalent (e.g. level 4 NVQ) • Foundation degree or equivalent (e.g. HND or level 5 NVQ) • Honours degree or equivalent (e.g. graduate diploma or level 6 NVQ) • Masters degree or equivalent (e.g. postgraduate certificate)	

		• Doctorate or equivalent (e.g. level 8 diploma)	
9	How many school-age children do you have?	• 1 • 2 • 3 • More than 3	
10	What kind of school(s) do they attend?	• Primary • Middle • Secondary • Special • They are home-educated • Other – please specify	
11	Were any of your children due to take exams this year (e.g. GCSEs)?	• Yes • No	
12	Are you, or anyone in your household, currently a schoolteacher or teaching assistant?	• No • Yes – I am • Yes – someone else in my household is • Yes – I am and someone else in the household is	
13	Have you worked as a schoolteacher or teaching assistant in the past?	• Yes • No	Piped question from 'No' on question 12.
14	Are you, or have you been, a science teacher?	• Yes • No	Piped question from 'Yes – I am' on question 12.

15	Is the other person in the household a science teacher?	• Yes • No	Piped question from 'Yes – someone else in my household is' on question 12.
16	Are either of you science teachers?	• Yes – I am • Yes – someone else in the household is • No	Piped question from 'Yes – I am and someone else in the household is' on question 12.
17	Do you think that the presence of a teacher or teaching assistant in the house during lock-down has given your child an advantage in their learning?	• Yes • No • I'm not sure	Piped question from any response except 'No' on question12.
18	Does your child/children use the internet at home?	• Yes • No • I don't know	
19	What do they use to connect to the internet at home?	• Laptop • PC • Tablet • Smartphone • Games console • Smart TV or internet-enabled TV • Other (Please specify)	Piped question from 'Yes' on question 18.
20	Please indicate how you allow your child/children to access the internet at home.	• I allow access for a certain amount of time each day or at specified times • I use parental controls on their device to control which websites they can access	Piped question from 'Yes' on question 18, following question 19.

		• They are allowed to use the internet whenever they want to • They are not allowed to use the internet except in communal living areas • They can use the internet anywhere in our home • Other - please specify briefly	
21	During lockdown, have you or your child/children experienced a break in your internet connection or a significant drop in its speed?	• Yes – quite often • Yes – occasionally • Not that I can recall	Piped question from ‘Yes’ on question 18, following question 20.
22	How do you think your child's/children's interest in science has been affected by the global coronavirus pandemic?	• I’m not sure • Their interest in science seems no different • They are less interested because of the pandemic • They are more interested because of the pandemic • They are now more interested in a specific part of science (e.g. medicine)	
23	Does your child/children appear to have been more worried or depressed about anything because of the coronavirus pandemic?	• Yes • No • I’m not sure	

24	What things do you think they have been worried or depressed about? (Please select all that apply - you can add others at the bottom).	• Health of other people (e.g. family or friends) • Their own health • Loss of opportunities to do things they enjoy (e.g. play communal sport, see friends etc) • Other long-term effects (e.g. whether life will return to 'normal') • Their education suffering because of lock-down • Other - please specify briefly	Piped question from ‘Yes’ on question 23.

Survey section 2: **Questions relevant for parents of home-educated children only (Total 22 questions)**

Q. no.	Question wording	Answering • Indicates options	Notes
25	How many children are home-educated in your household?	• 1 • 2 • More than 2	
26	Please state the age of the child you home-educate.	Text entry	Piped question from '1' on question 25.
27	Please state the ages of the children you home-educate.	Text entry	Piped question from '2' or 'More than 2' on question 25.
28	Have you experienced much of a change in your home-education routine due to lock-down?	• Yes – quite a lot • Yes – a little • Not really • Definitely not • I'm not sure	
29	What sort of things have caused this change? (Please select all that apply)	• Inability to visit public places as part of the education I/we provide • Inability to visit homes of other home-educated children • Other member(s) of the household has been at home rather than at school • Other member(s) of the household has been at home rather than at work • I have had to take on extra work due to lock-down • Other - please specify briefly	Piped question from 'Yes – quite a lot' or 'Yes – a little' on question 28.

30	How, if at all, has your child's/children's motivation for doing home-education work changed during lock-down?	• I'm not sure • It hasn't really changed • They have become less motivated • They have become more motivated	
31	Do you normally communicate with other parents who provide home-education for their children, for instance to share ideas or resources?	• Yes – frequently • Yes – occasionally • No	
32	How does this communication usually happen? Please select all that apply.	• Face-to-face meetings, • Social media (e.g. Facebook, Twitter, WhatsApp etc) • Email • Phone • Other - please specify	Piped question from either 'Yes' option on question 31.
33	How has this communication changed, if at all, during lock-down? Please select all that apply.	• The amount of communication hasn't changed • There has been less communication • There has been more communication • The method(s) of communication have changed • The methods of communication have stayed the same	Piped question from either 'Yes' option on question 31, following question 32.
34	Is science normally something your child/children would learn about as part of their home-education?	• Yes • No	

35	How has the quantity of science education received by your child/children changed in lock-down, compared to normal?	• I don't think it's changed • I've done a lot less • I've done a bit less • I've done a bit more • I've done a lot more • I can't tell	Piped question from 'Yes' on question 34.
36	How do you think the quality of science education received by your child/children has changed in lock-down, compared to normal?	• It's definitely better • It's definitely worse • It's probably better • It's probably worse • The quality hasn't changed • I can't tell	Piped question from 'Yes' on question 34, following question 35.
37	Does the internet (e.g. using websites, watching videos on YouTube, video-conferencing etc) normally form a part of how your child/children learns about science?	• Yes • No	Piped question from 'Yes' on question 34, following question 36.
38	Are there any particularly useful websites or online tools which would normally help them learn about science? Please specify these if so.	Text entry.	Piped question from 'Yes' on question 37.
39	Has anything changed about the way the internet has been used for your child's/children's science education during lock-down, compared to	• Yes - it's been used more • Yes – it's been used less • Yes - it's been used to do or look at different things	Piped question from 'Yes' on question 37, following question 38.

	normal? Please select the most appropriate response.	• No - it's pretty much the same • I'm not sure	
40	What do you think the reasons are for the change in how the internet has been used?	Text entry	Piped question from 'Yes' options on question 39.
41	Please indicate if any of these other things have helped your child/children learn about science during lock-down. (Select all that apply - you can add more at the bottom).	• Observing nature (e.g. life in the garden, the weather etc) • Doing practical things with you at home (e.g. cooking, gardening etc) • Reading or looking at books • Going for walks outside • Talking to other family members or friends • Watching TV • Other – please specify	Piped question from 'Yes' on question 34.
42	Do you use any other public services or places to help you provide home-education for your child/children? (E.g. museums, libraries, parks, galleries etc)	• Yes – occasionally • Yes – often • No	
43	Are any of these public services or places particularly useful to help your child/children learn about science?	• No • Yes – please specify	Piped question from 'Yes' options on question 42.
44	How do you think the closure of public services like parks and libraries etc	• I don't know • It hasn't made much difference	Piped question from 'Yes' options on question 42, following question 43.

	during lock-down has affected your child's/children's science education?	• It's accelerated their learning about science • It's made it harder for them to learn about science • It's made it easier for them to learn about science • It's slowed down their learning about science	
45	Is there anything else that you have done during lock-down to help your child/children learn science, that you think has been important? Please describe it briefly.	Text entry	Piped question from 'Yes' on question 34.
46	Thank you very much for the time you have spent on this survey, and your responses. Would you be prepared to participate in an interview to have a more in-depth discussion about some of the issues raised in this questionnaire?	• Yes • No	'Yes' included text entry to supply an email address.

Survey section 3: **Questions relevant for parents of schooled children only (Total 31 questions)**

Q. no.	Question wording	Answering • Indicates options	Notes
47	You have indicated that your children attend different schools. To make it easier for you to answer the following questions, please select just ONE of the schools to base your answers on	• Primary • Middle • Secondary • Special • Other	Piped question if Q9 was greater than or equal to 2 and Q10 is *not* 'They are home-educated'.
48	How, if at all, has your child's/children's motivation for doing schoolwork changed during lock-down?	• It hasn't really changed • They have become less motivated • They have become more motivated	
49	Has your child/children been looking forward to returning to school?	• Yes • No • I'm not sure	
50	During lock-down, has the school provided or sent work for ANY subject for your child/children?	• Yes • No • I'm not sure	
51	Did the work provided or sent by the school include science?	• Yes • No • I'm not sure	Piped question from 'Yes' on question 50.
52	Do you think your child/children has learnt any science during lock-down anyway, even without science work from school?	• Yes • Maybe • No	Piped question from 'No' on question 50.

53	What things do you think have helped them learn science? (Select all that apply)	• Observing nature (e.g. life in the garden, the weather etc) • Doing practical things with you at home (e.g. cooking, gardening etc) • Watching TV • Watching science videos on the internet • Home lessons or talking to family members • Looking at books • Going for walks outside • Other – please specify	Piped question from 'No' on question 50, following question 52.
54	How important have these things been for helping your child/children learn science during lockdown? Drag them into a rank order. 1 is most important.	Ranking question	Piped question from 'No' on question 50, following question 53; choices carried forward from question53.
55	How has your child/children been made aware of their science work during lockdown? Please select all that apply.	• I'm not sure • By an email to my child • BY an email to me/parent/guardian • By post • By a message on the school website • By social media (e.g. Facebook, Twitter, WhatsApp etc) • Other method – please specify	Piped question from 'Yes' on question 51.
56	Do you know what kind of science work has been provided or sent by the school?	• Yes • I've got a rough idea • No	Piped question from 'Yes' on question 51, following question 55.

57	What sort of science work has been provided or sent? Please select all that apply.	• Written tasks such as worksheets • Looking up information on the internet • Watching videos online (e.g. on YouTube) • Online 'lessons' such as BBC Bitesize • Video conferences in which the teacher has taught in 'real time' • Tasks using physical resources such as books • Home experiments or observations (e.g. the weather, astronomy, living things etc) • Other – please specify	Piped question from 'Yes' on question 51, following question 56,
58	How important do you think these things have been for helping your child/children learn science during lockdown? Drag them into a rank order. 1 is most important.	Ranking question	Piped question from 'Yes' on question 51, following question 57; choices carried forward from question 57.
59	Do you know any of the websites that the school has asked your child/children to go on for science? Please list any that you know.	Text entry	Piped question from 'Looking up information on the internet' option on question 57.
60	Do you know any of the specific video channels (e.g. on YouTube) that your child/children was asked to watch to help them learn science? Please list any that you know.	Text entry	Piped question from 'Watching videos online' option on question 57.

61	Were there any technical problems with the videoconferencing?	• Yes – they were quite significant • Yes – minor ones • Not that I'm aware of	Piped question from 'Video conferences in which the teacher has taught in 'real time'' option on question 57.
62	Has your child/children expressed any opinion about the science work provided by the school?	• Yes, very positive • Yes, slightly positive • No, they have not told me their opinion • Yes, slightly negative • Yes, very negative	Piped question from 'Yes' on question 51.
63	Apart from the work provided or sent by school, has your child/children done any other things to help them learn science during lock-down?	• Yes • No • I don't know	Piped question from 'Yes' on question 51, following question 62.
64	Apart from what the school provided or sent, what things do you think have helped your child/children learn some science? (Select all that apply)	• Observing nature (e.g. life in the garden, the weather etc) • Doing practical things with you at home (e.g. cooking, gardening etc) • Watching TV • Going on websites about science • Watching science videos on the internet (e.g. on YouTube) • Home lessons or talking to family members or friends • Looking at books • Going for walks outside • Listening to podcasts • Other - please specify	Piped question from 'Yes' on question 63.

65	How important do you think the things you selected have been for helping your child/children learn science during lockdown? Drag them into a rank order. 1 is most important.	Ranking question	Piped question from 'Yes' on question 63, following question 64; choices carried forward from question 64.
66	Apart from what the school might have suggested, do you know any of the websites or other online content your child/children has used to help them learn science? Please list any that you know.	Text entry	Piped question from 'Yes on questions 18 and 61.
67	Have you had to learn anything to help your child/children learn science during lock-down?	• Yes • No	
68	Please indicate the sort of things you have had to learn so that you could help your child/children learn science. (Select all that apply).	• Facts, concepts or theories to do with science • Things about the science curriculum (e.g. what children need to learn) • Things about how to teach at home • Things about resources that I could use • Technical skills (e.g. how to use software or apps) • Other – please specify	Piped question from 'Yes on question 67.
69	How easy has it been for you to learn these things?	• Very easy • Quite easy • Neither easy nor difficult • Quite hard	Piped question from 'Yes on question 67, following question 68.

		• Very hard	
70	Please indicate which of the following statements you agree with about the science work your child/children's school has sent.	• I would have liked more science work for my child/children • I would have liked less science work for my child/children • I think the amount of science work sent was suitable • The quantity of science work was not an issue but the quality was • I have no opinion about this	Piped question from 'Yes' on question 67.
71	Please indicate briefly how or why the quality of the science work sent by the school was an issue for you.	Text entry	Piped question from 'The quantity of science work was not an issue but the quality was' option on question 70.
72	Have you or your child/children contacted school for any reason to do with science?	• Yes – I have • Yes – my child/children has • No	
73	Were you satisfied with the speed of the response from the school?	• Yes • No • Not applicable	Piped question from 'Yes' on question 72.
74	Was the response from the school helpful?	• Yes • No • Not applicable	Piped question from 'Yes' on question 72, following 73.
75	From your experience during this lock-down, how confident do you feel about helping your child/children learn science at home if there is another	• I feel more confident • I'm not sure • I feel less confident	

	lock-down, next academic year for instance?		
76	Is there anything else that *you* have done during lock-down to help your child/children learn science, that you think has been important? Please describe it briefly.	Text entry	
77	Thank you for the time you have spent on this survey, and your responses. Would you be prepared to participate in an interview to have a more in-depth discussion about some of the issues raised in this questionnaire?	• Yes • No	'Yes' included text entry to supply an email address.

Appendix 6: Parent survey flow diagrams

Numbers in boxes represent questions. Question wording can be found in appendix 5.

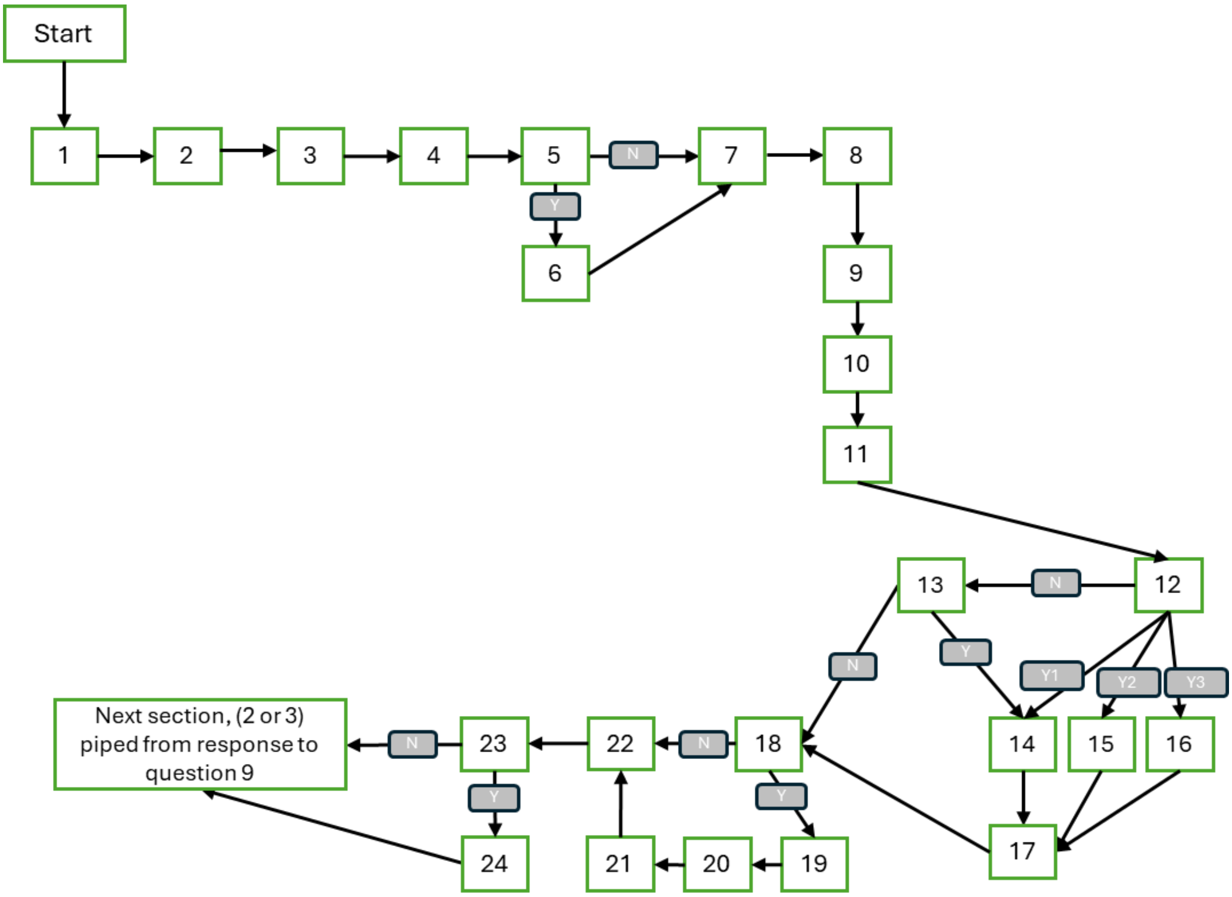
‘Y’ and ‘N’ show different pathways for ‘Yes’ and ‘No’ responses, respectively.

* Shows a pathway for another specific response.

Parent survey section 1:

About you, your home and family

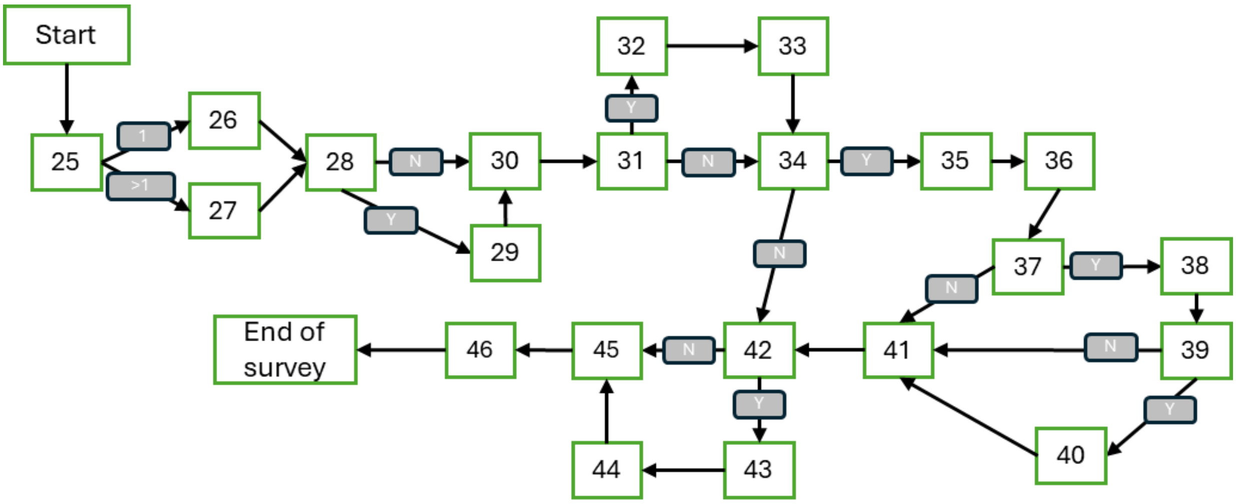
(Total 24 questions)



Parent survey section 2:

Questions relevant for parents of home-educated children only

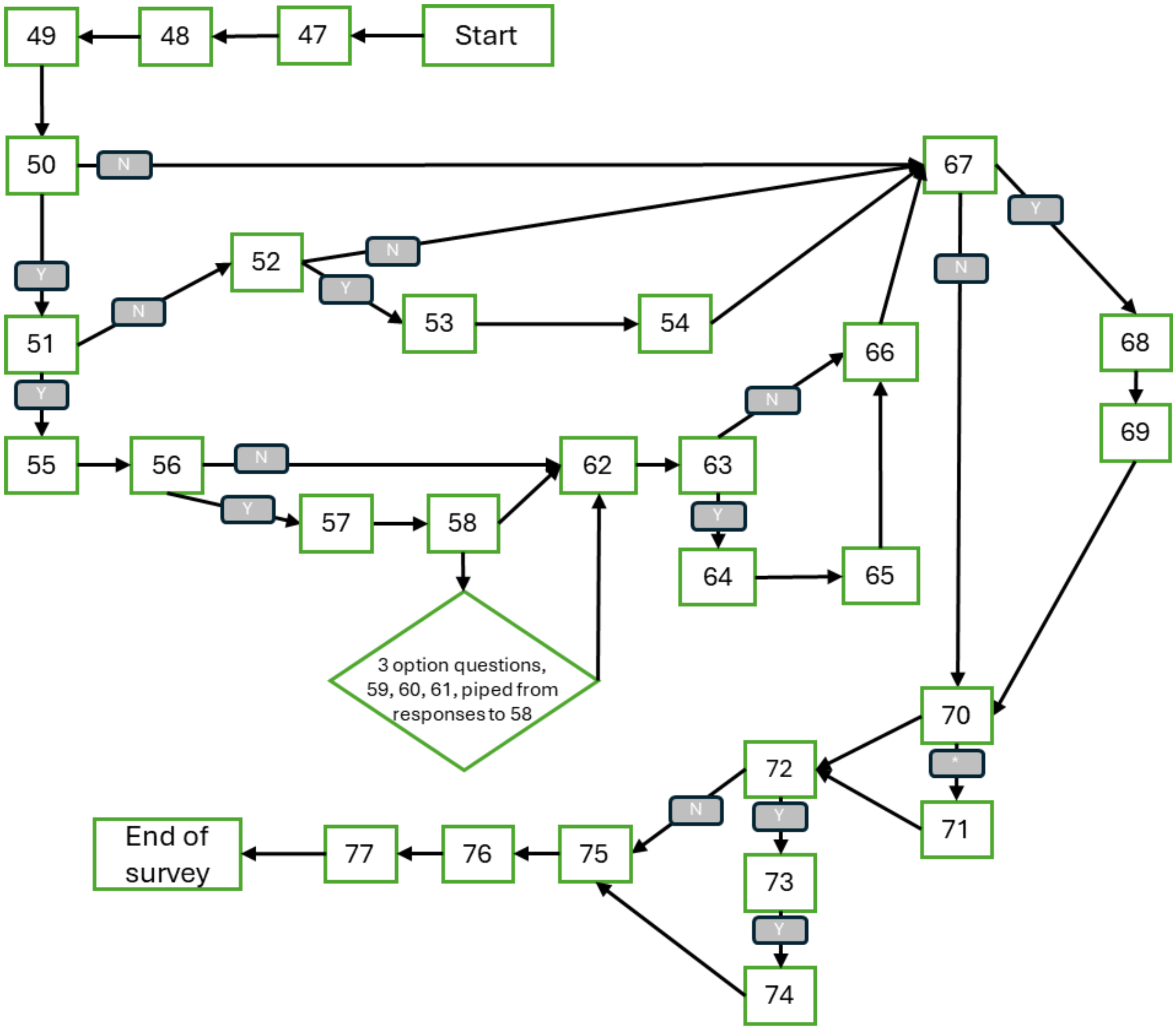
(Piped according to question 9 in section 1 - Total 22 questions)



Parent survey section 3:

Questions relevant for parents of schooled children only

(Piped according to question 9 in section 1 - Total 31 questions)



Appendix 7: Example of an interview script

The script below is from the teacher interview with Julia.

Julia (chemistry specialist)

Preamble

First of all thank you for giving up your time…summer holiday etc.

I've scheduled an hour; can I check if you need to dash off at 11 – if we over-run by a little bit is that OK?

Obviously I know you're probably at home, so if you need to go and deal with things, answer the door etc that's fine.

I'll tell you when I start recording and you can say as much or as little as you like in response to the questions, and if you want to change your mind about anything that's fine, just say whatever it is you're thinking. And if you want to ask any questions please just do so.

I've got two screens here so I might not be looking at the camera all the time.

Notes from survey	Interviewer script
	• I'd like to start with a pretty general question about the role of digital technology in your life generally, either in your personal life or for work. So, I mean things like computers and everything you might use them for, the internet, social media and so on. This is just to help me get a sense of the kind of relationship you have with

	technology; so for example, whether you really like technology or if you just see it as a useful tool; if you've used technology for a long time, perhaps getting into it as a child or whether you were an adult before you really started using it, and so on - just feel free to tell me about things like that.
• Julia is a secondary school science teacher with 5-10 years' experience. • She teaches KS3 and 4 in a school of 500-1000 pupils in the SO45 postcode district (Fawley area of Southampton). • The last inspection rating for the school was Good. • During lockdown she was teaching in school occasionally.	• Tell me about how the working in school occasionally worked. • Was it the same for other science teachers and other teachers?
• Julia uses a laptop at home. • She does not use social media for personal use, but does use Twitter for work purposes, (I use it to communicate with a group of colleagues in my school about work issues, I look at what other people are saying, I follow specific individuals whose work or views I am interested in). • Julia has a laptop provided by school.	• Do you use Twitter with pupils? • How do you think your classes benefit from what you do on Twitter?

• Most pupils have a smartphone, but suggests there is a lack of computers at home. • She feels science has not maintained its importance in the school curriculum during lockdown.	• Is the lack of computers at home something you've picked up? • Why do you think science hasn't maintained its curriculum importance at school?
• Before lockdown Julia Showed pupils things from the internet (e.g. YouTube videos),Showed pupils presentations (e.g. PowerPoint),Set tasks which required pupils to use the internet in lessons, Set homework that required pupils to use the internet (e.g. for research or to access tasks you'd set),Set tasks in which pupils used digital technology for experiments (e.g. data-loggers, digital microscopes etc)	• It looks like you make quite extensive use of technology in your lessons. Is this something you've refined and developed over the years you've been teaching?
• Lockdown has made her think about changing aspects of her teaching: more simulations/videos for practical work • PhET has been a particularly useful resource.	• Tell me what things have made you want to make these changes. • Did you use PhET before? • Tell me what's good about it.
• Julia has set science work during lockdown; about half of her pupils have engaged with it. This level of engagement has stayed the same, and has depended on the specific class rather than age. • The work has required pupils to use the internet. I've emailed parents, I've emailed pupils, I've	• Why do you think the other half haven't engaged? • Which classes have engaged most and least – is this how you would have expected it? • What has been the main way you've provided science work? • How has the 'live' teaching been – what has worked well and what have been the challenges?

put work or instructions on the school website or social media, I've done 'live' teaching using a video conference tool (e.g. Zoom, Teams etc), I've used the school's Virtual Learning Environment (VLE) • The work has included: Go on specific websites (e.g. BBC Bitesize), Watch science videos (e.g. on YouTube),Complete tasks that you've set (e.g. worksheets),Send digital content to you (e.g. completed tasks, photos or videos)	• Were the websites and science videos well-matched to what you wanted pupils to learn? • How has your workload compared?
• She has used Zoom, Adobe Connect, Microsoft Teams for videoconferencing. • Less than half of her pupils have been able to use videoconferencing.	• Why have you used more than one platform? • Did one perform noticeably better?
• The VLE required a moderate amount of updating.	
• Julia feels the science education has been almost as good as normal, which is from My own opinion, Pupil communication or feedback,	• How has this feedback reached you?

Parent communication or feedback, Senior leadership communication or feedback. • Things which would have improved the quality of science education during lockdown: If I'd had better quality technology (e.g. better hardware, better broadband etc), If pupils had had better access to technology, If there had been better ways to communicate with pupils or parents	• Tell me about the ways that you think these things would have made it better.
• Pupils and parents have contacted her with science-related questions, and extra work has been requested.	
• She has used websites of Association for Science Education, National STEM Centre, TES, BBC, Royal Society of Chemistry to help her provide science education.	• How have these sites been helpful?
• Julia has asked pupils to do stuff other than use the internet. This has included practicals - speed of sound/measuring shadows, 3d modelling of leaves, creative construction solar system	• Tell me a bit more about these things – are they things you were doing already?
• It has become easier to provide science education during lockdown.	• Some people have said it's been harder to keep providing science education – why did you find it getting easier?

• It has been quite difficult to monitor pupils' science learning.	• What was difficult about monitoring pupils' learning?
	• During lockdown, have you been participating in any CPD? What has been your experience of this, and how useful has it been? • Do you think there is any CPD which would have helped you respond to the challenges of lockdown better? • Looking ahead, has lockdown helped you identify any professional development needs? • Do you think anything in science education will get better or worse as a result of lockdown, and if so what?

Appendix 8: Example of an interview transcript

Julia

Time	Person	
0:00	John	I'd like to start by asking you a general question about the role of technology in your life and by that I mean particularly digital technology things like computers mobile phones maybe till digital cameras The Internet all of that kind of stuff and how much of a role that plays in your life whether it's something you've been doing a long time or whether it's something you've come to perhaps more recently whether you really like it whether you don't like it and you just do it because it's necessary so just tell me somethings about your relationship with digital technology
0:44	Julia	So not particularly much myself obviously I've got three teenage boys so they use it loads they tend to sort of sort things out for me don't go on Facebook obviously with the school thing but tend to use Twitter a lot with the education bloggers I find that really useful so again phone wise personally just general use catch up with the family but the kind of Twitter for education is particularly good Internet again kind of general basic use TES for various things school wise it kind of knocks into simulation like PhET programmes we use in school University of Reading have got a really good photosynthesis simulation so we do use those currently in school but where we are at the moment is quite a weird area kind of compared to where I've worked before in that the kids don't have a lot of access at home to the digital stuff so although a lot of them have phones we tend to kind of prioritise that what they can do on their phones we use a lot of QR codes linking to homeworks that they can kind of scan watch experiments we can't always get computer room to get research in school so they will use their phones in the classroom to look stuff up again it's just kind of clear signals but when they can get their phone out and when they can put it away and we use visualisers in the classroom again we use things like Kahoot and that how we use things linking to quizzes and clicker as well
2:41	John	it sounds like you do quite a lot actually work wise with technology then
2:44	Julia	More than I expected
2:48	John	but it sounds like you perhaps are sort of deliberately avoiding some of the social media like Facebook you

		mentioned that you weren't doing that what's your kind of take on that
3:01	Julia	well as I say I know our kids have quite big trust issues they feel like cos we have quite a high turnover of staff in the school there's quite a lot of trust issues and they kind of don't expect you to stay and there's a lot of suspicion about you so again if you tend to release information they will go searching for you and have a look and see what they can find and it's just a bit about a) kind of managing that but then if they ask you know just being able to have that conversation with the kids that it's not the be all and end all there's ways to talk and catch up with your friends but actually again from our point of view verbal literacy is really important and that they understand how to talk science and talk to each other and talk to adults and if kind of every tutor time or every break time they just stick their head down and jump on their phone and start pinging pictures across to each other that's kind of missing that step out which then helps to the extra learning when you want to get it down on paper
4:09	John	so it sounds like obviously phones are allowed in school
4:14	Julia	yeah it's the first one I've been at where they have been it is break time and lunchtime is that time to use it unless the teacher explicitly says they can come out in lessons
4:26	John	I'm quite interested in that actually nobody else has mentioned that so far how do you find it's working because a lot of schools obviously actively avoid getting children to bring their phones in or they try to avoid it whereas your school clearly is making use of it so how well does that seem to be working
4:50	Julia	I think different departments deal with it different ways again there's got to be trust with your students that if you're asking them to use it there not pinging texts across and doing stuff that you're not asking them to do one way we've done it similar to the way we've used laptops is if actually the kids kind of hold their phone up in front of their face but everyone faces the back of the room and you can see all of their screens so if they're you've kind of got a bit more control then you can have a quick scan you can be walking around the room and seeing what they're doing so they understand that kind of their screens are more visible I think you can't avoid it in a way and I'd rather promote the positive use of what the phone can do to them or for them in their learning there's loads of free revision apps that come on for year 11 if they are used to using it as part of their learning and they

		maybe don't have laptops or tablets at home they are going to rely on that technology and teaching is going more and more towards it at the moment as we found out in the last kind of few weeks so I'd rather kind of have that trust in a way and kind of instil ways that their phone can be useful they can watch a video for 10 minutes and recap kind of topics that they don't understand or we can put the links into the homework for them to watch it also QR code it but it hopefully it gives it a more positive relationship rather than just being something they can have a go at their friends on
6:24	John	thank you that's something actually that we'll perhaps come back to or it will be relevant to some of the things that we're going to talk about so I've got your survey responses here and really the questions I'm asking are largely based around those so you said that during lockdown you were working in school occasionally just tell me how that worked and whether it was the same for other science teachers and other teachers in school
6:55	Julia	so as head of Department I was in once a week so that was again initially sorting out the year 11 tiering and grades it then was crossover with the technician and sorting out again all of our practical areas and then how we're going to change that moving forward and then when the year 10s came back we worked in bubbles one day a week so we had one English teacher one maths teacher one science teacher that worked with the Monday bubble and then equivalent for the rest of the week to ensure that we could isolate if we needed to so it's kind of been a bit of a variety but in general it's kind of been one day a week across the entire time
7:42	John	okay and one of the other questions that was on the survey I'm just trying to find that it was about the importance of science in the curriculum and how you felt that had been during lockdown you put that you thought science hasn't maintained its importance in the curriculum during lockdown I was just interested in why you thought that
8:17	Julia	so obviously we schedule work on a portal which is kind of the school's VLE system and initially we were expected to load work on that was equivalent to their timetable so we had last year our key stage three got dropped a lesson so they were having 6 lessons a fortnight and our key stage three went down to five lessons a fortnight so we were scheduling five hours a week for them and our key stage four is 8 hours a fortnight and our triple scientists don't get any extra time so kind of that's kind of been a bugbear in general but as we have moved on through lockdown it was

		thought that the pressure on the students trying to complete a full day at home was too much and they needed to reduce the load but that load kind of meant that science and the options subjects went down to kind of one hour a week and English and maths got two to three hours a week which I then put my foot in it but science went back up to two to three hours a week as well but kind of from a general school perspective it just seemed to be that you know science wasn't a priority which I thought was a bit of a shame especially where it kind of crosses with so much else in the curriculum with your geography and your maths and kind of other stuff I think it's really beneficial that kind of they really keep their hand in with it as well as all the Practical skills
9:53	John	yeah it sounds like you fought your corner and won some time back
9:57	Julia	Yeah and it just surprised me that I needed to really
10:02	John	OK thank you so you mentioned that you use Twitter and you sort of follow people on Twitter do you ever use that with pupils at all or is it that just for your sort of your own professional purposes
10:18	Julia	no we kind of use it more of a sort of plenary or assessment for learning that they can write a tweet in their book in the style of Twitter so we kind of used that format and by them having to obviously condensed there answers down to 140 characters kind of is quite a nice tool they don't actually physically do it but we will make reference to it or they'll create Facebook pages for kind of important scientists in the curriculum kind of as part of that so it won't necessarily be that we expect them to kind of physically use it but we will use that format as part of their learning because that's what they're familiar with and it kind of gives them a bit more interest
11:02	John	so it's like a different medium for them to communicate you know in a particular way good thank you just going back to your professional use of Twitter I'm just interested in how you think you're students or maybe even your colleagues are benefiting from what you do and what you look at on Twitter
11:24	Julia	so there's a variety of kind of scientists on there so Adam Box is probably one that most people follow and he's has a chemical orthodoxy which is a Bank of resources that you can dip into and he is very free and kind of sharing a lot of things because he is so kind of open and forward and encouraging to people then a lot of other scientists

		contribute to that so it gives you kind of a way of developing your teaching and learning and looking at new styles of teaching that are coming in which can then get kind of spread out within the Department from kind of our point of view but it just broadens your horizons if as I say you're not able to get out there and attend conferences so again lockdown's being quite good in that kind of the amount of zoom kind of free webinars and things that have come up have been particularly useful but kind of my access to that from a CPD point of view is almost kind of self searching through a lot of what's coming through frontline on Twitter
12:33	John	well CPD is something I'm going to ask you about probably nearer the end actually so we'll definitely come back to that so you said that most kids have a smartphone but you suggested that they probably don't have computers at home or there's a lack there is that something that kids have told you or you just sort of think that's probably how it is how do you know about that
12:59	Julia	so if obviously we've loaded uploaded all our work onto the VLE we're quite a small school so about six 700 if the students haven't been able to access things online so we've obviously done the live lessons and we've had the resources available on the portal if there's been any issues so our contact as a tutor has being once a week and again if they can't access it we've not been able to get initially laptops out to them they've had to request a paper pack which has then been sent home so we I think sent I think last count was about 97 paper packs having gone out to students because they don't have access but I don't know what the final count was but that kind of gives us quite a good broad basis of the haves and have nots really a lot of the haves are having to so with the live lessons scheduling and timetabling they've again said they can't attend because their parents use it for work and they're actually not they're either working right at the beginning of the day or right at the end of the day when they've got access to the computer rather than during the middle of the day when our sessions are on so they've had more difficulty accessing those in addition
14:21	John	so even though the kids have maybe got their own smartphone it's been hard for them to do the live sessions with that
14:30	Julia	Yeah I'd say a lot of them haven't been too bad as I say they can access the lessons on the smart phones it's the ones where again we've had discussions with parents because obviously parents restrict phone time and what the Kids are

		doing on the phones and again making sure they understanding is there with the communication from the school to the parents about what's actually happening and what our expectation is with their phone time and how they're using their phone at home and how it can support their learning cos a lot of parents are very suspicious about that as well
15:10	John	right yes I mean it must have been really hard because obviously you've got to communicate with pupils and you've got to communicate with parents and you can't obviously see them face to face so I guess a lot of the time you're just hoping that pupils and parents are sort of on the receiving end of whatever it is you've communicating
15:32	Julia	yeah I mean we're getting about 2/3 attending this live lessons so of a class of 30 I'd expect kind of around 20 to be turning up consistently so again the uptake from that point of view slightly higher than we were expecting but again I think that's more phone access than computer helping that out
15:54	John	while we're on that then let's talk about that I mean how have you found that live teaching you know what have been some of the things that have worked and what have been the challenges of doing that
16:09	Julia	so as a safeguarding p.o.v. again we record or we have another adult in the room so whether it's a member of support staff that's joined us or another member of the Department so there'll always be extra adults in the room that's been really important because where we use the chat bars some of them have been really hesitant about having their video on and talking so a lot of them will sit there with their videos off and then type in on the chat bar we then have to again be able to monitor that chat bar so if you're teaching a lesson and they're going off on a tangent saying hi to each other how do you monitor that so having an extra adult in the room initially until we got into a really good routine What's really useful the other thing is that the kids are probably more tech savvy than most of us so they were finding ways to kind of take control of the programme and that so we had to get very up to speed on all of the kind of permissions and how we
17:08	John	just give me an example of how they were doing that
17:11	Julia	so depending on so you can join them to your class as a teacher or a student which is fine but if you join them as a guest so add an extra onto your class then unbeknownst that guest has the kind of teacher permission so they can

		take control of the PowerPoint and they can also kick students out of the lesson and just remove them as participants so they were quite enjoying that loophole for a while until we got hold of that one . so challenge initially was getting into a really good routine getting the students into the correct habits challenges were because a lot of them did kind of prefer to work with their cameras off you've got no facial expression to cue into if you're sat in front of them in the class it's really obvious when sometimes they just not getting it or losing interest in this one you've got no visual cues whatsoever Fortunately they like the emojis so you can get them to do quick thumbs up thumbs down emojis again it doesn't involve much time and they're quite happy to do that kind of as a general rule of how they're doing with it we did manage to get a couple of practicals done so some very basic practical that they could see and then go off Try themselves that was really successful cos again more of the quiz[] style more successful but again A lot more limitations we were using Microsoft Teams it seemed to glitch more as we went through as more people were using it and we had kind of more issues with it slowing down and the kids get frustrated with it getting a bit laggy and writing an answer to a question and not appearing for a minute or so but on the whole I say we could deliver a good PowerPoint we could come out of that and again share the screen and do a little bit of practical but I definitely found the visual cues quite tough if they weren't being particularly communicative kind of through the microphone and quick responses
19:30	John	you mentioned that you'd managed to do a little bit of practical what kind of things were they were these things you were demonstrating showing them and then things they could go off and do
19:39	Julia	yeah things like making a pinhole camera we had measuring size of shadows as you move the light source towards and away I've got pondweed in the garden so we could do a little bit of photosynthesis we made a 3D leaf model so again it was kind of showing ways of doing that measuring the speed of sound and how that so very basic cos again CLEAPSS don't allow you to bring anything home so I could possibly kind of video stuff in school and show it to them but again from home []complete at home anyway
20:23	John	so I notice you put those examples on the survey it sounds like they were things that you did in conjunction with the live teaching is that right
20:36	Julia	yeah yeah

20:39	John	OK thank you that's really interesting actually and maybe we'll come back to that so just really kind of going back to you and using technology generally when you're teaching it looks like you actually do make quite extensive use of technology in your lessons not many people for example tend to use the digital technology for experiments so you mentioned that one so I'm just interested in to hear about how you've developed your practice in using technology in your teaching whether it's something you've always done or if it's something you've learned you know gradually over the years or whether somebody in your Department is particularly keen on it and therefore it's rubbed off on you how have you developed and refined your practice
21:37	Julia	I think it's general absorption of different places I've worked definitely so the last school in Basingstoke I was at they were particularly good things like the photosynthesis is kind of the counting bubbles of oxygen from pondweed when you move the light closer and farther away is notoriously kind of fickle that means although it's really nice for the kids to actually do it because as I said Reading's got a really nice simulation and it's very clear and easy to use then that makes it a lot more identifiable with them because they seem to have such a small amount of patience for things working and things not you know we're trying to give them things in science where they don't know so we know what's going to happen a lot of that is We need to find experiments where they don't know what's going to happen and they've got more kind of patience to try and find out but things Faustad do a really good wave simulation So again the ripple tank's being one that kind of sometimes works sometimes it isn't so good so being able to support it and back it up with kind of a definite that you know will give them that answer I think they definitely need to see it you know I wouldn't want to replace them totally but I think again going back in September we've been told you know there's a limited amount of practical we can do so these again have become more and more important and useful to the kids to be able to get experience because it might just be me standing in front doing a demo or very limited practical that we can give them for the next three or four months so yeah I think it's kind of been used in support but I think most of them will increase and kind of my I think CLEAPSS have already put out a list onto their website of again useful resources and useful technologies so they're kind of making it explicit to a lot of science teachers that there is a lot available out there to dip into
23:59	John	yeah that makes sense actually in the light of one of your other answers on the survey which was about how lockdown

		has made you think about what you might change in your teaching so you did put that you were thinking of more simulations and videos for practical work and I can understand that now in the light of restrictions on doing practical work so and you said that PhET has been particularly useful were you already using that
24:30	Julia	I used some but again having gone back in and looked at them there's a hell of a lot more available now than kind of I looked at previously so again they will be ones I'm dipping into quite a bit more the other thing again not particularly technology based but microchemistry is coming to the fore as well now but again all of the information for that is coming through Twitter and the ASE website to kind of promote how we can get more practical into the classroom in a limited experience but again whatever information were kind of given as teachers at the moment tends to be coming from again these large organisations either doing webinars or promoting kind of things on their website that is going to be helped so you do kind of need to dip into kind of these main resources fairly frequently to check the updates and where other people are going really
25:31	John	yeah do you have any prior experience of doing the microscale chemistry
25:36	Julia	a little but not much
25:40	John	okay right great so just now moving to lockdown work you've obviously been setting work for children you've been doing the live teaching you said that about half your kids engaged with it although I think you said that it managed to reach about 2/3 during the live teaching what reasons do you think there are for the others not engaging I know you mentioned a couple of things already but just go back over for me why you think some children just haven't been able to engage
26:18	Julia	compared to other schools I've taught at this school seems to be quite a niche environment so we have two very high performing large secondary schools probably kind of within 5 miles either side of us we are very much more a smaller community based school where that again relationships are really important but what we found we are very close to a refinery and the parents have had jobs in the refinery which have been very well paid and because of the time they've kind of walked into those and the kids seem to feel like you know the school for their parents wasn't necessarily as important but they've walked into a really good high paid job that's very secure and their ambition is a lot lower so as a combination of kind of that ambition and having a high

		number of disadvantaged students and also a larger number of military kids as well they seem to have other priorities to the learning and we can kind of address that in the classroom but if it's a case of again trying to get hold of them on email or on the phone and have a chat and say well I haven't seen anything from you I haven't heard from you how's it going what's it doing you know they can be a lot more separate and kind of shut that door on school for a while which they find some of them find a particularly difficult environment to get on with so I think you know there's been a lot of different ways that we've tried to engage them and I say they have tutor meetings once a week so we will get in touch with them try and ask them what's it you know what's it going give them alternatives if they are finding it hard if there's been a bereavement which we've had a few of again you know we can work around that and make adjustments but as I say there just seems to be a few that really don't even our Y10s into year elevens just haven't found it a priority and have just really enjoyed taking their foot off the gas and aren't intending to put it back on however we try and help
28:38	John	OK thank you, you did say in your survey response that the level of engagement had depended on specific classes rather than ages so were there some classes that were particularly good at …
28:52	Julia	so the top sets so we do set English maths and science. English and maths obviously they have to pass, so there's a bit of an investment in those topics because they know they have to get their grade four or repeat the exam. The options are one(s) they've chosen so again they've got a bit more investment because that's something they've actually Picked to do the science is the one that gets left behind they might not like it they have to do it but they don't have to pass it so if they're going to prioritise their work and some of the lowest sets obviously find it more difficult and have that greater pressure for the English and maths then science tends to be the one that gets put on the backburner in preference of all the other subjects
29:39	John	okay thank you so we've mentioned that you've done live teaching and you've been providing other things and you've told me that you managed to fight to get two to three hours per week for science how much of that two to three hours has been the live teaching then and how much of it has been other things you've maybe put on the website or the portal or whatever

30:09	Julia	So if they attend their live lesson that counts as an hour of their teaching if they don't attend the live lesson then there is the kind of PowerPoint put onto the system which has kind of a voice-over attached so they can either come to the lesson do it live and be able to ask questions answer questions get some feedback or they do it purely independently and then the task to either of those lessons are then part of that so again if they came to the live lessons they've already had a quick peek at what they're expected to do or we also have a chat what they're expecting to do they've got that opportunity to kind of ask questions the start of the next following live lesson the following week would then be a feedback on what they've done any issues they've had anything they've misunderstood or that we need to address before we move on with the learning so although they haven't been compulsory they've been a lot more useful and as I say the feedback from the kids is that because they're getting the feedback and kind of they are prompting for how to attach or how to go about the task it's been kind of more productive and more time saving to kind of be part of that and to do it rather than to try Battle through everything on their own so kind of word of mouth wise when we first started doing the teams lessons the numbers picked up over the first kind of 3 four weeks really quickly where the kids were talking to each other and actually saying it's a better way of trying to learn rather than kind of hit it all themselves
31:52	John	and then did it kind of plateau after a while the numbers
	Julia	yeah
31:58	John	okay I'm just interested then because obviously you've been doing sort of two things there some live teaching and some providing stuff for those who couldn't attend and how easy did you find it providing the stuff for those kids who didn't attend you know if you were asking them to look at websites or videos did you really sort of struggle to match what you wanted them to learn to things that were available on the Internet or was that quite easy
32:29	Julia	it took time again knowing kids and what set they were meant that maybe if I had a top set in the bottom set class both doing the same thing the same resources wouldn't be applicable if you're looking at kind of key stage 4 there's a lady called Primrose kitten I don't know if you've heard of her she's particularly good at doing very short videos for kids and again Mr Thornton is hitting those ones that are borderline ‘C’ so for key stage 4 from a revision purpose we know that again there are people out there who are

		providing good summaries of topics and again short sharp chunks that kids will engage with key stage three is a lot harder because it's either very cartoony very animated almost feels too young to get the simpler message across or it goes too far in the opposite direction so actually the kind of GCSE level side of it was fine and the key stage three was a lot more difficult
33:38	John	and in terms of your workload doing this how would you say that is compared to what you would be normally doing
33:46	Julia	probably a lot worse again because although I'm only teaching one lesson a week those one lessons are very intensive and I'm having to be very particular with the resources because if the resources aren't right the kids won't be able to do them anyway we then have to provide feedback so obviously I'll give live feedback in a lesson but I also need to provide a feedback sheet so my marking kind of comes as a feedback sheet some students will email their work back and expect individual feedback the ones that just kind of upload it to the VLE we give again a feedback sheet for that Week so that they have some sort of recognition of their work and what they've done well and any issues that we've seen with that learning again as a school they wanted to keep track of who was learning and who wasn't so that meant that once a week for my well I did 11 classes and then I had a teacher leave So I picked up kind of 14 classes but for each of those individuals we then had to every week look at whether they saved work on to the portal in response to learning whether they'd emailed back kind of myself as a teacher I also had to look at GCSE pod which is a platform that the schools buy into so I had to check on there to see whether they'd logged onto that then be able to rate their learning as kind of red yellow green and their engagement kind of with the work and throughout the topic which again was really Labour intensive it did give us quite good feedback in that you could see maybe if the engagement for that week was really bad it was that the resources weren't right and we weren't doing the right thing for that particular subject because again if maths and English engagement remained high but science dipped then you know maybe we had done something that didn't particularly suit but the planning took a lot longer the feedback was kind of more contrived and again more difficult but the actual kind of monitoring was pretty horrific as well
36:04	John	yeah I noted that you put that and just to clarify when you said you're only teaching one lesson per week you mean I think one lesson per class per week

36:15	Julia	per class per week yeah
36:27	John	thank you so yeah just going back to the live teaching I know that you said you've used some different methods some different platforms for doing that zoom adobe connect and Microsoft Teams was there a reason why you used more than one platform
36:46	Julia	so in general school go off teams the zoom one is for Hampshire heads of science so they met once a month just to see how they were doing and how things worked and then the adobe connect tends to be more of the national based so things like the PiXL or the ASE that are giving kind of national conferences national information out tends to so school wise it's mainly teams but using it kind of across the board for kind of various meetings that I've had to attend
37:24	John	and how have you found that I'm not particularly familiar with it I've used zoom a lot and I know the sort of pros and cons of that So what are the good things and the weaknesses of teams from your experience
37:40	Julia	so again teams at the start again was very much about the settings and that we were very clear in who did what it's more difficult to change between screens quickly so you could share your desktop and obviously put up any videos animations songs PowerPoints up on desktop but again if an email popped up unless you turned your notifications off that was obviously would then be visible too if you'd loaded your PowerPoint into the system and showed your PowerPoint through teams if you then wanted to come back to camera to maybe do a bit of practical work you then had to reload the PowerPoint back in which took quite a bit of time again depending I don't know whether it's kind of usage or what but that could be really really slow I'm trying to switch between screens it also didn't play all of the videos and animations that we had available for the kids so sometimes we had to ask to put them into the PowerPoints on the system and say Oh no you've watched the live lesson but if you did want to watch this you need to refer back just in case again you know you'd play them on the screen but until you've got teams on you weren't 100% sure whether that would actually play for the Kids or not as well sometimes the slides didn't roll over for the kids as I was moving them along on screen so I quite regularly had to say we're now on slide 5 just to make sure the kids were on the same screen but yeah as I say it's just getting into new routines and new habits and how to firefight and things that kind of cropped up as we went along really

39:27	John	and where you having to take account of the device that the students were actually using to participate as well
39:36	Julia	yeah so on the mobiles they found it harder to add onto the chat it was more difficult general feedback was they were doing okay I think a lot of the issues we had initially was that we never had any formal training as a school on how to use teams just all of a sudden appeared and we did a couple of briefings on it and then it was like off you go so we've had to have you know a couple of people that feel that you know they're good at using it at certain tiers so I took the beginner tier and anyone that had questions or kind of wanted to meet and go through had to do stuff and I would do it and other people in the school kind of took expert roles so that we could all get up to speed as quickly as possible but again trying to jump into a platform that no one had ever used before and be expected to be uploading stuff and kind of presenting to kids with very little experience was quite difficult to start with
40:36	John	yeah I mean it sounds like the school tried to address that by the means that you've just said with the sort of beginners and experts groups good thank you you've had some feedback from various sources children parents senior leadership how has that feedback reached you has it all come directly to you or has it been funnelled through you know has it been the senior leadership team telling you what pupils have said or what
41:16	Julia	yeah it's come through so we had a briefing once a week and then that stream was available so if you couldn't make it if it was made available to re watch again parent comment fed into how we loaded the work onto the system so the kids were very clear on what they were addressing at what point what their expectation was so whether we loaded one lesson on the day that it was due to happen which staff particularly found Labour intensive but the kids preferred because it was very explicit about what they had to do when compared to if we loaded a weeks worth or a month's worth on then the kids found it more difficult to understand what they had to do and so a lot of our labelling of our folders on the system got changed through kind of feedback from parents and students as a priority and the actual want from the kids for us to feedback to them and how we could do that effectively without again that becoming too time consuming by addressing kind of 30 emails per class per week I'm still give them some constructive feedback that they feel they could work on really

42:34	John	yeah that sounds like it's been quite helpful for parents and pupils actually being able to feed back like that I wonder is that something that you know you think there's some way that that could carry on once we get back to normal
42:51	Julia	well it's definitely evolving it's our school so there's been a lot of work during lockdown on upgrading our student system so I don't know whether you've heard before but the kind of planning for next year is what we call blended learning it's kind of the buzz word that's flying around at the moment in that you're expecting to teach your kids in possibly a slightly limited capacity in school but the likelihood of them having to go back to possibly either a year group isolation or a whole group isolation or school isolation is pretty high so our resources are going to have to be able or our planning is going to have to work between both effectively so where we recorded live lessons as part of lockdown those have all been archived and possibly could possibly be used as cover lessons so normally you'd get a supply teacher in or another member of staff and they would be expected to deliver book work we won't be able to do that because we can't share textbooks without them then having to go into isolation for two days and quarantined so if we could then book a computer room and give them the live lesson that's happened from a bank online they can then still get taught by a science teacher and complete the tasks that have been available on portal that match in so we are intending to kind of keep a live lesson format or the ability to record and overwrite PowerPoints as a bank that will kind of back up and substantiate learning I think our kind of homework system again is going to support that the kids have got used to using that as a way of handing in work so I think there's going to be a lot less paper homework I think everything is going to be online the other thing that's going to happen next year is that again with the quarantine rules the kids would have to not use their class books for two days we could then mark them safely but then they would have to be quarantined for another two days before we gave them back so that means that kids would not have their books for a week if we wanted to mark them so it's going to go to a no marking system for the foreseeable future so how do we actually know how well the students are progressing what they do now there's two again options to that do you set an online quiz once a week that is marked by the computer and again we get printouts we could do it as more of a Kahoot based where again they answer the questions and you get a whole class feedback spreadsheet from Kahoot saying who got which question right and the proportions that answered each question or we could again work in class on the basis of a PowerPoint where you have

		a question and answer sheet and then marking Back off that but I think again all of our assessment for learning and our progress checks for the immediate future are all going to have to have some sort of technology basis to them because we won't particularly be marking books and assessing their work in books
46:05	John	so potentially lockdown then what you've had to do has made quite a transformative impact or it could be doing that
46:19	Julia	yeah as I say I definitely think we're going to be using more of it and using the resources that we've already done and further adding to those resources to kind of support in future
46:30	John	just going back to the monitoring learning then you know you've just mentioned about inability to mark books of course going forward and you said that in the survey it’s being difficult to monitor pupils’ learning just elaborate on a little bit the difficulties but there have been
46:56	Julia	so during lockdown or moving forward
	John	yeah during lockdown
47:01	Julia	well the problem is that we obviously have a significant amount working on paper we can't ask for that paper to be given back to then work off Similarly if kids have accessed the work on paper sorry accessed the work on portal but written it on paper although we ask again for them to take photos with their phone and email that work in that's not always been picked up so although on tutor contact or kind of head of Department contact the kids are saying yeah yeah we're working we've got it already to come back into school at the end we've actually got no evidence of that happening so again if they've used the pod that records logs in dates for the last date that this student logged in and of work that's been completed if they’re downloading or just you know attaching work to the portal that we can actually see that’s happening but the ones that prefer to write and prefer to do it physically on paper are less likely to take pictures of that work and email it back into you again possibly as part of you know not using the technology in the first place there are less likely to send it back to you
48:22	John	yeah and I'm thinking you know that normally when you would be teaching in the classroom of course you'll be using various sort of formative ways to just evaluate whether kids are getting the learning as you intend and I suppose when you're doing live teaching and you've just got a screen full of faces who are actually physically isolated from each other

		it's perhaps difficult to you can't just ask one group for example to talk about something so has that also been a limitation of the live teaching for you
48:58	Julia	yeah because normally we would if someone was sat next we would give them thinking time or talking time to bounce stuff off it kids are notorious again at not wanting to fail and not wanting to get things wrong and only the really confident kids again are going to offer an answer if they think it's not going to be right then that kind of speaking time and collaboration time is really important for them to gain a bit of confidence and resilience so yeah that has been lacking I know they do or some of them will kind of contact each other and speak on the phone still about school work as well as social and there have been little help networks going within year groups but again I think it has been really tough for them and again if they've not got their friends to talk to it about they've got their mum and dad but the kind of science capital of the family kind of varies massively between different people so some of them the parents have kind of really struggled and said actually you know we can't even help our year seven kid we're finding it really hard and again it feeds back into finding those right resources and that time it needs for you to get it right
50:14	John	thank you Julia for that so I'm going to talk about professional development a little bit and you mentioned that your school had a system for helping you work on teams was there any other CPD which occurred to help you with the challenges of teaching in lockdown or was that it
50:38	Julia	Only not necessarily created by the school there is as I say a heads of Department so that goes through Hampshire so I did get forwarded their meetings which were really useful but anything else has been kind of off my own back and of my own chasing so future learn I've done a really good CPD place that do free online lessons and there's something called stem learning and they do various courses on practicals differentiation AFL behaviour they put down a lockdown learning kind of series so a 3 hour course on how to teach effectively online so again I could feed that through into my Department to kind of have a look at and look at the considerations about how we could use that and what measures we could kind of take from it to make our teaching more effective the ASE have put on a series of webinars which have been particularly good that tends to be again a panel of six people that have set questions given to them and then kind of that would be useful to everyone attending and then you have an opportunity to dip in at the end with anything more specific that you want to know PiXL have

		also done a couple as well but again it's just making sure you're on those mailing lists or you've been checking their websites for information because otherwise it wouldn't be widely available to suddenly realise oh wow that could be really helpful
52:29	John	it's interesting isn't it because obviously we've never been in this situation before so for example the people on the panel in the webinars that you mentioned what kind of things were they advocating because clearly we haven't got sort of prior experience of doing this so how was what they were saying helpful to you
52:55	Julia	so it was consideration about where we're going with the curriculum and how we're developing so do you carry on with your scheme of learning that you developed kind of previous September and expect that to carry you through the lockdown period and stick with it no matter what or do you use your better judgement and say actually there might not be you know a year nine might not learn this till year 11 but independently it's kind of more of a general knowledge more of a common sense topic it's something they're going to be able to access more independently do we bring that forward and move the other topics to when we can do it face to face and ensure they are learning it was conversations about if you're obviously delivering all this online and how the gap is increasing between those that do and those that don't when you go back in September do you then repeat the topics they've done online and make sure the understanding's there and Interestingly and I think rightly it was really clear that that shouldn't happen at all because you're just punishing those that have worked really really hard and that what you need to do again is go back through your curriculum find the places that those topics link in to the future curriculum and adding more time there to then re-establish the knowledge and go back over the gaps there so again interleaving platforms are becoming really important Adam boxer again is trying to launch one at the moment but there's a series of spreadsheets that you can drop in kind of questions across the curriculum but then have it pick random series between you know Row 3 and 50 or 80 and 100 you can select topics where it randomly throws out questions each lesson and those kind of interleaving remembering coming back to questions are going to get more important to kind of cover those gaps so it was more about how are you adapting your curriculum now and how will that impact in the future lessons and what your priorities should be which I think was quite useful The ASE was more they did one purely on practical science and where we need to go all the considerations we need to think about moving

		forward and how we can avoid students doing no practical whatsoever because it's just too difficult to how can we switch up into different formats like videoing Ourselves so they can still see it or again so going back in September it seems that most schools are putting a year group in a particular part of the school and they stay in that classroom for the entire day and the teachers are moving between so again what I've done is I've kept 2 science rooms empty as kind of bookable rooms that we would have to collect the students move them up to the room complete practicals so the practical would all have to be set up ready to go they would complete that get taken back to their room but then the rooms then shut so that it can be cleaned and sorted so I could possibly over 2 rooms offer four lessons of practical a day but again that would have to be shared between five members of staff teaching 5 lessons a day
56:37	John	yes so there's a big logistical operation
56:41	Julia	yeah but it's just again helpful to know how other people are going to attack this and whether we think that it's worth doing and we should do it and it's valuable but having these kind of larger nationwide kind of forums it's quite a good kind of temperature gauge of where we should be going and what we should be planning and how we can go about doing it and not disadvantaging the kids any more
57:10	John	I'm interested to know whether anybody has raised the possibility of any financial implications of the adaptations that might be necessary for example you mentioned about microscale chemistry you know and if you've not got that equipment already then that's something that would have to be bought in so is that something that you've been made aware of or are thinking about
57:37	Julia	no I've been costing it up at the moment obviously if we were to work off those two rooms that means that we've got 15 we'd need to have 15 individual trays for each room and those trays have to have all the equipment for that pair on the table so that's going to have implications on glass bottles droppers chemical jars as well as things like spotting tiles so if we wanted to do a neutralisation reaction you're going to need a minimum of 15 bottles of hydrochloric acid 15 bottles of sodium hydroxide plus anything else so that would be kind of 30 bottles glass bottles each per room if both rooms wanted to run that at once that’s 60 bottles we don't hold that in the Department of the moment so even the basic consumables are going to limit what we can and can't do because our budget has stayed the same to last year so anything that we wanted to make for the microchemistry

		anything that we need to increase in number to accommodate any practical we're doing all has to get absorbed into our current budget
58:49	John	just looking ahead, we obviously talked about the implications for teaching and organisation are there any professional development needs that you personally have identified as a result of the experience of so you've had in lockdown
59:07	Julia	I'd say the main thing is going to be our assessment for learning and how we cope with the non-book marking and how we adjust our lessons at the moment so that's kind of my project for a couple of members of staff is how we're going to ensure that we're delivering that for The students because it affects both how they're doing in lesson but our understanding of what they get and whether we need to adjust our planning and resources for the following week to ensure the understandings there because again we can't walk around the room we're going to be restricted to the front of the classroom there's going to be a line we can't cross you know we can't get anywhere near the students to be able to deliver any one to one support or kind of even look at their books normally again we'd use a visualizer we can put books underneath we can look at model answers and kind of discuss feedback and kind of editing and learning from that point of view so I think most of our CPD I don't think I have any issues with kind of my Staffs planning and ability to deliver lessons and their actual teaching capacity but I think we're going to have to be really explicit as a Department on how we are going to monitor that progress
1:00:29	John	OK thank you so this is really the last question that I've got for you and I think you've probably hinted at some of these things actually but it's what things you think might get better as a result of lockdown in science teaching and what things you think might get worse as a result of lockdown
1:00:51	Julia	again so the better again is going to be our uses of technology we're going to have to adapt to using more the simulations again I think our homework's are going to benefit from being purely online I think you will have to produce a paper copy for a limited amount of pupils but I think with this kind of new behavioural pattern that we've established during lockdown I think that means that you know homework's will transfer a lot more easily across more difficult my concern is absolutely votes the ability for the kids to be able to do practical because most of our kids are kinaesthetic learners they want to do it, it helps so again I

		think how we go about that and the ways we do it is going to be more problematic I think we're going to lose a bit in our relationship with the kids I think again where again this school in particular They see the kids are a lot less trusting they don't expect you to stay the fact that we know them so well and we've had a lot of time to come and help them to kind of have that physical presence as well as support is I say it's a two edged sword that one because we've spoken to them once a week kind of us part of a tutor catch up and in some of those it's really strengthened the bond and you found out things that you wouldn't normally do you know they're more open about how they're getting on with stuff and their social life and their family life but again I think you're going to appear more standoffish whether you like it or not you know your lessons are going to be more chalk and talk you're going to be preaching at them rather than what they see is trying to come and help them and I think I don't know kind of how that's going to affect them especially if they're in the same room all day they're going to find that quite restrictive quite uncomfortable quite oppressing and the fact that kind of we're not offering them what they normally get were offering them less it's how we're going to get round that to keep them kind of engaged and wanting to learn the last lesson of the day when they've really had enough
1:03:26	John	right well thank you very much and thank you for all of your responses a lot of detail and a lot of insights that you've shared there with me the last thing is just to ask you whether there was anything that you were thinking that you might have mentioned or discussed that you've not yet had a chance to talk about
1:03:50	Julia	no I think we're all done really

Appendix 9: Codebook for teacher interview analysis

Theme 1: Science work - set or submitted

Categories	**Codes**
Amount of work	Amount of work pupils produced
	Amount of work sent to pupils
	Expectation of time pupils will spend on work
	Low amount of science work set
	Too much work set by science
Non-IT work	Advantages of paper-based learning
	Non-internet-based science activities to do at home
	Outdoor learning
	Paper based work sent home
	Printed work packs
	Work for pupils without internet access
Organisation or management of work	All work requiring the internet
	Continuation of providing work over lockdown
	How science work was provided
	Managing provision of science work
	Not varying the type of work set
	Organisation of work for pupils
	PowerPoints provided by MAT
	Unclear instructions to pupils about what to do
Pupils submitting work	Amount of submitted work
	Expectations about number of children returning work
	Online submission of work
	Pupils attaching their own videos
	Pupils filming their own investigations
	System for pupils getting work to teachers
Type of work	Combining working in books with using apps
	Comparison of type of work sent with other departments
	PowerPoint sent home
	Research tasks
	Setting appropriate work for pupils
	Type of science activities set in lockdown
	Type of work provided in science

Theme 2: Lockdown outcomes

Categories	Codes
Benefits or advantages during lockdown	Benefits of electronic marking and feedback
	Benefits of external providers of educational activities
	Benefits of social media during lockdown
	Breathing space of lockdown for focusing on planning
	Decreased workload
	Lockdown affording greater freedom and independence for some pupils
	Lockdown as a catalyst for developments in teachers' practice
	Lockdown establishing new behavioural patterns
	Lockdown experience improving pupils' confidence
	Lockdown experience improving pupils' independence
	Lockdown making children value teachers more
	Lockdown making teachers aware of online resources
	Lockdown providing time to find online resources
	Lockdown strengthening relationships between teacher and pupil
	More flexibility of teachers' time
	Recognition of something good coming out of lockdown
	Reflections on benefits of lockdown
	Role of teacher made prominent during lockdown
	Teachers' enjoyment of lockdown
Random, unexpected or accidental outcomes	Advantage of lockdown happening in the summer
	Advantage of no precedent
Uncategorised codes	Comparison of state and independent schools
	Effect of lockdown on teacher's own goals
	Financial implications of contingency plans
	Other things that have declined during lockdown
	Personal outcomes of lockdown for teachers
	Pupils changing sleep patterns
	Quality of pupils' work
	Time-saving benefits of using online animations or modelling

Theme 3: Pupils learning away from school and teachers

Categories	Codes
Other home factors	Difficulties for pupils working at home
	Difficulty of doing practical science at home
	Difficulty of no teacher supervision
	Not knowing home circumstances
	Other family members at home
Parental factors	Ability of parents to motivate children
	Ability of parents to support children's science learning
	advantage of parents being teachers
	Different engagement of parents
	parental attitudes to schoolwork
	parents choosing to keep children at home when allowed to return to school
	Parents helping pupils
	parents leaving older pupils to their own devices
	parents not monitoring children's schoolwork
	parents restricting mobile phone time
	parents struggling to motivate children
	parents working
	varying science capital of families
Technology factors	Affluence or deprivation effects
	Affordability of internet access
	Avoiding asking pupils to print stuff
	Awareness of pupils accessing work on a smartphone
	Children's internet access at home
	Difficulty of having to remember passwords for online tools
	Ensuring pupils had logins for online tools
	Fewer printers at home than in the past
	homes without Wi-Fi
	Pupil access to technology at home
	Quality of school data about home technology provision
	School delivering technology to homes
	shared access to technology at home
	surveying children's home internet access before lockdown

Theme 4: Experience of live remote teaching

Categories	Codes
Uncategorised codes	Differences between classroom teaching and 'live' online teaching
	Emojis as a way of seeing how pupils were feeling in 'live' teaching
	Evidence about whether live lessons are better than recorded lessons
	Internet speed
	‘Live’ social or wellbeing sessions
	‘Live’ teaching starting
	Mixing ‘‘Live’ teaching with other approaches
	Old-fashioned ways of teaching
	Parents with pupils in ‘‘Live’ teaching
	Partial opening for Y6 affecting attendance in ‘‘Live’ sessions
	Helping other staff to do remote teaching
Negative aspects	Drawback of no practical in ‘‘Live’ teaching
	Greater planning requirement of ‘‘Live’ online teaching
	‘Live’ online teaching more exhausting
	Live teaching clashing with family activities
	‘Live’ teaching draining
	‘Live’ teaching timetable demands on time
	Shortcomings of ‘‘Live’ teaching
	Subjects that suffered through ‘‘Live’ teaching
Pedagogical aspects	Absence of visual feedback during live teaching
	Accommodating SEN pupils in ‘‘Live’ teaching
	Breakout rooms
	Chat function during ‘‘Live’ teaching
	Children's confidence to ask questions in ‘‘Live’ teaching
	Coping with silence during online ‘‘Live’ teaching
	Difficulties judging whether pupils are engaging with work during ‘‘Live’ teaching
	Difficulty of not seeing pupils' faces during ‘‘Live’ teaching
	Importance of seeing faces during teaching
	Importance of seeing faces during teaching to judge comprehension
	Importance of teacher-pupil relationship during ‘‘Live’ teaching
	Inability to see all pupils in large online classes
	Lack of visual feedback during 'Live’ teaching
	Live teaching to larger classes
	Reducing the demand of work in ‘‘Live’ teaching
	Reliance on vocal individuals in the class during ‘‘Live’ teaching
	Reproducing classroom teaching techniques in ‘‘Live’ teaching
	Teacher not having video on in ‘‘Live’ teaching

	Teachers not knowing what was happening during ''Live' teaching
	Techniques for helping pupils contribute during ''Live' teaching
	Things taking longer in ''Live' teaching
	Using the VLE to complement ''Live' teaching
	What worked well in ''Live' teaching
Positive aspects	Ease of transitioning to ''Live' teaching
	Example of ''Live' teaching being better than face to face
	Good aspects of ''Live' teaching
	Judgement about live online teaching
	'Live' lessons not as hard as expected
	Live teaching overcoming geographical constraints
Procedural aspects	Complications of ''Live' teaching
	Doing practical demonstrations in ''Live' teaching
	Extra adult during ''Live' teaching
	Format of ''Live' lessons
	Frequency and duration of ''Live' teaching
	'Live' teaching every lesson
	'Live' teaching from school during lockdown
	Logistics of ''Live' teaching
	Managing practical work during ''Live' teaching
	Monitoring chat stream during ''Live' teaching
	Preparing ''Live' lessons
	Restrictions imposed during ''Live' teaching
	Routines in ''Live' teaching
	Setting boundaries in ''Live' teaching
	Trying to do face to face and online ''Live' teaching at the same time
	Ways of doing ''Live' teaching
Pupil aspects	Attendance in ''Live' lessons
	Feedback from teachers' own children about ''Live' teaching
	How ''Live' teaching affected pupils
	Pupils becoming familiar with technology through ''Live' teaching
	Pupils being mischievous during ''Live' lessons
	Pupils needing the support provided by ''Live' teaching
	Pupils' reluctance to speak during ''Live' teaching
	Pupils responding better than expected in ''Live' lessons
	Pupils' reticence during 'live teaching
	Pupils who responded verbally during ''Live' teaching
	Pupils willing to speak in ''Live' teaching
	Pupils reluctant to email or type in chat
Technical aspects	Having two devices for ''Live' teaching

	Having video on or off during ''Live' teaching
	Limitations of technology for ''Live' teaching
	'Live' learning more difficult with a mobile phone
	'Live' lessons on a smartphone
	Shortcomings of technology used for ''Live' lessons
	Technical issues of ''Live' teaching
	Technical limitations during ''Live' teaching
	Video recordings of ''Live' lessons

Theme 5: Teaching during lockdown (apart from LRT)

Categories	Codes
Comparisons with non-lockdown teaching, learning, working	Amount of educational progress during lockdown
	Amount of work done comparable to non-lockdown teaching
	Comparison to face-to-face teaching
	Difference of teachers' work in lockdown compared to normal
	Doing things that were not done before lockdown happened
	Keeping modular assessment would have been beneficial
	Lockdown learning worse than normal
	Lockdown science almost as good as normal
	Pupils regressing during lockdown
	Quality of lockdown science teaching
	Quality of science education a lot worse than normal
	Realisation of what was missing in lockdown teaching
	Teachers not recognising pupils' capabilities
	What teachers have missed during lockdown
Feedback, marking and monitoring	Difficulty of knowing if pupils are doing work at home or not
	Difficulty of knowing whether pupils are submitting their own work
	Difficulty of monitoring understanding
	Difficulty providing individual feedback by email
	Emailed work taking longer to mark
	Feedback to pupils contrived
	Inability to mark all work
	Inability to see what pupils were doing at home
	Marking and feedback online
	Methods of giving feedback to pupils
	Monitoring horrific
	Monitoring of work pupils were doing
	Monitoring understanding online
	New ways to assess understanding without marking books
	Potential for pupils cheating through online tasks
	Shortcomings of monitoring methods
	Time-consuming nature of marking some online work
	Uncertainty about what pupils are doing with online materials
	Using lists to check pupils were engaging
	Using monitoring to inform planning
	Ways of monitoring if pupils have accessed work
	Ways to make cheating harder

Pre-recorded lessons and other online provision	Duration of narrated PowerPoints
	Duration of recorded videos
	Method of making recorded videos
	Narrated PowerPoints
	No non-internet work during lockdown
	Phet simulations
	Putting activities on the web
	Teachers trying to make things easy and accessible
	Thoughts on 'live' teaching by teachers who didn't do it
	Typical online work sent for non-'live' teaching
	Use of online systems and tools
Other difficulties or constraints of teaching during lockdown	Challenge of finding suitable online material for pupils
	Children's difficulties accessing work
	Demography of the school's area
	Difficulty keeping going during lockdown
	Difficulty of setting appropriate lockdown work
	Difficulty of spending hours in front of a screen
	Equity of provision
	Factors preventing innovation
	Having to turn documents into pdfs
	Inconsistency of preparing pupils for lockdown
	Inconsistent attendance
	International pupils
	Lack of awareness of what other departments experienced
	Lack of day-to-day contact with pupils
	Lack of educational interaction in lockdown
	Lack of feedback from pupils
	Lack of school technology
	Lack of teacher input on work set
	Lack of training on using Teams before lockdown
	Lack of usual school attainment data
	Limitations of online platforms or tools
	Limitations of smartphones for accessing work
	Limited access to school online systems
	Non-live teaching and pupils' difficulties understanding
	Not knowing how long lockdown was going to last
	Not knowing if activities were helpful for pupils
	Phone compatibility of work
	Poor broadband
	Problem of compatibility of software on devices

	Problem of different online platforms
	Problem of putting the onus on pupils
	Problem of setting more difficult tasks
	Problems of pupils having to learn independently
	Psychological difficulties during lockdown
	Pupil resilience
	Pupils having to use mobile phone data allowance
	Pupils needing lots of help
	Pupils not checking email
	Pupils not understanding instructions
	Pupils not using their school email address
	Pupils preferring to do things other than schoolwork
	Pupils preferring to print out and write
	Shortcomings of face-to-face resources for online learning
	Shortcomings of online learning
	Shortcomings of online systems
	Suitability of online resources for pupil age
	Suitability of work for mobile phones
	Teacher frustrations during lockdown
	Teachers' internet connection at home
	Teachers not knowing what work was being done at home
	Teachers own families at home
	Teachers seeking consent for children to use a video-link platform
	Technical limitations of certain online tools
	Time demands of creating online activities
	Too many methods for pupils sending work
	Unrealistic expectations about what pupils will do
	Using technology to provide online learning activities
	Work that required a printer
Practical work during lockdown	Avoidance of chemistry practicals at home
	Compensating for the absence of practical work
	Home experiments
	Importance of practical work in science
	No practical work in lockdown a big drawback
	Pupils doing experiments at home
	Pupils using technology for home experiments
	Simulations to complement practical work
	The need for school science experiments to 'work'
	Using simulations instead of practical work
	Attempts to address pupils’ difficulties or misconceptions

Things that worked or helped	Different methods for achieving the same solution
	Differentiation
	Doing science through literacy
	Importance of structure and routine for pupils
	Importance of the teacher's passion for the subject
	Increased independence during lockdown benefiting pupils
	Pupils helping each other overcome technical difficulties
	Pupils supporting each other
	Teacher perspectives on work from other subjects
	Teachers' awareness of what pupils will experience
	Teacher's own YouTube channel
	Teachers' perspectives as parents themselves
	Teaching flexibly for pupil need
	Team diversity
	Technology helping pupils organise their work
	Technology helping with structure and routines
	The importance of modelling in science teaching
	Trusting children to do things when the teacher is not there
	Vital nature of a piece of technology
	Ways of helping pupils understand
Pedagogical impacts of lockdown teaching	Impact of lockdown on pedagogy
	Reflecting on quality of provision over lockdown
Pupil response, motivation, engagement	Amount of work set influencing pupils' perception of its importance
	Attempts to get pupils to engage with work
	Better response rate from younger pupils in submitting work
	Comparison of pupil engagement in science with other subjects
	Creative and practical potential of science
	Different levels of engagement for different types of work
	Different levels of engagement from pupils
	Difficulty of knowing actual level of engagement
	Difficulty of pupils being intrinsically motivated
	Engaging with different types of work
	Expectation of better engagement
	Inability to engage with every pupil
	Increasing or decreasing levels of engagement over lockdown
	Judging engagement
	Levels of engagement
	Lower engagement for 'live' teaching than other online work
	Monitoring engagement
	Monitoring engagement through online tools

	Poor engagement of pupils
	Proportion of children who engaged with online learning
	Pupil boredom
	Pupil feedback on missing science lessons
	Pupils enjoying lockdown work
	Pupils' motivation to do work when not in school
	Pupils seeing no repercussions for not doing work
	Pupils who like science
	Reasons for pupils' lack of motivation
	Teacher speculations
	Work not done even when reminders sent
Factors which helped teachers or pupils during lockdown	Accessing school resources
	Advantage of your own child going to the school you work in
	Being able to see what children were receiving from across school
	Effective teamwork
	Exploiting opportunities to engage with external providers
	External organisations providing activities
	Flipped learning
	Just-in-time work for pupils preferred
	Privacy of work submitted electronically helping overcome pupils' insecurities
	Privileged pupils
	Cross-departmental collaboration
	Teachers collaborating to move lockdown practice on
	Teachers helping other teachers during lockdown

Theme 6: Communication

Categories	Codes
Communication to home during lockdown	Contacting parents
	Frequency of communication with home
	Phone communication with home
Communication to pupils during lockdown	Communication with pupils
	Communication with social media during lockdown
	Difficulty of communicating through parents
	Email
	Emailing pupils and-or parents
	Instagram
	Problem of communications not coming from a familiar teacher
	Responding to pupils' questions by email
	Teacher contact with pupils during lockdown
	Teacher difficulties with communication with pupils
Communication from home or pupils during lockdown	Amount of communication from parents
	Complaints from parents
	Etiquette of electronic communication
	Families with no contact at all during lockdown
	Feedback from pupils during lockdown
	Not getting a response from home
	Parental feedback on lockdown work
	Parents communicating with teachers
	Parents' feedback informing how schools provided online learning
	Positive feedback from parents
	Praise from parents
	Pupils becoming more confident with communicating with teachers during lockdown
	Pupils contacting the teacher about science
	Pupils emailing with questions
	Pupils emailing work
	Questions from home to school
	Useful feedback from parents about 'live' teaching
Uncategorised	Parental satisfaction with school's provision during lockdown
	Positive feedback for science department

Theme 7: Technology provision and tools

Categories	Codes
Social media	Age limit on social media
	Aligning with young people
	Avoidance of social media
	Changing use of social media
	Close control of school social media
	Facebook
	Negative aspects of social media in school
	Online systems able to do what social media does
	Parental use of social media
	Personal use of social media
	Pupils benefiting because of teacher use of social media
	Pupils use of social media
	School use of social media
	Simulating social media in lessons
	Social media used in school transition
	Social media used in teaching
	Teacher beliefs on children learning from social media
	Teachers not allowed to use social media to contact pupils
	Teaching children about responsible use of social media
	Work use of social media
Specific technology	Apple pencil
	Choice of online platform
	Effect of school iPads
	Google classroom
	Google classroom better than Teams
	Google suite
	iPads in school a long time
	iPads not previously being fully exploited
	Lockdown causing iPads to be more fully utilised
	Moodle
	OneNote
	SAM Learning
	Seneca
	Show my homework
	Tassomai
	Twitter
	Using iPad for 'live' teaching

	Using iPads outdoors
	Vimeo
	YouTube videos
	Zoom
Uncategorised	Balancing technology costs with savings elsewhere
	Comparing different schools' IT provision and use
	Multiple video conference platforms used for different things
	Parents buying pupils technology
	Providing technology to children during lockdown
	Pupils using technology in the classroom
	School IT support during lockdown
	School policy on mobile phones
	Schools not providing teacher laptops
	Support for pupils without technology
	Teachers having to buy own laptop during lockdown
	Teachers having to use their own technology for work
	Teachers not having school laptops or IT equipment
	Websites pupils were sent to

Theme 8: Skills, confidence, attitudes, views

Categories	Codes
Children's or Parents'	Assumptions about children's IT abilities
	Attempts to overcome pupils' IT difficulties
	Children being more tech savvy than teachers
	Children's ability to learn new skills
	Children's capabilities revealed through quality of lockdown work
	Children's confidence to ask for help
	Children's lack of basic IT skills
	Getting pupils to learn how to use online systems
	Identifying the need to train pupils in IT skills
	Illusion of children knowing about technology
	Pupils and parents not knowing how to use pre-existing school online systems
	Pupils or parents' views of English and Maths
	Pupils struggling with online tools
	Skills pupils have missed out on
Teachers'	Different views of technology between departments
	How long teachers have been using technology
	IT as a dull subject
	Personal attitudes to technology
	Personal confidence with technology
	Personal use of mobile phones
	Personal use of technology
	Positive view of social media for school
	Reliance on other people for help with using technology
	Staff confidence using technology
	Teacher commenting on their own lack of skill or knowledge
	Teacher confidence with technology
	Teacher view on deficiencies highlighted by lockdown
	Teacher views of PowerPoint
	Teacher views of social media
	Teacher views on technological competence
	Teacher views on technology
	Teachers gaining confidence in online teaching tools
	Teachers' lack of IT skills
	Teachers learning new skills because of lockdown
	Teachers not knowing how to use online platforms
	Teachers wanting to advance their use of online teaching
	Teaching skills that have improved during lockdown

	Using a class to try online teaching techniques out on
Training teachers to teach using technology during lockdown	Cascading training to staff
Teachers' changing their views of things	Changing views of online activity
	Changing views of social media
Uncategorised	Difference between using technology in and out of work
	How teachers teach
	Mobile phones in school
	Nature of teaching
	Not the best way of learning from home
	Pupils putting questions into Google
	Pupils' technical difficulties
	Switching from one IT system to another
	Teacher experience with technology
	Teachers being compelled to use technology
	Teachers learning to use technology in their teaching
	Teachers updating their technological knowledge
	Teachers' uses of IT in the classroom
	Teachers wanting to promote use of mobile phones for learning
	Teachers wanting to use technology more
	Teachers who don't like technology
	Technophobes
	The need to do things better
	Understanding how software can be used in teaching
	Use of technology in class
	Using phones as dataloggers

Theme 9: Wellbeing

Categories	Codes
Wellbeing of staff	Attempts to minimise staff workload
	Consideration of other teachers' working conditions
	Factors affecting workload during lockdown
	Frustration of spending so long in front of a computer screen
	Health and safety of home-working
	Increased workload
	Teacher workload
	Teachers concerns with their own families
	Teachers' health
Wellbeing of pupils or child protection	Bereavement in pupils' families
	Child protection on 'live' teaching
	Minimising risk during lockdown
	Not putting pressure on
	Priority of pupils' well-being
	Pupil anxiety about work missed
	Pupils' mental health
	Pupils missing interaction with friends and teachers
	Well-being calls
	Length of time in front of a screen
	Non-screen time
Uncategorised	Safeguarding and YouTube videos
	Senior management
	Struggling not seeing and talking to colleagues
	Supportive management team
	“These are weird times that we're in”
	Tough time

Theme 10: Whole-school aspects

Categories	Codes
Professional development during lockdown	Availability of online CPD
	Benefits of online CPD
	Comparing online with face-to-face CPD
	Content of online CPD
	CPD about online teaching or learning
	CPD during lockdown
	CPD needs because of lockdown
	CPD needs made visible because of lockdown
	CPD on using Teams
	CPD that would have helped teachers deal with lockdown
	CPD to address future challenges caused by lockdown
	CPD to address teaching online
	Disadvantages of online CPD
	Expectation to do CPD during lockdown
	Greater availability of online CPD
	No CPD during lockdown
	Online CPD causing reflections about online 'live' teaching
	Online CPD overcoming travel constraints
	Personal learning for CPD rather than external
	Potential of online CPD
	Reading as CPD
	School-run online CPD
	Seeing the value of online interaction through online CPD
	Teachers doing online CPD
	Teachers taking charge of their own CPD
	Twitter as a source of information about CPD
	Usefulness of online CPD
Curricular priorities during lockdown	Bed student prioritising English and Maths
	Choosing what science to teach when it was optional
	Curricular importance of science during lockdown
	Curriculum coverage during lockdown
	Not following the national curriculum
	Parents prioritising English and Maths
	Pupils engaging with only English and Maths
	Pupils prioritising English and Maths
	Pupils recognising importance of standardised assessments
	School prioritising English and Maths
	Science optional during lockdown
	Science seen as optional
Looking ahead	Challenges when pupils return from lockdown
	Concerns looking ahead
	Difficulties in September

	Expectation of technology in education becoming more prevalent
	Expectation of using more simulations
	Gradual re-opening of school at the end of lockdown
	Prediction about difficulties coming up
	Predictions about practical work after lockdown
	Problems anticipated when pupils return
	Teaching likely to be less interactive when pupils return
	Teaching moving towards use of mobile phones for teaching and learning
	Technology improving efficiency
	Things that might improve as a result of lockdown
	What teachers would change as a result of lockdown
	Worries about longer term effects of lockdown on science education
Changes and evolution of practice during lockdown	Catch-up days
	Changes of approach as lockdown went on
	Changes to the amount of work sent home
	Pupils re-engaging during lockdown
	Teachers adopting 'expert' roles on online tools for colleagues to learn from
	Technology necessary for changes in practice
	Things becoming easier over the course of lockdown
Preparedness and preparation for lockdown	A bit of a scramble'
	Preparing online tools for pupils before lockdown
	Pupils sending irrelevant stuff
	School advance planning before lockdown
	Setting up online systems at the start of lockdown
	Suddenness of lockdown
	There was an element of panic about it'
	Training pupils on Teams before lockdown
Ways of working during lockdown	Contingencies for covering transition
	Doing other planning during lockdown
	IT systems facilitating workflow
	Lockdown work as optional
	Other teachers' working arrangements in lockdown
	Own working arrangements in lockdown
	Pupils' working day during lockdown
	Recorded videos as work supplied for pupils
	Regular timetable followed
	Routine for setting work in lockdown
	Running exams during lockdown
	Running graduation online
	Setting work every day
	Shared drive for all departments
	Strategies for compensating for cancelled exams
	Teachers working in isolation
	Things that happened because exams were cancelled

	Using a memory stick to transfer work between school and home
	Using the VLE to provide structure for pupils
	Ways of pupils sending work to the teacher
	Ways of working during lockdown
	Weekly staff online briefings
	Year 6 transition
Lockdown influencing future policy & practice	Continuing lockdown practice afterwards
	Home learning policy
	Homework shifting online
	Identifying new roles because of lockdown
	Instrumental pathfinder
	Move to blended learning
	New role arising from lockdown
	Recorded lessons as cover lessons

Appendix 10: Categories of quantitative analysis from teacher survey

Quantitative analysis label	Description, with number of individual analyses performed shown in brackets
T1	Survey completion (4)
T2	Basic gender data (2)
T3	How teachers were working during lockdown 1 (4)
T4	Teaching experience (2)
T5	Personal use of social media (4)
T6	Social media platforms for personal use (4)
T7	School size (2)
T8	Technology used at home (2)
T9	Teachers' roles and ages taught (4)
T10	Provision of teachers' IT equipment by school (6)
T11	Social media used for work purposes (12)
T12	Usage of specific social media platforms (5)
T13	Reasons for using social media for work (1)
T14	Teachers' awareness of pupils' internet access at home (2)
T15	Teachers' views of curricular importance of science during lockdown 1 (2)
T16	What teachers used technology for in their science teaching before lockdown (5)
T17	How lock-down has made teachers think about changing teaching in future (6)
T18	Provision of science during lockdown (5)
T19	Ofsted related data (6)
T20	Teaching during lockdown that required the internet (9)
T21	School postcode areas (4)
T22	Reasons given for not asking pupils or parents to use the internet (1)
T23	Teachers' views of quality of science education during lockdown (8)
T24	Ease of monitoring pupils' science learning during lock-down (1)
T25	What would have made lockdown teaching better (3)
T26	Type of work set requiring the internet (7)
T27	Continuing to provide science education over lockdown (3)
T28	Additional work not requiring the internet (1)
T29	Pupil engagement (10)

Appendix 11: Codebook for parent interview analysis

Theme 1: Parental factors and actions

Categories	Codes
Things that helped or gave an advantage	Advantage for children whose parents were teachers
	Advantage of parents' networks
	Allowing children to follow their natural curiosity
	Benefit of getting away from home for a while
	Benefit of Loom
	Benefit of seeing the teacher in recorded PowerPoints
	Benefits of home-education
	Children as natural scientists
	Children getting help from parents' friends who are teachers
	Children liking learning through doing not reading
	Days when parent and children did activities together
	Family doing educational activities at home anyway without lockdown
	Family physical activity
	Family quite focused on education
	Going outdoors during lockdown
	Health benefit of being at home for children with specific health conditions
	Helpful to have more suggestions from school about questions parents could ask children
	Parent accustomed to working from home
	Parent asking child to teach them
	Parent who is a teacher
	Parents adopting their own structure for children's lockdown learning
	Parents allowing children to self-regulate internet use
	Parents and children finding their own learning resources
	Parents and children watching TV programmes about science together
	Parents being open with children about the pandemic
	Parents collecting work from school
	Parents' confidence with technology helping provide science learning experiences
	Parent's desire to have been able to learn alongside the child
	Parents giving children choices about schoolwork
	Parents' qualifications giving them confidence with science
	Parents' work circumstances enabling home education
	PE with Joe Wicks

	Positive view of Oak National (Nodes)
	Science learning that wasn't inspired by school
	The internet as a way of finding resources for home education
	TV programmes as a useful way to learn
	TV programmes more enjoyable to watch as no expectation to do tasks alongside
	Two parents taking it in turns to help children
	Using revision books and Children's University to supplement schoolwork
	Using the internet to supplement school science work
	Zoom French lessons allowed children to talk to each other
Discussions about science at home	Children asking questions about the pandemic and related science
	Parents noticing children's science interest due to the pandemic
Outcomes of ongoing lockdown	Changing home-education strategy because of lockdown
	Children changing their appreciation of teachers
	Children developing in spite of not being pushed
	Home education on a trial basis
	Improvements that wouldn't have happened without Covid
	Lockdown changing parents' attitude to education
	Lockdown making children realise how much they like school
	Lockdown resulting in children not judging themselves against others
	Lockdown revealing the value of teachers
	Lockdown schoolwork keeping parents busy
	Pandemic influencing children's choices
	Parental sympathy for science teachers having to teach in ordinary classrooms
	Parents accepting lack of science
	Parents appreciating what child's school have done during lockdown
	Parents' awareness of what other schools were doing
	Parents changing their view of learning and education because of lockdown
	Parents choosing to continue home-educating
	Parents having to learn new things to help their children learn science during lockdown
	Parents more confident to help children learning at home due to the experience of lockdown
	Parents motivated to learn new things in helping their children
	Parents recognising importance of structuring children's time in lockdown
	Parents recognising opportunity of spending more time with their children
	Parents recognising other people's circumstances
	Parents recognising schools' difficulties setting lockdown work
	Parents reflecting on their own lack of enthusiasm for science
	Parents teaching skills developing as a result of lockdown

	Parents understanding difficult position of schools
	Realisation that primary school lockdown work was similar to what family does in its spare time
Positive perceptions about remote education over lockdown	Children positive about science work set by schools
	Engagement with nature and outdoors during lockdown
	Helpful to have more structure in terms of outdoor activities rather than worksheets
	Home-educating less stressful
	Home-education facilitating a more authentic life experience
	Increased socialising for an autistic child due to WhatsApp and online gaming
	Lockdown as an opportunity to give things a go
Home-educator aspects	Contact with other home-educators not happening in lockdown
	Home education routine pre-lockdown
	Home educators avoiding school-type resources
	Home educators doing more science than usual during lockdown
	Locations used as learning resources for home education
	Lockdown easier for home educators
	Lockdown easier for home-educated children
	Lots of play in home-education
	More home-education playing during lockdown
	Possibility of school for home-educated children
	Reasons for home-educating
	Routine of home-education
	We had you know a lot of people who were not home educators sort of turning to our community to get ideas what on earth to do with their children
	What other home educators did during lockdown
Positives for parents	Parents confident about school responding to needs if they arose
	Parents not too worried about prospect of helping children learn at home
	School well organised during lockdown
	She said I wish my teachers were like you which was a lovely thing to say
	Time spent with children helping parents connect with their learning more
Practical work at home	Buying things for home experiments from the internet
	Home experiments
	Home experiments helping children's science learning
	Home experiments helping parents see children's abilities
	Home experiments inspired by parents looking on the internet
	Importance of practical work
	More home experiments would have been helpful
	Not doing home experiments (Nodes)

Problems or difficulties faced by parents	Addressing different children's educational needs away from school
	Children at different schools
	Children left to their own devices
	Children not paying as much attention to parents as other adults
	Children not very accepting of parents in teacher role
	Children put off by parents' scientific backgrounds
	Confusion caused by awareness of what other primary schools were doing
	Daunting prospect of parents helping children with their school learning in lockdown
	Decision to not send children back when schools re-opened
	Difficulty of children being in different year groups and doing different work
	Difficulty of co-existing in lockdown in a small house
	Difficulty of home being school
	Effect of the lack of routines, expectations and boundaries
	Everything was driven by me rather than by them and I think it would have really helped her having some face-to-face teaching in this kind of setup maybe they did for some of the older students but not for her year group
	Failure of initial daily routine
	Friction between spouses caused by pressure of own work and helping children with schoolwork
	Guilt from knowing other parents are doing stuff with their children
	Having multiple devices for children
	Having suitable furniture for children to do schoolwork at home
	Helping children with lockdown learning more difficult than expected
	I didn't want her sitting down for all that time for the whole day
	It got to the stage where she actually said I need a teacher
	It was quite hard going
	Knowing the curriculum in advance would have been helpful
	Limited space at home for everyone to work
	One parent taking the teacher role mainly
	Only feedback to children coming from parents
	Open plan houses not conducive to online working
	Parent feeling guilty about inability to help children due to pressure to do own work
	Parent finding it easier to help older child
	Parent giving lots of supervision for science
	Parent having to prioritise their own work in the morning
	Parent judging whether children's work was a satisfactory standard
	Parent not confident with science
	Parent not knowing what the school science curriculum was (unlike for other subjects)
	Parental frustration with school during lockdown

	Parents balancing children's schoolwork with their own work
	Parents critical of lack of science (Nodes)
	Parents expanding the science curriculum
	Parents finding things for children to do
	Parents interpreting school instructions for the child
	Parents' lack of teacher skills
	Parents monitoring children are not distracted when they should be working
	Parents needing to know more about the curriculum
	Parents not sure how much time to spend helping children with lockdown learning
	Parents not wanting to criticise school's lockdown provision
	Parents not wanting to make children dislike learning
	Parents planning their work around children's schoolwork
	Parents' strengths or difficulties with specific subjects
	Parents trying to encourage children to be independent
	Parents trying to get children outdoors as much as possible
	Parents unsure of curriculum priority of science at primary
	Parents using schoolwork from a different school for their child
	Parent's view of how well they coped (Nodes)
	Parents wanting more science work for children
	Parents wanting to avoid letting children play all day
	Parents wanting to encourage children's curiosity
	Problem of children spending too much time online gaming
	Siblings working in separate locations
	Specific times for children working
	Starting with good intentions in terms of daily routine
	Stress caused by parents having to work at home
	Structured home approach requiring planning and research
	Video conference calls requiring quiet
	Younger children needing more attention

Theme 2: School provision – content, quality, or quantity.

Categories	**Codes**
School or Science provision during lockdown	A child missing one day of education is a lot to miss
	Absence of anything specifically labelled science
	Absence of 'live' teaching
	Amount of science work not allowing for any bedding in
	Children not recognising work was science
	Difference between grammar school and non-grammar school

	Difference between primary and secondary school noticeable through lockdown approach
	Different amount of structure in work provided by schools
	Different schools approaching lockdown differently
	Different teachers in same school setting work in a similar way
	Domination of primary maths and English
	Everybody was caught short
	Hard to find school resources for doing work
	Lack of consistency in school's approach
	Lack of context for watching online videos set by school
	Level of difficulty of work set
	Live' lessons after Easter
	New content making science difficult
	No assessment or feedback
	No expectation from school for children to do the work
	No provision to send anything into school
	Oak National
	Other subjects' similar approach to science at primary
	Paper packs
	Parent critical of school
	Parent surprised there wasn't more primary science
	Primary school doing ad hoc things
	Primary school not doing 'live' lessons
	Primary science being set by just one teacher in the school
	Primary science work weak
	Primary work coming from different teachers
	Production quality of YouTube videos not as good as TV
	School approach chaotic at the start
	School asking parents to just do what they could with their children
	School avoiding setting any structure
	School directing children towards TV programmes about science
	School not changing the curriculum
	School prioritising reading and the outdoors
	School provision felt chaotic
	School provision 'Seriously lacking'
	School science being less practical than children expected
	Schools seeking feedback from parents about their lockdown provision
	Science being delivered through English comprehension tasks
	Science work from school not well tailored to age groups
	Science work not pitched appropriately

	Secondary school initially using paper packs
	Secondary school making assumptions about what science teaching had been done at primary school
	Usefulness of written tasks in lockdown
Technology aspects	Age threshold on social media
	Availability of laptops at home
	Confusion of using different platforms
	Difficult keeping track of things on ClassDojo
	Drawback of continuity on Oak National
	Drawback of watching online videos
	Duration of Loom videos
	Effectiveness of the app used for setting work
	Electronic socialising not as good as face-to-face
	Finding old computer hardware for children to use
	Importance of a printer to help lockdown learning
	Importance of apps for school's lockdown approach working
	Importance of the internet during lockdown
	Inability to use a platform or application the school had signed pupils up to
	Internet connectivity at home
	Internet connectivity not mattering for learning at home
	Invitation for parents to put children's work on Twitter
	Laptops as the main item of use for children during lockdown learning
	Parents controlling internet access
	Problem of all ClassDojo stuff coming to the parent not the child
	Problems when internet connection wasn't working
	Same work put online as in paper packs
	School use of apps before lockdown
	School using a parent and child app for setting lockdown work
	Sharing computer time
	Type of device that was useful during lockdown
Communication with school	ClassDojo as main point of communication
	Email to parents at the beginning of the week
	Improved relationship between child and school because of parent contacting SENCO
	Inability to ask teachers for help during lockdown
	Not much contact from school
Lesson content	Content of online lessons
	Follow-up work to supplement loom videos

Theme 3: Children's emotions or wellbeing.

Children's wellbeing	A few times there'd be real tears and her saying I just wish things were back to normal
	Child missing the places that have been closed during lockdown
	Child not admitting they hadn't been doing science work
	Children disgruntled at parents being too busy with work during lockdown
	Children missing teachers
	Children missing things they enjoyed doing
	Children needing reassurance
	Children not being worried or depressed during lockdown
	Children pleased to go back to school
	Children wanting things to go back to normal
	Children worried about health of family or friends
	Children's anxiety caused by the pandemic
	Children's behaviour changes during lockdown
	Children's concerns about not seeing friends during lockdown
	Children's mental health
	Children's wellbeing not adversely affected during lockdown
	Difficulty for children not knowing whether exams will happen or not
	Increasing stress over lockdown
	Media contributing to children's anxiety
	Parents balancing children's emotional health against concerns of online gaming
	Parents helping children cope with frustrations of the pandemic lockdown
	Parents recognising children needing downtime
	School not wanting children over-worked
	School's concern for pupils' wellbeing
	School's lack of expectation took pressure off
Children's motivation or engagement	Child getting bored of BBC Bitesize and Oak Academy
	Children choosing to do physical exercise over other work
	Children doing research projects
	Children enjoying independent projects
	Children enjoying not being at school
	Children finding it hard to ask teachers or school questions
	Children finding lockdown schoolwork boring
	Children having different attitudes to specific subjects
	Children preferring activities like Bitesize with a person leading it
	Children preferring science in lockdown to normal
	Children's different motivations
	Children's enjoyment of science

	Children's motivation affected by sibling's school's work
	Children's motivation varying on a day-to-day basis
	Children's negative opinion of school science during lockdown
	Children's stimulation for independent learning
	Live' lessons more motivational
	Monotony of lockdown learning
	More direct interaction using Zoom desirable
	Motivation of children at home to get on with work
	Older children not wanting to speak or have cameras on in Zoom
	Reason for children's motivation declining over lockdown
	Reasons for children's engagement with a subject during lockdown
	Self-motivation of home-educated children
	Subjects that children were more positive about than science
	Things children were looking forward to about returning to school
Ways children worked, learnt and played during lockdown	Children collaborating on schoolwork via video calls
	Children communicating electronically via different methods simultaneously
	Children following normal school timetable
	Children socialising online via computer games
	Children socialising online via social media
	Children teaching each other during lockdown
	Children using the internet for purposes other than schoolwork
	Daily routine
	Different characters of siblings and their approach to lockdown
	Format of a lockdown school day
	Learning coming from collaboration not academic work
	Move away from structured approach to incorporating learning into other activities
	School setting week's work on a Monday
	Structured work better than watching videos
Things children found hard during lockdown	Children struggling to be independent
	Children struggling with change of routine
	Problems of lockdown for autistic children
	What children missed during lockdown
	Younger child struggling with the basics

Uncategorised codes

Reason for not requesting extra work
Reason why looking things up on the internet was more beneficial than YouTube videos
Rural home location
School's approach affecting children's attitude to doing work

Work set the night before for the day ahead
Work that made children do something
YouTube as a science learning resource for home education

Appendix 12: Categories of quantitative analysis from parent survey

Quantitative analysis label	Description, with number of individual analyses performed shown in brackets
P1	Survey completion (4)
P2	Basic data (4)
P3	Educational qualifications (1)
P4	Whether parents work in education (2)
P5	Home technology (6)
P6	School types (1)
P7	Schoolwork set (8)
P8	Other science learning (2)
P9	Children's motivation over lockdown (3)
P10	Parents' learning over lockdown (3)
P11	Children's wellbeing (2)

Appendix 13: Introductory information and statement of research ethics on teacher survey

The parent survey had almost identical wording.

Teaching Science in Lock-down
This survey is for teachers in primary or secondary schools. It is aiming to find out about science education for school pupils during the coronavirus lock-down. It should take you around 10-15 minutes to complete.

Look for the arrows to navigate between pages of the survey.

Research Ethics information
The survey is part of a doctoral study by John Walker at Sheffield Hallam University which is looking at how teachers of science use digital technology.

The University undertakes research as part of its function for the community under its legal status. Data protection allows us to use personal data for research with appropriate safeguards in place under the legal basis of public tasks that are in the public interest. A full statement of your rights is available. All University research is reviewed to ensure that participants are treated appropriately and their rights respected. This study was approved by UREC with Converis number ER10294710.

The research will be carried out in accordance with Sheffield Hallam University's Research Ethics Protocols and in conformity with data protection legislation. This means all data will be kept securely and treated as confidential. All personal data will be anonymised and non-attributable. Further information about how data is stored and used by Sheffield Hallam University is available.

Should you wish to withdraw from the research project you are free to do so at any time, simply by contacting the researcher.

You should contact the Data Protection Officer if:

- you have a query about how your data is used by the University
- you would like to report a data security breach (e.g. if you think your personal data has been lost or disclosed inappropriately)
- you would like to complain about how the University has used your personal data

You should contact the Head of Research Ethics (Professor Ann Macaskill) if you have concerns with how the research was undertaken or how you were treated.

Postal address: Sheffield Hallam University, Howard Street, Sheffield S1 1WBT
Telephone: 0114 225 5555

Appendix 14: Parent interview consent letter

Sheffield Hallam University

John Walker
Teacher Education Department
Sheffield Institute of Education
Charles Street
Sheffield
S1 2LX

j.walker@shu.ac.uk

August 2020

"Children's Science Education During Lockdown."

Dear Parent/Guardian

Thank you for completing the survey about children's science education during lockdown, and for indicating you are interested in participating in a follow-up interview to discuss this in more depth. The form on page 2 is for you to provide your consent to the interview. The points below are a summary of the research and interview process and how your data will be stored and used.

- The research for which the survey and interviews are being conducted will form part of a doctoral thesis, the focus of which is science teaching and the use of digital technology.
- The interview will be conducted remotely using a video-conferencing platform at a mutually convenient time.
- The interview is expected to last up to an hour.
- The interview will be audio-recorded to enable accurate transcription and analysis for research purposes. You may request a copy of the transcription at any time.
- The audio file of your interview, and the transcription, will be securely stored in accordance with the university's data protocols, which you can find out more about by visiting https://www.shu.ac.uk/about-this-website/privacy-policy/privacy-notices/privacy-notice-for-research
- Your data will be anonymised to make any views expressed non-attributable. Any views you express will be treated in the strictest confidence.
- You may request to have your data withdrawn from the research at any time.

If you have any questions or concerns that you would like to raise before providing your consent, please do not hesitate to contact me using the email address above.

Yours sincerely

John Walker

Doctoral researcher

" Children’s Science Education During Lockdown."

Participant consent form

If you are happy to take part in the research, please complete the following consent form and return it to me.

Please answer the following questions by circling or shading your responses:

I have read and understood the information about the research activities.	Yes	No
I have received enough information about the research to allow me to decide whether or not to take part.	Yes	No
I understand that all data that is generated as part of the research will be anonymised so that none of it can be attributed to me.	Yes	No
I understand that I am free to withdraw from participation at any time, and can also withdraw consent for my data to be used in any analysis or publication.	Yes	No
I understand that it may not be possible to do this retrospectively as my data may have already been anonymised and combined with data from other participants for analysis.	Yes	No

By signing below, you indicate that you have voluntarily decided to take part in this study having read and understood the information provided.

It will also indicate that you have had adequate opportunity to discuss the study and that all questions have been answered to your satisfaction.

Thank you for agreeing to take part!

Signature of participant:
Date:

(A printed name will suffice if you do not have an electronic version of your signature)

Name:

Contact email address:

Contact telephone number:

If you would prefer to use a different video-conference platform to Zoom, please indicate it here: