

Evaluating Science Outreach:
Case study in the Wohl Reach
Out Lab

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Statement of Originality

The content of this thesis is my own work. This thesis has not been submitted for any degree or any other purposes. I certify that the intellectual content of this thesis is the product of my own work and that all the assistance received in preparing this thesis and sources have been acknowledged.

Roberts M. Zivtins

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Abstract

The science sector has inequitable participation from certain socio-demographic groups; women, black and working-class individuals are under-represented. These inequalities are thought to emerge in early life and formal education may exacerbate them. This study evaluates the work of an initiative which aims to redress this inequality: the Wohl Reach Out Lab (WROL).

The WROL is a specialist outreach centre at Imperial College London. It was founded to encourage under-represented students to continue participating in science by providing hands-on science experiences. The WROL hosts several outreach programmes, including a partnership with a local school. This study focusses on the school-WROL partnership programme.

Using a mixed-methods approach, three questions are answered:

1. What are the desired outcomes of the WROL?
2. Does visiting the WROL increase students' levels of science capital?
3. What are the features and pedagogical practices of the WROL?

Data were collected using a combination of methods. Interviews were conducted with visiting teachers and the session leaders to determine what they hoped the WROL would achieve. Questionnaires were used to measure students' levels of science capital both before and after visiting the WROL to assess any resulting changes. Group interviews with students were also used to supplement the questionnaire data. Finally, WROL sessions were observed to reveal common pedagogical practices.

This study found that teachers value the WROL as an *informal* educational setting, because it provides students with non-school experiences of science. Observation showed some practices within the WROL successfully delivered this, by providing non-standard equipment and university mentors. However, this thesis also describes a tension between formal and informal learning in the WROL, where sessions often replicated elements of 'school science', rather than providing students with a new experience. This thesis concludes with recommendations, building on the WROL's existing strengths to make the practices used within more inclusive.

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1. Chapter one: Participation in science

This thesis begins by exploring patterns of participation in the science sector and describing how it is largely stratified by gender, race, and class. The UK's formal science education system is then explored as a potential explanation for the underrepresentation of members from certain socio-demographic groups. Informal science education is then proposed as a possible means of widening participation, particularly at university level. The chapter then establishes the context of this research project, Imperial College London's dedicated outreach space: the Wohl Reach Out Lab (WROL).

1.1. Patterns of science participation

The UK is currently considered to be at the forefront of the international scientific community (OECD, 2015), with science frequently being the largest export industry (Office for National Statistics, 2017). Yet, the insidious and persistent problem of under-representation haunts the sector. It is recognised that participation from various socio-demographic groups in science is inequitable (McMaster, 2017). The science sector is stratified along three distinct lines: class, gender, and race.

Gender representation has been of particular concern within the science sector and reflects wider social biases with prejudices against women. Women account for a minority of the world's researchers globally; UNESCO estimates that, in 2015, women represented just 28.8% of the total science research and development workforce (UNESCO, 2018). These global data lack some granularity, yet the gender gap persists even in the UK. According to WISE (2019), women make up just 24% of the core STEM (Science, Technology, Engineering, Maths) UK workforce.

Gendered science participation varies in the different sub-categories of the STEM subjects. A relatively high proportion of students studying the biological sciences in 2017/18 were women (48.5%) (Office for Students, 2019b). Yet, despite ~30 years of initiatives, engineering has remained obstinately inequitable (Smith, 2011); just 9.3% of engineering and technology students are women (AdvanceHE, 2019). There are also concerns regarding the proportion of women in senior roles within the science sector. Women are underrepresented in the highest managerial and professional positions; they are half as likely to occupy such roles as their male counterparts (The Royal Society, 2014).

While *direct* gender discrimination, such as sexual harassment (Greider et al., 2019), may exclude women from science, other subtler factors also have an influence. For example, language and linguistic cues mediate girls' science engagement; Rhodes, Leslie, Yee &

Saunders (2019) found that describing science as an identity (“Let’s be scientists”) decreased girls’ persistence in science games, when compared to describing science in terms of actions (“Let’s do science!”). The famous ‘Draw-A-Scientist Study’ revealed that children sketch male scientists more frequently than female scientists (Chambers, 1983), showing how children seem to perceive science to be a ‘masculine’ discipline (Archer et al, 2016; 2010; Archer, Dewitt, & Willis 2014) (though this trend has diminished slightly in the past decades, Miller et al., 2018).

Another concern is the low rate of participation of those from specific racial/ethnic backgrounds. Again, the picture is complex. Definitions of ethnicity have changed over time; for example, there were originally seven ethnicity categories in the British Cohort Study (BCS). These have subsequently been subdivided into 16 (Royal Society, 2014), making long-term tracking of participation of various ethnic groups difficult. However, the current demography of science is dominated by those of White, Indian, and Chinese heritage, whereas those from Black, Pakistani, and Bangladeshi backgrounds are less represented (Elias, Jones, & McWhinnie, 2006). Participation in the physical sciences is of most concern, with most groups from ethnic minorities being under-represented compared with wider society (*ibid.*). This situation is similar in the chemistry subsector, where the percentage of academic scientists from minority groups drops significantly with increasing career stage (Royal Society of Chemistry, 2018). Even after graduation, black and minority ethnic students who do not pursue an academic track are less likely to progress to scientific jobs than their white peers (Royal Society, 2014).

The exclusion of certain minority ethnic groups from science is likely to be partially grounded in early educational experiences. Elias et al. (2006) suggest that the lower attainment of ethnic minority students at school largely explains under-representation later in the educational cycle. Yet, low attainment in these groups only partially explains the situation; when minority ethnic students are appropriately qualified, they are still more likely to choose *not* to study the physical sciences at university than their equally qualified white peers (Jones & Elias, 2015). It has also been suggested that since science largely reflects Western or Euro-American culture (Aikenhead, 1996), this culture is hostile to black students (Hanson, 2007). This may result in black students viewing science as ‘not being for them’ (Archer, Dewitt, & Osborne, 2015; Dawson, 2014).

Socio-economic class is an often neglected variable in science education research (Jensen & Wright, 2015), yet it is a significant socio-demographic factor relevant to understanding participation in science. Young people from higher social class backgrounds

have previously been found to study science, alongside other ‘prestige’ courses such as medicine, law, music and modern foreign languages, in a higher proportion than their less well-off peers (Henderson et al., 2017; van de Werfhorst, Sullivan, & Cheung, 2003). Further to this, The Royal Society (2008) found a similar disparity in the number of students eligible for free school meals (FSM)¹ who studied science subjects after the age of 16, again relative to their more well-off peers. This inequality worsens later as students from poorer families who continue to study science are less likely to obtain the grades required to progress (Gorard & See, 2009).

Evidence confirms that family plays an important role in helping shape young people's engagement and their aspirations and attainment in science (Archer et al., 2012). As an academic subject, science confers a level of prestige sought after by middle/upper-class families. As socio-economic position increases, students are more likely to choose science subjects even over other ‘high-return’ subjects (McMaster, 2017). It is argued that science participation is also influenced by a family's capacity to activate various social and cultural resources which encourage and enable their children to participate in science. These resources are termed ‘science capital’ by Louise Archer and her colleagues (Archer et al., 2015). Families who possess science-specific capital can leverage these resources and are likely to be both strongly ‘pro-science’ and actively encourage science participation (Archer et al., 2012). For example, Alexander, Johnson, & Kelley's (2012) longitudinal study found that a parent's ability to answer science-related questions is a strong indicator of a child's interest in the subject and in VanMeter-Adams et al. (2014) retrospective study, the authors found that parents and other relatives were amongst the strongest factors that influenced the decision of academically successful students to pursue science subjects. This thesis is influenced by the concept of science capital (see chapter two below for a more expansive exploration of the theory).

Evidently, patterns of science participation from various socio-demographic groups are deeply complex. The use of class, gender, and race as socio-demographic identifiers helps to understand experiences of science from different perspectives. Yet, the picture becomes increasingly complex with each axis considered. Indeed, Strand (2014) conducted several

¹ Student eligibility for free school meals (FSM) is frequently used as a proxy measure of economic deprivation in the UK, as it indicates that the household income is below a certain threshold. Although the appropriateness of using FSM as a measure has been questioned by some Ilie, Sutherland, & Vignoles (2017) found it correlates strongly with other measures of socio-economic disadvantage and is predictive of educational attainment, so its use is justified.

modelling exercises from data on 15,000 16 year-old students to explore the causes of the educational attainment gap. In his conclusion, he states: “...interpretations of educational success and failure based **exclusively** on social class, ethnicity or gender do not explain the complexity in the data” and suggests that nuanced analysis is required. Lemke (2001) further adds to this, saying that the terms “class, gender ... and **especially** race” lack objective definition. Using socio-demographic identifiers in isolation risks reducing individuals to stereotyped labels and oversimplifying the complexity of human experiences.

For this reason, an intersectional approach is often advocated. Intersectionality theory (not to be confused with the branch of algebraic geometry ‘Intersection theory’!), has its origins in black feminist research. Crenshaw (1989) used the term to argue that socio-demographic variables are not mutually exclusive. For example, an African American woman's life experiences cannot be understood in independent terms of either A) being a woman or B) being black. The combined experiences associated with ‘womanhood’ and ‘blackness’ are not simply additive (Yuval-Davis, 2006). Rather than reducing individuals to single facets of their identities, intersectional theory argues that people should be regarded holistically. Intersectional theory has previously been used to explore participation rates in science (e.g. Archer et al., 2016; Calabrese Barton et al., 2013; McMaster, 2017; Nomikou et al., 2019). This research stresses that a single element of one’s identity is not an absolute determinant of science participation. For example, being white does not automatically ensure science participation, nor does being a girl inevitably preclude participation.

Advocates of science equity have argued that contemporary science can be seen as a subculture of Western (or Euro-American) culture (Aikenhead, 1996). This is largely a reflection of the foundation of modern science during the Enlightenment by predominately white, privileged men (Francis Bacon and Isaac Newton come to mind). Evidently, there have been many other scientific advances from different cultures throughout history, yet these are not celebrated with the same standing. Furthermore, popular depictions of scientists rely on ‘Einsteinian’ characteristics, which further feed into science stereotypes (Chambers, 1983; Miller et al., 2018; Ruiz-Mallén, Gallois, & Heras, 2018).

Ultimately, this creates a perception of science where some authors have gone as far as to use the acronym WWMS (White Western Male Science) to describe the community (Pomeroy, 1994). The logical corollary of this view is that those not from white middle-class backgrounds may not recognise themselves and/or be recognised by others as being ‘scientific’ (Archer, et al., 2015). Throughout the literature, various collective terms are used to refer to members of those underrepresented in science; historically underrepresented (Byars-Winston

et al., 2016; Hayton & Bengry-Howell, 2016), marginalised (Dawson, 2018), minoritised (Dawson, 2019), non-traditional (Wong & Chiu, 2019), non-dominant (Archer et al., 2018), under-resourced and excluded groups. By and large, these terms are not precisely defined and are used interchangeably. Throughout this dissertation, I will refer collectively to members of those excluded from science as ‘underrepresented’ because it is commonly used and understood.

Further to the underrepresentation of those from certain groups, the science sector also struggles with a so-called ‘skills gap’ (POST, 2013), where the sector does not recruit enough adequately qualified scientists. In a joint survey by the Biotechnology and Biological Sciences Research Council and Medical Research Council, particular vulnerabilities were found in the areas of interdisciplinarity, quantitative skills (maths, stats and computation), physiology and pathology, agriculture and food security (BBSRC & MRC, 2014), and STEM Learning estimates the skills shortage costs £1.5 billion per year (STEM Learning, 2018). Some have questioned the severity or existence of the ‘recruitment crisis’ (Chatette, 2013; Salzman, 2013; Smith & Gorard, 2011) and have described it as a perpetual problem (Smith, 2010). However, the situation remains a significant matter in educational policy discourse (House of Commons - Science and Technology Committee, 2017), with many jobs on the Home Office ‘Shortage Occupation List’ being in either science-related roles or industries (Home Office, 2020).

Brexit further threatens to make the situation worse. Even before the referendum, there was concern that leaving the EU might affect scientific research (House of Lords- Science and Technology Select Committee, 2016). Despite various government reassurances (House of Commons - Science and Technology Committee, 2018), there are concerns on the effect Brexit will have on recruitment (Institution of Engineering and Technology, 2017) and that the confidence of researchers in the UK and potential researchers from the EU has been undermined (The Royal Society, 2020a).

In response to the fall in the numbers of trained scientists, STEM(M)² has emerged as a policy concept— it is an acronym used to group the four disciplines (Science, Technology, Engineering and Maths/Medicine) which are seen to be part of the recruitment problem (Wong et al., 2016). STEM, as a concept, has however been criticised. Firstly, ‘STEM’ is considered to be an ambiguous term (Sanders, 2009), which is ill-defined across organisations (House of

² There is some evidence to suggest the original acronym used in the 1990’s was SMET, but the acronym sounded too much like ‘smut’ and was re-arranged to STEM by the National Science Foundation (NSF) in America (Sanders, 2009)

Lords- Science and Technology Select Committee, 2012: 12-13) and for many outside the ‘STEM community’ the term has little meaning (Breiner et al., 2012). Secondly, ‘STEM’ has been seen to promote subject-specific elitism, leading to subsequent calls by the House of Commons Culture, Media and Sport Committee (and others) to include the arts to make ‘STEAM’ (House of Commons, 2013: para. 117) (see also: Land, 2013; Madden et al., 2013). However, STEAM further lacks conceptual clarity and epistemic validity (Colucci et al., 2017). For these reasons, the terms STEM/STEAM are largely avoided in this dissertation, ‘science’ avoids many of the above problems and adequately conveys discipline-specific information about the sector.

Patterns of science participation emerge early in a student’s life and education is likely an important factor in explaining these patterns. The following section explores early experiences and the relevance of education as the sources of the sector's current state and possible remedy for inequality.

1.2. Science education

1.2.1. Formal science education

Perhaps the most common form of science engagement and participation is the science experienced during formal schooling. As early as the mid-19th century, the case for formal science education was made by prominent scientists and educators (BAAS, 1868). With the introduction of the National Curriculum in the Education Reform Act, 1988 by Kenneth Baker (now Lord Baker) science was codified as a ‘core’ subject, alongside English and Maths, as a legal obligation for all students in the UK to study (until at least age 16). Yet, despite the provision of science education for all students, the patterns of participation described above persist. It is argued that current educational practices serve to educate a small minority of scientific elites and therefore exclude the vast majority of the general public from meaningful participation in science (Claussen & Osborne, 2013; Goodstein, 1993).

The progression of students across various stages in the formal science education sector is commonly represented by a ‘pipeline’ metaphor. The customary stages in England are seen as: compulsory science 5-14, science GCSE, then science A-level, undergraduate science degree, MSc, PhD, finally culminating with a career in science. At each transition along this ‘pipeline’ there are ‘leaks’ where students choose not to continue with science (alternatively conceptualised as a ‘filter’ by Blickenstaff, 2005). As described above, students from underrepresented backgrounds are disproportionately represented in these leaks. Although

reliance on the ‘leaky pipeline’ metaphor has been criticised³, science and formal education appear to be inextricably linked. Indeed, the practices of ‘doing science’ and ‘doing school’ have become strongly associated (Varelas, Kane, & Wylie, 2011) and prior academic attainment is a significant predictor of future science participation (Homer et al., 2014).

Formal science education begins in English and Welsh schools at age 5 (as mandated by the National Curriculum). Initial science education largely reflects childrens’ developing understanding of their environment, through observation and immediate sensory descriptors (e.g. Tomkins & Tunnicliffe, 2007) before progressing onto more abstract scientific concepts (such as light or density).

Early experiences are important for developing positive perceptions of science. Murray & Reiss (2005) suggest that a strong negative or positive primary science experience can carry through for the next six or seven years. There are however concerns about the provision of science education at primary level. Although science remains on the National Curriculum, it has been suggested that the removal of mandatory national examinations at the end of KS2⁴ has resulted in its relegation as a priority subject in primary schools (with both time spent teaching and also resource allocation being reduced) (SCORE, 2013). Just 30% of primary teachers consider their senior leaders as viewing science as ‘Very important’ (compared to 83% and 84% viewing English and Maths as ‘very important’) (Wellcome Trust, 2017a). Overall, science is taught to primary school students on average for just 1.7 hours a week (*ibid.*) and is frequently taught by teachers who lack subject specific content knowledge outside of their own academic discipline (Abrahams & Reiss, 2012; Ofsted, 2009; SCORE, 2013)

The compound effect of the shortcomings of science provision, at such a young age, have a knock-on effect on students’ interests and attainment in science. (House of Lords Science and Technology Committee, 2001). Indeed, when considered retrospectively, 11% of students report that primary school science had a negative impact and they were ‘put off’ by science at primary school (Murray & Reiss, 2005). Furthermore, students as young as 10 have

³ The ‘leaky pipeline metaphor is criticised for being reductionist. It over-emphasises a singular ‘acceptable’ linear trajectory which ignores the multiple other pathways which *could* precede a career in science (Maltese, Melki, & Wiebke, 2014; Petray, Doyle, Harrison, Howard, & Morgan, 2019) Furthermore, using the pipeline whose only end-point is science employment negates the value of those studying science even with no intention of working in the sector (Archer, et al., 2013)

⁴ KS2 refers to Key Stage Two of the five stage in state education system, with students ages 7-11. A selected sub-sample of students at the end of KS2 do take a science test, every two years, to monitor national performance in science; the results of these tests are no longer reported to schools or parents.

been found to subscribe to stereotyped notions of scientist identities, subsequently deciding that science is ‘unthinkable’ and ‘not for them’ (Archer et al., 2010).

A similarly troubling picture is observed in students’ perceptions of science at secondary school. Most young people report liking school science and report positive views of scientists (Archer et al., 2013). Jenkins & Nelson (2005) report that 68% of students agree that ‘everybody should learn science at school’ and 61% agreed that science is interesting. However, it is understood that 52% of students do not intend to study science beyond 16 (Reiss, 2005 quoted in Abrahams & Sharpe, 2010). Below, several potential reasons for this are explored.

Mirroring the paucity of primary school teachers with the requisite scientific content knowledge (Abrahams & Reiss, 2012; Ofsted, 2009; SCORE, 2013), secondary schools in the UK are also struggling to recruit and retain science teachers. Numbers entering initial teacher training in the 2019/20 years, in all subjects, fell short by 15% of the estimated numbers required in the future cohort intake (Department for Education, 2019a). Recruitment is even worse in chemistry and physics, reaching just 70% and just 43% respectively of the teacher supply model (TSM) targets (*ibid.*). This situation has been recognised by the Home Office, with “*secondary education teachers in the subjects of...physics, science (where an element of physics will be taught)*” featuring on the Shortage Occupation List (Home Office, 2020). To ‘plug the gap’ in specialist teachers, non-specialists are often asked to teach outside their academic area (Millar, 1988). Indeed, since the Education Reform Act 1988, the school curriculum dictates that students are taught ‘science’. Those hired as ‘science teachers’ may have a specialism, but this is not necessarily recognised by schools.

Science content in the national curriculum has been criticised for being irrelevant to students’ lives and lacking in ‘authenticity’ (Bencze & Hodson, 1999; Braund & Reiss, 2006). While evidently some concepts within science are inherently abstract (e.g. ‘the electron’), Claussen & Osborne (2013) suggest that the science curriculum is lacking in the history of science, underemphasises the applications and implications of science and omits ‘how science works’. There is a sense that many students complete their science education, quite successfully, yet lack familiarity with the scientific concepts which they are likely to meet outside school (Millar & Osborne, 1998). This may in part be a reflection of the relative lack of input that practicing scientists have in developing the English curriculum, this is in contrast to, for example, the Israeli curriculum where academics have a significant input (A. Yarden, personal communication, 18th December 2019) (see also Machluf et al., 2017). To explain how the curriculum is used in the UK, Ross, Lakin, and Callaghan (2004) (quoted in Braund &

Reiss, 2006) use the analogy of garden, where the science knowledge is sown, grown and then harvested (during exams) leaving nothing but a fallow field afterwards.

The focus on exams in the formal education is another concern. Even with the limitations of the science curriculum, teachers are required to having ensure their students achieve good grades, to borrow Nott and Wellington's (1999) turn of phrase: "...*the assessment tail is definitely wagging the science dog*". Hodson, (1992) supports this view, stating: "*It is inevitable that both teachers and students will put most value on that which is examined and for which academic credit can be gained.*" Indeed, students are abundantly aware that most of their science education is built on exam success and this focus causes them to view science as an inherently difficult subject (Shirazi, 2017). As a result of the high-stakes associated with the exam performance league tables, the UK educational system has been compared to a pressure cooker (Perryman, Ball, Maguire, & Braun, 2011).

To move science education beyond purely conceptual learning and make science more authentic or interesting for students, particular attention is often given to the importance of practical science. Indeed, practical science education has a long history of advocates, with the British Association for the Advancement of Science (now the British Science Association) arguing that: "*Of the value of experimental teaching in physics,... there can be no doubt.*" (BAAS, 1868: liii). More recently, the Gatsby Foundation (2017) has suggested five beneficial aspects to practical science education:

1. *To teach the principles of scientific enquiry*
2. *To improve understanding of theory through practical experience*
3. *To teach specific practical skills*
4. *To motivate and engage students*
5. *To develop higher level skills and attributes*

Many of these appear self-evident to science educators; because of these perceived benefits, a significant proportion of lesson time is dedicated to practical activities in UK science classrooms, when compared to international counterparts (Sturman, 2007). Students also rank practical science in the classroom as an effective way of learning (after taking notes from the teacher and discussion) (Murray & Reiss, 2005).

However, despite the potential advantages of practical science, the reality often falls short in the classroom. Osborne (2015) questions what benefits practical science has over other teaching methods and suggests that the pre-eminent position of practicals over-emphasises this particular pedagogic practice where reading, writing and talking about science are neglected techniques, saying:

...the current clamours for the value of practical work in school science is misconceived and places too much emphasis on just one of the many activities necessary to do and understand science (p.16).

Hodson (1991: 176) is perhaps even more damning:

As practiced in many schools, it [practical science] is ill-conceived, confused and unproductive. For many children, what goes on in the laboratory contributes little to their learning of science or to their learning about science and its methods. Nor does it engage them in doing science in any meaningful sense. (p.176)

Practical science in secondary schools has been criticised for over-reliance on ‘cookbook’ practicals (Boz & Boz, 2005), resulting in ‘hands on’ but ‘minds off’ activities. By following a ‘recipe’, students (re)produce scientific a phenomenon, but cannot explain *why* the phenomena occurred. Abrahams and Millar (2008) argue that students often have difficulty in linking the domain of theoretical ideas with the domain of physical experimentation, explaining that tacit knowledge is not readily built during practical sessions, and go on to quote Lunetta (1998) who says: “...laboratory inquiry alone is not sufficient to enable students to construct the complex conceptual understandings of the contemporary scientific community...”. Perhaps unsurprisingly, the frequency of practical science in schools has been falling, particularly field-based practical work (Dillon, 2008). Therefore, although practical science is seen by some as the solution to counter the issues with abstract curricular concepts (above), practical science is also problematised.

The conclusion of compulsory formal science education occurs with the GCSE examinations. Science GCSE can be taken as a ‘combined’ subject, where students study biology, chemistry and physics, worth two GCSEs or ‘double award’. Alternatively, students can study each of the three separate subjects in more detail, with each being worth a single GCSE, this is dubbed ‘triple award’ and is generally considered more prestigious. Courses studied at 14 are strongly influenced by differences in socio-economic status, gender and ethnic factors, even when accounting for prior attainment (Henderson et al., 2017). Again, the patterns of socio-demographic exclusion (explored above) are observed in the selective practices of which students who are allowed to study double or triple science. Just 14.7% of black Caribbean students were entered to study the more prestigious triple science GCSE, in 2013, compared to 24.6% of white British students, 38.5% of Indian and 48.4% of Chinese students

(Wong, 2016), disproportionately filtering students from underrepresented backgrounds away from studying science in depth (Archer et al., 2017).

After the age of 16, students are no longer legally required to study science, in fact many choose not to (Millar & Osborne, 1998). Although students have the opportunity to continue to study science in either A-level or BTEC courses⁵, we see similar patterns of uptake in science which, at this stage in this chapter, might not be surprising. For several years there has been a decrease in the number of students electing to study science and maths A levels, as a percentage of the total number of entries for all A level subjects (Banerjee, 2017b; Hoyles, Reiss, & Tough, 2011). Only one fifth of students in England who continue to study after the age of 16 take more than one science or maths subject and this is generally stratified by socio-economic status and gender (Gorard & See, 2009) as well as gender and ethnicity (Mcmaster, 2017).

Along with the concerns about secondary practical science (described above) changes in the assessment of practical science in Key Stage 5 (KS5) have caused further concern within the sector (Biology Education Research Group, 2014). From 2016 onwards, Ofqual, the UK's examination and qualification regulatory authority, no longer require practical work to directly contribute to overall grades. Instead, students studying science at KS5 are expected to complete Practical Activity Group tasks (commonly termed 'PAGs'). A record of completed PAGs is kept by the school, and if a student completes the required PAGs, they will receive a 'Practical Endorsement' on their A level certificate. Students may also be indirectly assessed on their practical knowledge in written exams. Yet, it is now possible to achieve a top grade at A level without actually completing *any* practical work. Abrahams, Reiss and Sharpe, (2013) conclude that overreliance on indirect assessment reduces the likelihood that practical work will be taught and learnt as well as it might be. Again, changes in the assessment of practical science is likely to disproportionately effect students from disadvantaged backgrounds, as they already conduct practical work less frequently than better-off peers (Wellcome Trust, 2017b). However, it should be noted that Ofqual's own monitoring suggests that the amount of practical work occurring in schools pre and post the changes has remained constant (Cadwallader, 2018) and during conversation with senior ministers it was reasserted that the DfE is committed to

⁵ A further post-16 option to study science will be added in 2021, the T-level (standing for Technical level) which promises to offer students the opportunity to study subjects, including science, in a vocational manner, including industry placements (Department for Education, 2019b)

continuing to provide practical science education (Lord Agnew, personal communication, 6th August 2019).

To summarise, students' experiences of science during formal education are not likely conducive to an equitable science sector. Overall, formal science education largely serves to educate a small minority rather than engaging the majority of the general public to produce a scientifically literate population (Claussen & Osborne, 2013; Goodstein, 1993).

1.2.2. Informal science education

Although most science participation occurs in a formal classroom environment and is the 'arterial' route into science, science learning can occur across many contexts (Bronkhorst & Akkerman, 2016) and informal science education can form a small, but significant addition to a child's experiences of science.

The DfES' STEM education mapping review found 470 STEM initiatives in the UK which focused on the enrichment and aspirations of students (Department for Education and Skills, 2006), with at least 50 distinct niches within the sector (Falk et al., 2012). Students and the general public have the opportunity to participate with science in a myriad of ways: science museums (Dawson et al., 2019), natural history museums (Mujtaba et al., 2018), science clubs, science centres, science festivals (Canovan, 2019), botanical gardens, zoos, aquariums, makerspaces, hackspaces, or even at everyday activities such as watching TV (Dawson, 2017) or using social media (Dawson et al., 2019).

Engaging with science in such environments may influence a student's participation in science in later life, as they provide an alternative, supplementary way to join in or experience science, beyond the science taught in classrooms. Braund & Reiss, (2006) propose five beneficial aspects of out-of-school learning:

- Improved development and integration of concepts.
- Extended and authentic practical work.
- Access to rare material and to "big" science.
- Attitudes to school science: stimulating further learning.
- Social outcomes: collaborative work and responsibility for learning

There is evidence to suggest at least some of these potential benefits have been realised. Bonnette, Crowley, Schunn, & Crowley (2019) found that students age 10-14 who participate in informal science learning were more likely to maintain or have greater fascination in science. In a retrospective survey of academically successful American High school students and

undergraduates, extra-curricular experiences were cited as the main stimulus in igniting an initial interest in pursuing science (VanMeter-Adams et al., 2014).

Braund & Reiss (2006) compare the formal and informal science education sectors and describe the contrast as ‘stark’. Where the formal sector is broadly conceptualised as being *“boring, irrelevant, and outdated; designed only to educate a minority of future scientists, rather than equipping the majority with the scientific understanding, reasoning, and literacy they require to engage as citizens in the twenty-first century”* the informal sector challenges many of these points and *“is often seen as exciting, challenging, and uplifting”*.

Of course, the distinction between formal and informal science learning experiences creates a false dichotomy and evidently there is some middle ground. Lin & Schunn (2016) present the idea of ‘semi-formal’ experiences. Formal providers often rely on external organisations to provide extra-curricular experiences. Indeed, school trips are often cited as highly significant educational experiences; out of 11 alternative strategies for learning science, *“going on a science trip or excursion”* was rated the most enjoyable way of learning and the fifth most useful and effective (Murray & Reiss, 2005).

However, informal science education is not a panacea and various aspects have previously been criticised. Firstly is a concern over access (POST, 2011); participation in informal science largely mirrors patterns of participation in the formal science sector. Analysis of museum attendees and other informal science experiences show again that participation tends to be dominated by those from socially privileged, white, affluent backgrounds (Dawson, 2014; DeWitt & Archer, 2017; Kennedy, Jensen, & Verbeke, 2018). Secondly, is the lack of evidence to show that informal science actually improves educational attainment (Banerjee, 2017a; Suter, 2016), which is particularly problematic considering the significance given to formal school performance data (Clapham, 2016). Equally, there is little evidence to suggest that participation in informal learning increases or widens later STEM participation (Banerjee, 2017b).

1.3. Widening participation

1.3.1. Public engagement, Outreach and Widening Participation

Given the moral and economic arguments for addressing the participation crisis in science, universities have engaged in informal programmes of communicating science to the general public. While engaging laypeople with science may appear a relatively modern concern, science has a long history of public engagement (Turney, 2006). During the scientific revolution, as a fledgling academic discipline, scientists were funded by royalty and

aristocracy, as such were expected to contribute to fashionable intellectual amusement for court entertainment. This exclusive audience for showcasing scientific advances is perhaps prophetic of the current situation, where science is perceived by the general public as the preserve of ‘boffins’ in elitist ‘ivory towers’.

The distance between ‘science’ and the general public is problematic. There is little doubt that scientific developments have improved global standards of living (e.g. the invention of medicines, refrigeration, telecommunications, time-saving devices such as vacuum cleaners etc.). However, as previously ground-breaking theoretical advances are applied in everyday life, they become disconnected from their origins in research. Contemporary scientific research is largely not publicly available. Academic conferences and academic journals are hidden behind prohibitively expensive paywalls (conference fees or journal subscriptions) which limits engagement to a select few specialists with institutional funding (although it must be acknowledged that the situation is changing, with, for example, open access publishing practices and bursaries for conferences). This is somewhat ironic considering that it is the public who (at least partly) subsidise scientific research— general taxation contributes to the 10% of funding which UK universities receive from the Government (UUK, 2016). The public relies on a level of ‘certainty’ from science and becomes disillusioned when there is a perceived ‘uncertainty’ or science is seen to ‘fail’, for example: the BSE crisis, arguments against anthropogenic climate change or the Wakefield MMR vaccine scandal. More recently, the UK government’s repeated assertion that it was ‘*following the science*’ in its COVID-19 response has been criticised as using science “*as a prop to create a false sense of security*” (The Royal Society, 2020b)

Cumulatively, this creates a paradoxical relationship between science and the public (House of Lords Science and Technology Committee, 2000). While there is a general interest and acceptance of the benefit of science, there has also been an erosion of the public’s confidence in science and science-based policy (*ibid.*) with many feeling excluded from the decision-making processes and benefits of science (particularly those with lower incomes) (Wellcome Trust, 2018).

In recognising the disconnect between science and the public, efforts have been made to engage laypeople. The Bodmer Report (The Royal Society, 1985) is seen as the origin for the rationale for modern science communication. Although often used interchangeably it is worth considering here key distinctions between some terms, which are sometimes used synonymously. Public engagement, outreach and widening participation initiatives may indeed share some of the same features, but they are not the same. They can be considered a nested

hierarchy which target different audiences (see Figure 1: Nested hierarchy of the different forms of public engagement).

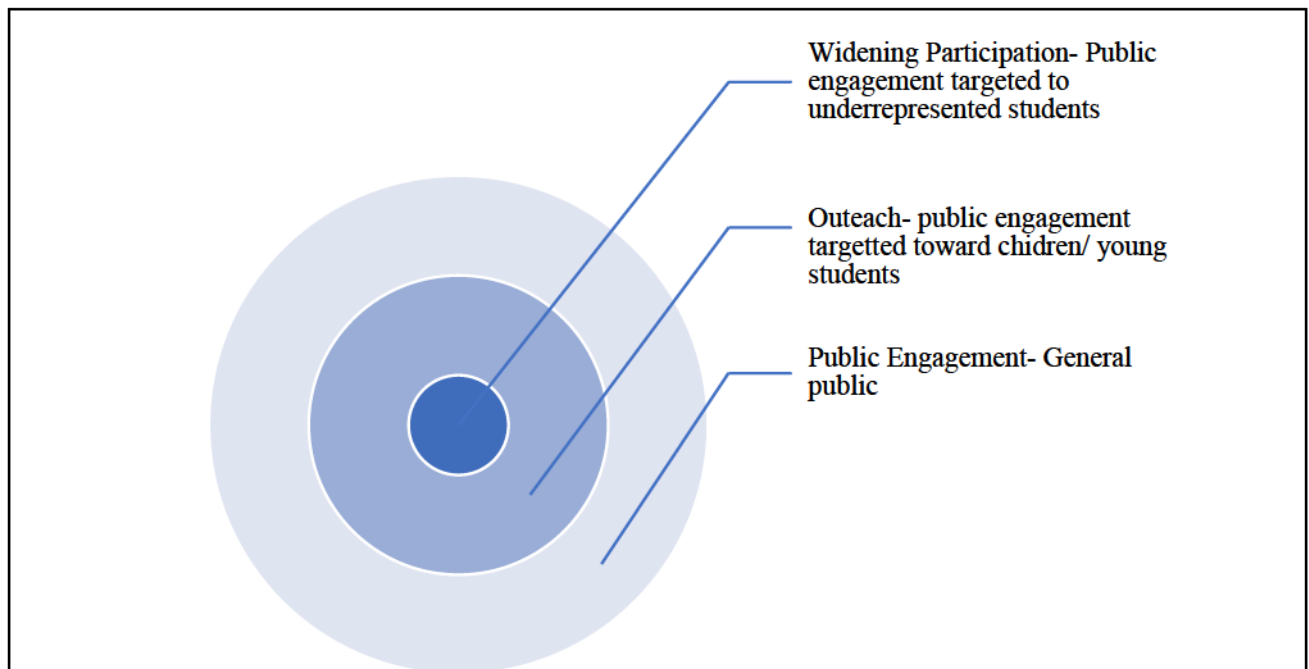


Figure 1: Nested hierarchy of the different forms of public engagement

Public engagement is sometimes (incorrectly) understood to be the unidirectional dissemination of scientific information to the public. This might include activities such as science festivals, public lectures, writing blogs, penning articles for newspapers etc. Yet, these approaches are what Irwin (2015) would term '*first-order*' or '*deficit*' models of public engagement. The deficit model of public engagement characterizes the general public as lacking information and assumes if this information is transmitted then they will be convinced of its benefit, however this model has been severely critiqued for its reductionist and patronising portrayal of non-specialists (Ko, 2016; Nadkarni et al., 2019). The House of Lords Science and Technology report of 2000 called for moving away from such didactic approaches of science communication to *more engaging* modes with two-way dialogue (House of Lords Science and Technology Committee, 2000). Thus, '*second-order*' approaches (Irwin, 2015), such as public consultations, acknowledge that both experts and non-experts have valuable knowledge to offer each other and meaningful democratic participation are favoured. 'Citizen science' projects could be considered second-order science outreach; these are projects allow non-scientists to participate in activities, alongside scientists, contributing directly to scientific research. Examples of citizen science projects include the 'Butterfly Conservation' charity's annual 'Big Butterfly Count', where the general public are asked to support a UK-wide ecological survey, observing butterflies and day-flying moths for 15 minutes, submitting their

data online and ultimately creating a large aggregated dataset for scientists to analyse and make inferences on the health of the environment.

Although sometimes used synonymously with ‘public engagement’ (e.g. Varner, 2014), the term ‘outreach’ is a sub-section of public engagement which focusses on communicating with schools, children, students and colleges. Where efforts to engage children with science may have previously been regarded as the purview of teachers, not learned academics, outreach has become an increasingly respected form of scholarship (Fear et al., 2001).

Although well intentioned, public engagement and outreach often tends to serve members of the general public who are already on the periphery of the scientific community (Dawson, 2014; DeWitt & Archer, 2017; Kennedy et al., 2018) and focussing on ‘low-hanging fruit’ or ‘deadweight’ (Harrison & Waller, 2017) is unlikely to address concerns over the racial, classed and gendered patterns of science participation (Dawson, 2019). Thus, a third and final form of public engagement has emerged with a specialist focus towards underrepresented groups and addressing the social inequalities (described above). Widening Participation (WP) interventions therefore target the narrowest audience possible for public engagement efforts and make a concerted effort to involve those from historically excluded backgrounds. WP doesn’t necessarily just focus on science, and also refers to making access to higher education more equitable (Connel-Smith & Hubble, 2018).

WP interventions can include activities such as short campus visits, long-term cohort mentoring programmes or summer schools, each with underrepresented students as the intended beneficiaries. A popular theme within WP intervention has been framed around ‘raising aspirations’. However, characterizing underrepresented students as ‘lacking aspiration’, falls foul of deficit thinking and situates the problem with children and their families, rather than longstanding social structures and absolves universities and schools from responsibility for exclusionary practices (Harrison & Waller, 2018). Research has shown that most children have relatively high aspirations for professional, managerial and technical careers and that parents value education and (perhaps unsurprisingly) want their children to do well (Archer et al., 2013). Harrison & Waller (2018) suggest *expectations* (rather than aspirations) of probable future employment is a better means of framing and understanding underrepresented students’ views of employment. However, this again highlights how the sector has previously viewed its role in public engagement as assimilationist crusades to educate and convert, rather than turn a critical eye inwards and be more inclusive (Dawson, 2014, 2018).

1.3.2. Recent developments in widening participation

As part of the participation concern in England and in response to worries over how increasing tuition fees⁶ would disproportionately exclude those from less advantaged backgrounds from HE, the Office for Fair Access (OFFA) was founded. OFFA monitored HEIs and made them justify charging increased fees. If a HEI wanted to charge the maximum fee they had to ensure adequate provision was made for WP, to offset any negative effect of the fees. It appears that these efforts were initially successful and that in spite of the fees, the ratio between students from the most advantaged and most disadvantaged groups entering HE reduced between 2006-2014 (UCAS, 2017). However, with the further raising of the cap to £9000 per year by the coalition Government in 2012/13 the decline in the ratio has stagnated (*ibid.*). The Higher Education Funding Council for England (HEFCE) also previously had a significant role in the WP landscape during its existence between 1992 and 2018. As the principal regulator of universities, WP was a major strategic objective for the organisation. Yet, there were concerns over HEFCE's ability to intervene with HEIs, should it be required (House of Lords- Science and Technology Select Committee, 2012).

The Higher Education and Research Act 2017 merged HEFCE and OFFA to form the Office for Students (OfS). The OfS is currently the non-departmental public body responsible for regulating higher education in England and has a significant role in WP. The OfS has set aspirational targets for itself and the sector by declaring their intention to “*eliminate equality gaps in higher education within 20 years*” (by 2037/38) and equalising the rates of participation of young people living in the least and most advantaged areas of the country within one generation (Office for Students, 2018).

To achieve its aims and to ensure that HEIs are compliant, the OfS has substantial powers. Firstly, HEIs are required to submit Access and Participation Plans (APPs) to the OfS for assessment and approval. APPs include a self-assessment of performance with regard to WP, set out targets, describe the strategic measures being taken to ensure targets are met (including interventions and financial support for students), as well as detailing how these measures will be monitored and evaluated (Office for Students, 2019). Furthermore, HEIs are required to notify the OfS of particular ‘reportable events’ (changes or occurrences in WP that would not be picked up by the usual data flows alone). Should a provider breach the conditions

⁶ Tuition fees were first introduced in 1998 and set at £1000 p/a, with subsequent increase of the maximum chargeable rate from to £3000 per year in 2003 and further raising of the cap to £9000 per year by the coalition Government in 2012/13.

of registration, a HEI may be subject to enhanced monitoring by the OfS. In more serious cases or continued breach of conditions, the OfS is permitted to impose formal sanctions such as financial penalties. Finally, the OfS can revoke degree awarding powers and university status from HEIs (even where these were issued by Royal charter) (*ibid.*).

1.4. Widening Participation at Imperial College London

Imperial College London forms the local context of this study and as a HEI which currently charges the maximum possible fee is subject to monitoring by the OfS. Imperial College London's student intake and WP work are described below to introduce the WROL as the case study of this research.

Imperial College London is a science specialist, high-tariff HEI. The motto reflects this specialism and also its imperial history: *Scientia imperii decus et tutamen*⁷. Imperial is regularly ranked within the top 10 of universities in various league tables (QS World University Rankings, 2019). Yet, despite its standing within the league tables, there is a distinct strand of academic literature that critiques participation in so-called 'elite' universities and how highly selective intakes mean that students from underrepresented backgrounds struggle to be accepted and, if they are, continue to feel "*as a fish out of water*" (Reay, Crozier, & Clayton, 2009)

As part of the science community in the UK, Imperial's student cohort largely mirrors the inequitable participation rates discussed above. In the 2017/18 academic year 67.7% of incoming undergraduate students to Imperial were male (national average for all UK HEIs was 44.1%) (Office for Students, 2020) This in part a reflection of the applications made, where men tend to apply to Imperial in higher proportion to women (2019: 5600 men, 3255 women applied), (UCAS, 2020), yet the question *why* men apply in such disproportionately high numbers remains.

Access of black students to Imperial College is just as, if not more, problematic; in 2017/18 only 60 students of the cohort of 1260 were black (Office for Students, 2020). This represents just 4.98% of the student population. Because 5% of the national population is black, it might be suggested that participation here is equitable, yet Imperial recruits largely from the local population where 18.3% of people are black and concedes that this local consideration

⁷ Translated: 'Scientific knowledge, the crowning glory and the safeguard of the empire'. As of 2020, the college will no longer be using the motto on any new materials. It does however remain as the official motto, as it cannot be changed or reworded without the issuing of a new Royal Warrant by the Queen, or approval from the College of Arms (Imperial College London, 2020b)

means that it should have a higher proportion of black students (Imperial College London, 2020a). Finally, Imperial College has a 14.3% gap between the students from the most deprived socio-economic quintile, when compared to the general population (Office for Students, 2020)

Market research, commissioned by Imperial College London, reveals how potential applicants from underrepresented backgrounds view the college. Firstly, prospective students were aware of the prestige and academic quality of Imperial. However, with prestige comes negative associations of stress, pressure and elitism (as also found by Reay et al., 2009 in other elite universities). Participants viewed Imperial as being *too* academic, lacking work/life balance and community, they could not see opportunity for extra-curricular activities. The participants further perceived Imperial as being male dominated (this perception is borne out empirically by the undergraduate gender ratio, above). Finally, Imperial is often grouped alongside other high-tariff universities Oxford and Cambridge, but this association with other prestigious institutions was again seen negatively, as other Russell Group universities are viewed as comparatively more approachable, relaxed and friendly (YouthSight, 2019). Staff at Imperial College corroborate these perceptions. Imperial College's report '*Exploring race, racism and race equity at Imperial College London*' (2019) collated comments from 39 staff, with several unfavourable comments regarding the working environment for those from underrepresented groups.

As part of their commitment to widening participation to HE and science, Imperial College London has a dedicated outreach team, which sits within the Department of Student Recruitment and Outreach. Although some *ad hoc* outreach activities are run by enterprising academics or departments, the vast majority of Imperial College's WP strategy is implemented by the outreach team. Imperial College London has a long history of public engagement, even from its original conception. Using funds from the Great Exhibition of 1851, Prince Albert developed a cultural area in South Kensington, including the Imperial Institute (the progenitor or Imperial College London) in 1888. The college has a long-running tutoring programme (45 years), where undergraduate students visit local schools (Goodlad et al., 1979)

A central elements of Imperial College's outreach work and WP strategy is the Wohl Reach Out Lab (WROL), the evaluation of which is the focus of this thesis.

1.4.1. The Wohl Reach Out Lab

The Wohl Reach Out Lab (WROL) is a dedicated teaching lab on Imperial College London's South Kensington Campus, purpose-built and reserved for the explicit purpose of being the science outreach facility for the university. Founded in 2010 by its patron Professor

Lord Robert Winston in response to the House of Lords Select Committee for Science and Technology findings around the falling interest and attainment in schools' science, linked to a lack of practical work and inadequate opportunity for professional career development for teachers (see above and House of Lords- Science and Technology Select Committee, 2001). Initially, the lab was run by an external consultancy, Exscitec, but in 2014 the WROL work was brought in-house to Imperial College London's Student Recruitment & Outreach department.

The physical and built environment of a space is important for learning (e.g. Marx, Fuhrer, & Hartig, 1999; Winterbottom & Wilkins, 2009) and the WROL was designed with this in consideration. As a physical space, the WROL comprises mainly of four rooms; the main laboratory, a seminar space, the prep room and lab technician's office (see Figure 2: Schematic of the Wohl Reach Out Lab). The main lab within the WROL is a 'wet lab'; a broad designation which highlights the potentially hazardous nature of chemicals or biological substances which need to be contained within a controlled environment and are governed by stricter safety precautions than a normal room. The lab has a capacity for ~30 students to be present at one time; however, sessions usually have slightly fewer participants for logistical convenience.

The main lab was designed to be somewhat like a school-lab with clusters of tables which are provisioned with gas-taps and sinks. Specific consideration was made to having clustered tables instead of traditional classroom rows to facilitate collaborative group work. There is a demonstration bench at the front, along with a sliding double-size whiteboard, projectors and a lectern which has audio-visual equipment. Separated by a collapsible wall, adjoining the lab is the seminar space, which can be used as 'dry lab' (that is science which does not require chemicals, such as computational chemistry or non-hazardous equipment). The prep room and technician's office are small spaces for the storage of some equipment and chemicals and the office space for the technician.

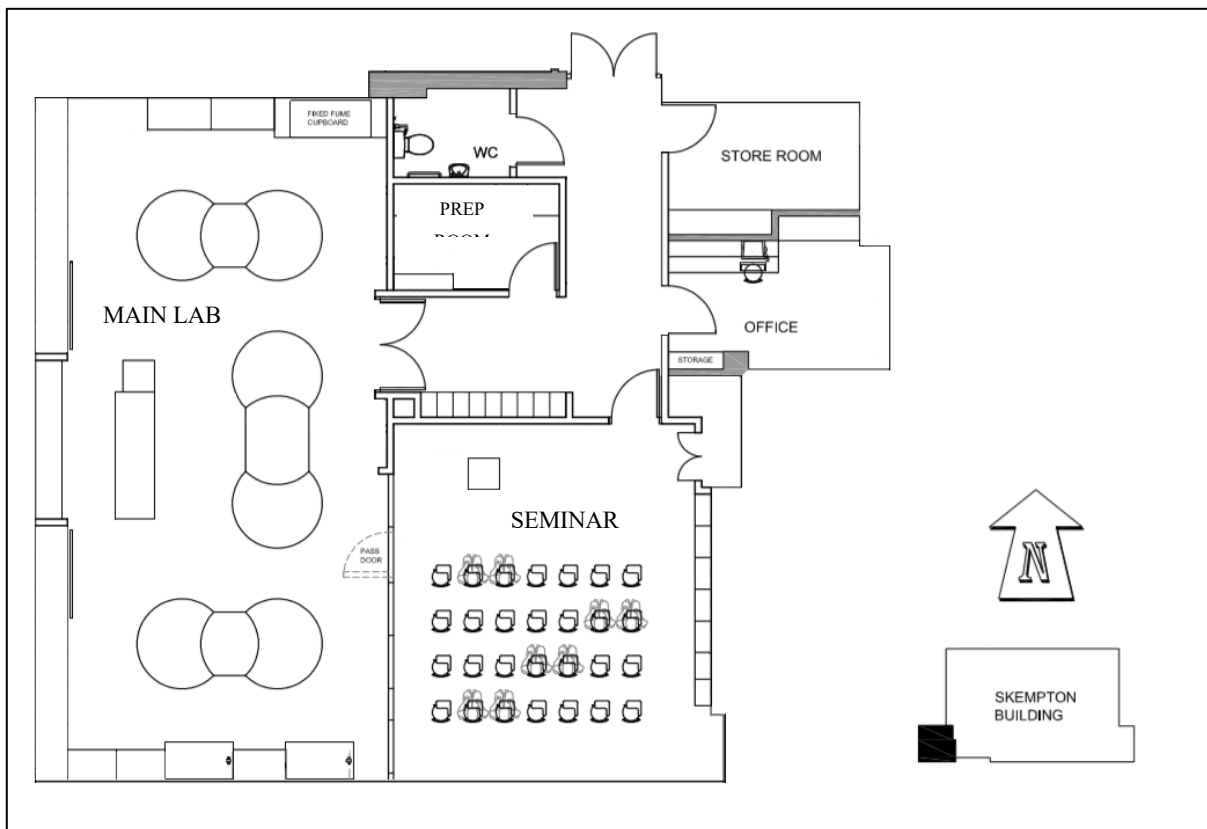


Figure 2: Schematic of the Wohl Reach Out Lab

Sessions in WROL are run by Academic Leaders, who are, or have been Imperial staff or PhD students who have been given three hours of training. The Academic Leaders are supported in the sessions by Mentors, who are undergraduate and postgraduate students. Both Academic Leaders and mentors are paid positions within the outreach department of Imperial College London.

Since its founding 10 years ago, the WROL has had 37,237 participants from 1894 schools (the majority of which are in London), attending a variety of programmes, ranging from a sustained cohort programme, several summer schools and *ad hoc* school visits. Although a variety of programme events are held within the WROL, this research project focusses on the long-term partnership between a local school and the WROL. School-university partnership programmes have emerged as a mutualistic relationship between two tiers of the UK educational sector (Handscomb, Gu, Varley, et al., 2014). The rationale for focussing on this particular programme is two-fold. Firstly, the academic literature suggests that there are cultural differences between organisations in such partnerships (*ibid.*). This intersection between formal and informal contexts leads to tension and ‘clashing agendas’ (Braund & Reiss, 2006) which need reconciling. Secondly, my own personal experiences

within the formal education sector (as an ex-science teacher), lend themselves to help explore this area.

Although the social justice agenda underpinning the WROL (and other WP projects) to address inequality is laudable, its work cannot be assumed to be working by default. The evaluation of WP initiatives has been a particular challenge for HE (Hayton & Bengry-Howell, 2016) and has been seen as seriously lacking in rigorous academic research (Gorard et al., 2006)

As a relatively small-scale project, the WROL has not been subject to as much research as larger institutions like museums or larger outreach programmes. However, the WROL has previously been the subject of another PhD project. Alex Moss used a grounded theoretical approach to develop a heuristic model to explore the influence that programmes at the WROL have upon pupils' engagement with STEM (Moss, 2015). His model suggests that student engagement with STEM is mediated by five psychological needs; 1) to resolve cognitive conflict, 2) feelings of competence, 3) autonomy, 4) self-verification and 5) social relatedness, which may be satisfied by STEM outreach and subsequently improve engagement and participation.

Crucially, Moss makes several recommendations for further research which influence this project to further our understanding of outreach and contribute to the corpus. Moss highlights the formal/informal dichotomy as an area of interest, whereby students' psychological needs can be met by different contexts. Furthermore, he suggests using science capital (section 2.2 below) as a theory to better understand the workings of the WROL.

Chapter one summary

In this chapter I have described what is known about the patterns of participation within the science sector. The current picture shows a sector that is stratified along racial, classed and gendered lines and is typically dominated by those from white, male, middle-class backgrounds.

I have argued that formal science education is a contributing factor to the inequitable patterns of participation observed. I have presented literature which critiques the practices used within formal education for not providing socially equitable opportunities for students from diverse backgrounds to engage with science. I suggest that the informal science education sector may have a role to play in helping address shortcomings with the formal provision (although concede this is not a panacea). I also presented how public engagement by

universities has emerged as a significant part of the informal science landscape and how a subsection of this public engagement effort is specifically aimed at widening participation.

The Wohl Reach Out Lab (WROL) at Imperial College London was then introduced as the case study for this research. As an example of a WP project, the WROL's mission is well justified, both for moral and economic reasons. Yet just because WP work is well intentioned, it cannot be assumed to work. The contribution of this study is to evaluate the school-university partnership programme held in the WROL in an academically rigorous manner and aims to inform the sector which practices may contribute to the social justice agenda.

The next chapter explores the theoretical resources used in this research.

2. Chapter two: theoretical resources

Chapter one described inequalities both science education and society. Pierre Bourdieu's and Louise Archer's work helps us understanding these inequalities as well as better understanding the work of the WROL.

This chapter begins by exploring Bourdieu's key ideas. Several of his concepts rely on neologisms, but when explored help us understand the origins and the persistence of inequalities across generations. 'Cultural capital', 'field', 'cultural arbitrary' and 'symbolic power/violence' are each described and linked to the reproduction of injustices in society. Archer's science capital theory builds on Bourdieu's cultural capital theory and helps us explore the inequalities specifically within science sector. Finally, this chapter is concluded by describing the implications that science capital theory has for pedagogy and science education.

2.1 Bourdieu's theory of cultural capital

2.1.1. Key concepts: cultural capital, field, cultural arbitrary and symbolic power

This research draws on the work of Pierre Bourdieu, whose concepts have been influential in helping explain social inequality and the effect of education.

However, before exploring Bourdieu's ideas, it is worth pre-emptively addressing a particular criticism of his work and how this thesis overcomes this. Bourdieu's style of writing has variously been described as "*jargon-ridden and convoluted*" (Shirley, 1986) and as using "*cumbersome specialized vocabulary*" (Lareau, 2011: 362) (amongst others)⁸. Considering that Bourdieu's theories help us understand how language can be used to exclude people from social groups (Bourdieu, 1991), it is deeply ironic that his writing is so inaccessible. Bourdieu attempts to justify his language in the introduction to his book *Distinction*, arguing that complex social reality can only be represented in an equally complex prose. However, Nash (1990) rejects this assertion as one that "*should not be taken seriously*". In an effort to make her book more readable, while still utilising Bourdieu's theories, Lareau (2011) deliberately

⁸ It must be noted that Bourdieu responded to his critics, defending his use of language he says: "*I think that, literary and stylistic qualities apart, what Spitzer says about Proust's style is something I could say about my own writing. He says, firstly, that what is complex can only be said in a complex way; secondly, that reality is not only complex, but also structured ... if you want to hold the world in all its complexity and at the same time order and articulate it...you have to use heavily articulated sentences that can be practically reconstructed like Latin sentences*" (Bourdieu, 1990: 51-52, quoted in Sullivan, 2002)

refrains from using his phraseology, instead opting to find alternative ways of conveying meaning. To engage with the literature on Bourdieu's terms, this chapter explores his key concepts using some of his terminology, but the remainder of this thesis follows Lareau's example; in applying Bourdieu's theories, but limiting the use of his dense lexicon to improve clarity.

The role capital has in generating social inequality has been explored for some time (e.g. Marx, 1887). It is widely accepted that financial resources have a significant role in determining a person's position in the social hierarchy. However, despite its importance, economic capital is not the sole determinant of social position. Being or becoming rich does not automatically confer membership to the upper class, as many other factors, behaviours, practices, and dispositions indicate membership and acceptance into of this group.

In *The Forms of Capital* (1986), Bourdieu describes three forms of capital which contribute to our understanding of social inequality. Although the precise definitions of several Bourdieusian terms has been widely debated (e.g. Nash, 1990; Sullivan, 2002), they are broadly understood and applicable:

- **Economic capital** describes the financial resources of an individual; income, wealth, property, etc. and can all be considered assets which comprise economic capital (Bourdieu, 1986: 16).
- **Cultural capital** consists of the socio-cultural assets held by an individual, which may be used to their benefit. Bourdieu considers three subdivisions of cultural capital:
 - *Embodied cultural capital*: Bourdieu suggests this comprises the “*long-lasting dispositions of the body and mind*” (*ibid.*: 17) and knowledge of the dominant culture. For example, in Western culture, enjoying and understanding certain highbrow cultural pastimes, such as opera, is considered valuable. A person's disposition and knowledge are largely determined by the environment in which that individual is raised. Thus, what seems ‘normal’ or has value in one culture isn't necessarily valuable in another; for example, in British society knowledge of cricket is more advantageous than that of baseball (Claussen & Osborne, 2013). Embodied capital is the most difficult aspect of the cultural capital to define because, unlike objectified and institutionalised cultural capital (described below), it is intangible. Embodied cultural capital can only be observed in an individual's behaviour and conduct. Embodied cultural capital determines subtle traits, such as dialect or a ‘posh’ accent.

- *Institutionalised cultural capital*: this includes the formally recognised background of an individual such as, academic qualifications or professional credentials or titles, which although lacking in direct monetary value tend to be respected by a community or institutions and therefore bestow social ‘kudos’. Bourdieu considers academic qualifications to represent “*a certificate of cultural competence which confers on its holder a conventional, constant, legally guaranteed value with respect to culture*” (Bourdieu, 1986: 20) and thus institutional cultural capital acts as a mutually recognised ‘currency’ which indicates possession of other forms of cultural capital.
- *Objectified cultural capital*: Bourdieu considers this to include material objects and media which have symbolic worth and possibly economic value. Physical artefacts with cultural value beyond their material worth, such as paintings, monuments, instruments etc. can all be considered objectified cultural capital. It is important to note that Bourdieu considers an object’s value to be determined by the possessor and others legitimising its worth. Claussen & Osborne, (2013) use the example of a first edition of Darwin’s ‘*Origin of the Species*’ which materially has very little value (old paper, scuffed cover and faded ink) yet holds great value to someone understands the cultural context of this as a ground-breaking volume.
- **Social capital** encapsulates the value of an individual’s social networks (Bourdieu, 1986: 21–24). This includes family, friends, work-colleagues, acquaintances, and recognised membership of a group. This form of capital can be broadly understood using the axiom: “*It’s not what you know, it’s who you know*”. Leveraging of social capital can lead to nepotism and the establishment of so-called “old boys’ networks”. An individual’s volume of social capital is related to the size of that person’s network and exchange of resources of those in that network. Social capital, therefore, is never completely independent of economic or cultural capital.
- **Symbolic capital** is not essentially different from the capitals described above, insofar as the value of either economic, cultural, or social can be symbolic. Instead, Bourdieu describes the concept of ‘symbolic capital’ as working in conjunction with economic, cultural, or social capital to describe the capitals that have a certain level of prestige, honour or respect. Symbolic capital relies on the acceptance and recognition by others

to determine its value. Examples include job titles, honours, awards or prestigious respected degrees.

Central to Bourdieu's theory of cultural capital is the 'reproduction' of social inequality across generations. He maintains that cultural capital is transmitted from parent to child through enculturation, socialisation or 'family education' (Bourdieu & Passeron, 1977: 88). This leads to offspring with 'culturally rich' parents inheriting the dispositions, knowledge, qualifications, social contacts etc. that help them occupy similar positions in society to their parents. The converse is also true, parents with 'low' cultural capital cannot endow their children with the culturally valuable resources. Unlike wealth, such as property, the intergenerational transfer of cultural capital is largely invisible, Bourdieu believed that "*the transmission of cultural capital is no doubt the best hidden form of hereditary transmission of capital*" (Bourdieu, 1986: 19). For example, it may be difficult to hide the inheritance of an estate, but the legacy of a social network that provides career opportunities for a child is more intangible.

The hidden value of cultural capital is central to how Bourdieu sees it generating social inequality. For Bourdieu, there is no innate value to cultural capital; it has no inherent justifications or qualities. He used the term "*cultural arbitrary*" to signify this, stating: "*the structure and functions of ...[a]... culture cannot be deduced from any universal principle. whether physical, biological or spiritual, not being linked by any sort of internal relation to 'the nature of things' or any 'human nature'*" (Bourdieu & Passeron, 1977: 8). Instead, the value of cultural capital is derived from mutual social recognition by others (*ibid.*: 9).

The arbitrary nature of cultural capital is well illuminated when considering subjective tastes and how the dominant class determines what is tasteful (or not) (Bourdieu, 1984). Historical fashion trends are a good representation of how cultural behaviours are arbitrary. For example, wearing a top hat was once an indicator of respectability in society (and the working-class flat cap was devalued), but trends change, the top hat now serves little purpose. Indeed, there are current social norms and cultural capitals which are considered natural and valuable, yet with objective scrutiny there is little justification for any perceived value over other capitals. This is a challenging concept because Bourdieu reverses the normal perception of things that are seen to hold cultural value (Moore, 2004) and questions the value of many of the things which we may personally hold dear.

It is perhaps easier to consider the 'cultural arbitrary' in a context that is different to our own. For example, Kayan women in Myanmar practice 'neck stretching', by sequentially adding brass rings their clavicle and chest cavity are depressed, giving the illusion of a longer neck. Where this practice may appear unusual to an outsider (especially when considering the

reduced expiratory volume) it is considered perfectly normal by individuals *within* that culture. Nash (1990) argues that, from an anthropological perspective, *all* cultural practices are arbitrary. He illustrates this by comparing cultural views on polygamy; in a monogamous culture, polygamy may appear unusual (indeed, there are strict anti-bigamy laws in monogamous countries). Yet, monogamy is seen as equally unusual in polygamous cultures, Nash summarises that “*both customary practices are equally possible and equally human*”.

To understand the arbitrary valuation of cultural capital within different cultures better, Bourdieu introduces the concept of ‘fields’. A field is the context in which cultural capital is ‘legitimised’ and consequently has any value. He argues that cultural capital rarely confers any immediate economic benefit to its possessor, for example in Western culture although fine art may be considered valuable as objectified cultural capital, to sell it requires a buyer with a mutual social recognition of its value. As Bourdieu & Wacquant, (1992: 101) note: “...*capital does not exist and function except in relation to a field*”. As such, the legitimisation process is constantly occurring and what constituted as ‘valuable’ is constantly changing. Pressley (2015) describes fields as “*networks of social relations, structured systems of social positions, within which struggles or manoeuvres take place over resources, stakes and access*”. The metaphor of a game is commonly used to clarify the field concept. Comparing the field to a card game allows us to imagine the ‘rules of the game’ being agreed upon by the players and the ‘cards’ (cultural capital) in their hands are the resources to play the game.

Because a field determines the value of cultural capital, the resources that are valuable and beneficial in one field may not be in another, again Claussen & Osborne's (2013) example of how cricket knowledge in the UK is valued and baseball in the USA is useful to exemplify how two fields can determine the value of cultural capital differently. This is important when considering education; what is considered to be valuable in a scholastic setting is not absolute— knowledge of curricular content *is* valuable, but only within certain contexts.

The final Bourdieusian concept relevant to this study is ‘symbolic power’ (Bourdieu, 1977, 1991). He uses this term to describe the pervasive, invisible and non-physical force which devalues (or ‘misrecognises’) the cultural capital of certain groups. For example, the soft power exerted by interview dress-codes, although no one is forced to wear a suit and tie, if one cannot afford or otherwise is unaware of this convention then they would both feel uncomfortable in a professional environment and also be viewed negatively by the employers, regardless of their actual competency. Bourdieu sometimes alternatively conceptualised this as ‘symbolic violence’ to strengthen the terminology and express how this power can be construed as force which excludes people, albeit not physically.

Given that several of Bourdieu's key concepts have been summarised, how do these help explain educational inequality?

2.1.2. Implications for education

Above, the importance of family education for transferring cultural capital intergenerationally was described, yet formal or '*institutionalized*' education (Bourdieu & Passeron, 1977) has an equally important role play "*...because it can be viewed as an academic market for the distribution of cultural capital*" (Claussen & Osborne, 2013).

Perhaps one of Bourdieu's most controversial positions is his view that schools actually serve to reinforce social inequality. Reflecting some of the criticisms of formal education made in section 1.2.1 of this thesis, Bourdieu argues that formal education fails to distribute cultural capital fairly. However, he goes further to argue that: "*All pedagogic action (PA) is, objectively, symbolic violence insofar as it is the imposition of a cultural arbitrary by an arbitrary power [emphasis added]*" (Bourdieu & Passeron, 1977: 4). This view is perhaps best explored by comparing the educational experiences of two students from families with different levels of cultural capital. Nash (1990) suggests that if the culture of a school reflects middle-class norms and values then students from working class backgrounds will "*...find themselves in a culturally alien setting and [be] unable to benefit to the same extent as middle-class students*". Watkins (2018) further expands on the disparate experiences of the two classes: "*Working-class students were considered to be at a distinct disadvantage given the schooling system's disavowal of their cultural knowledge and privileging of understandings to which the middle-class child was far more attuned*". Therefore, students who start school without being primed with a stock of cultural capital begin at a disadvantage and are considered to require 'remedial instruction' from the beginning (Delpit, 1988).

Bourdieu argues that formal education systems do not perform this remedial function, instead students without institutionally valuable cultural capital continue to be disadvantaged. For example, students with familial stocks of the dominant form of cultural capital are often mistaken as having natural aptitude and those with low cultural capital are seen as having 'low ability', where in actuality both are quite capable. Jaeger (2010) found that, regardless of their actual academic competency, teachers' perceptions of children's academic and social skills are positively correlated with children's level of cultural capital (those with low cultural capital were seen as less able). I am certain many teachers would refute this, arguing that they assess children's capability fairly, regardless of their background, but it is difficult for those within a

field to recognise the cultural arbitrary to which they have been habituated, as Bourdieu & Wacquant (1992) put it:

Intellectuals are often among those in the least favourable position to discover or to become aware of symbolic violence, especially that wielded by the school system, given that they have been subjected to it more intensively than the average person and that they continue to contribute to its exercise (p.170)

Several studies highlight how the cultural arbitrary acts in excluding students from lower-class backgrounds during their education.

Firstly, Bourdieu's work has several implications for how we view the curriculum and how it affects students from underrepresented backgrounds. Those who set the curriculum make choices about what content is included and what information is excluded. These choices typically act to further reify cultural capital of the dominant classes. To give an example, Michael Gove's⁹ reform of the English literature syllabus refocussed teaching towards the canon of English cultural heritage, including the works of Shakespeare, Romantic poetry and 19th century novelists. While there is little doubt of the merit of teaching students these texts, to make these changes meant excluding an equally rich corpus of contemporary literature and international authors, including the removal of two classics of American literature, *To Kill a Mockingbird* and *Of Mice and Men*. Indeed, this 'cultural heritage' approach has been increasingly dismissed by teachers and students, from devolved nations (Elliott, 2014). The focus on 'country specific' curricula highlights the importance of context (or Bourdieu's 'field') for determining cultural capital's value. While English literature is important in England, it is less relevant and culturally valuable in other contexts. It follows that students studying curricula that do not align with their personal cultural background will be at a disadvantage.

While the cultural arbitrary may be most apparent in the curricula of arts subjects, Claussen & Osborne's (2013) argue the science curriculum is also subject to the same phenomenon. They describe the science curriculum as

...a curriculum full of details that lacks coherence- a knowledge not of its broad overarching themes but of a large body of detailed facts... At its core,

⁹ Michael Gove was the Secretary of State for Education 2010-2014.

such an education is a reflection of a belief that the function of science education is first and foremost a form of preprofessional training (p.65)

If this is so, the current science curriculum is better suited to students from families who have been habituated to overlook the cultural arbitrary and see the science curriculum ‘natural’ or self-evident from an early age. Conversely, students whose first experience of science is in school may find little personal relevance or interest and question its significance. Therefore, the formal curriculum is likely to serve those with a pre-existing stock of science capital, leading to differential educational outcomes, to the detriment of those from non-science backgrounds.

Alongside the formal curriculum, it is important to consider the ‘hidden curriculum’. Although the academic content delivered by teachers is largely dictated by the National Curriculum, it is apparent children learn more at school than the knowledge prescribed by formal syllabi. Children’s experiences differ from school to school, despite efforts of standardisation. The hidden curriculum therefore describes the *implicit* information communicated to students, for example, language use, behaviours, values, norms and beliefs, rather than the *explicit* information formalised in curricula (Burton, 1998).

Due to its implicit nature, not all students ‘take in’ the hidden curriculum (Acar, 2012). This is true of subtle or unspoken behavioural expectation; teachers’ implied instructions can be interpreted differently by different students and what may be seen as disobedience, is actually a case of linguistic queues being missed (Delpit, 1988).

Redish (2003) explains how the hidden curriculum affects physics education. He argues “*Most of our students don’t know what you and I mean by “doing” science or what we expect them to do*” (p. 52) and that model of ‘doing science’ implied by school science that students ‘learn’ is:

“• Write down every equation or law the teacher puts on the board that is also in the book.

• Memorize these, together with the list of formulas at the end of each chapter.

• Do enough homework and end-of-the-chapter problems to recognize which formula is to be applied to which problem.

- *Pass the exam by selecting the correct formulas for the problems on the exam.*
- *Erase all information from your brain after the exam to make room for the next set of materials.”*

This is evidently not the intended model of ‘doing science’ described in physics syllabus but is what is commonly deduced by students by implied instruction. While some students will be able to infer how abstract formulae are relevant to ‘doing’ science or understanding the world, many students will go through these motions without ever fully understanding unambiguously how Newton’s second law ($F=ma$) has any relevance to their lives. To make education more inclusive requires educational practitioners to make cultural capital explicit (Zipin, 2005).

One of the more difficult elements of schooling, for some students, lies in the language used by teachers. Bourdieu wrote extensively about language and viewed it not only as a means of communication but also as an exercise in symbolic power (Bourdieu, 1991). Research into the use of differing forms of language has a long history in education, of note is Basil Bernstein’s work on ‘restricted/elaborated codes’ (1971) which differentiates the language of middle and working class groups. Language, accent and diction (or as Bourdieu puts it: ‘articulatory style’ (1991: 86)) can all be considered forms of embodied cultural capital. Students whose linguistic capital aligns with the language of schools will be at an advantage to students from backgrounds that have non-standard modes of communication.

While it is evident that there is some need for common meaning in education for clarity and communication, the extent to which students’ language needs ‘correcting’ is unclear. Cushing (2019) argues that rather than ‘polishing’ students’ linguistic capital school language policies can instead be seen as ‘policing’ or ‘punishing’ students with nonstandard language. Claussen & Osborne’s (2013) also argue that the academic language of science is the dominant barrier to comprehension, and therefore participation is restricted to students from the dominant cultural elite.

The power that linguistic capital has in educational settings is further illustrated by Archer et al., (2016) study of museum engagement. A museum visitor and study participant correctly identified a museum object as a birthing stool, but the label states it is a ‘parturition chair’, the participant subsequently decides they are wrong, thus the language used denies the participants’ correct knowledge of science. The selective use of language in educational contexts, which students don’t understand can be considered a form of symbolic violence (Claussen & Osborne, 2013).

The final educational practice which I use to exemplify Bourdieu's idea of symbolic violence in education is that of setting/streaming. It is common in UK schools for students to be grouped in classes with other students of similar prior attainment. Setting may have some advantages for teacher differentiation but also has several adverse consequences for students allocated to low or 'bottom sets' (Boaler, Wiliam, & Brown, 2013). Francis et al. (2017) suggest there are seven key areas which explain this:

- Misallocation to groups
- Lack of fluidity between groups
- Quality of teaching for different groups
- Teacher expectations of students
- Pedagogy, curriculum and assessment applied to different groups
- Pupil perceptions and experience, and impact on learner identities
- Self-fulfilling prophecy

To those who occupied 'top sets' in school, the practice of setting may appear natural and grouping of students in such a hierarchy may seem desirable, yet for those in 'bottom' sets the system appears more unfair (Archer, Francis, et al., 2018). Slavin summarises that students in bottom sets have "*...a slower pace and lower quality of instruction, have teachers who are less experienced or able and who do not want to teach low-track classes, face low expectations of performance and have few behavioural models*" (Slavin, 1990). As such, setting can be seen as another example of symbolic violence in the educational system (Archer, Francis, et al., 2018).

These examples support Bourdieu's criticism of formal education, namely that the curriculum (formal and hidden), the use of language in schools and the practice of setting are instances of symbolic violence. Following the Bourdieusian assertion that 'all pedagogic action is symbolic violence' there are many more practices which may reveal how formal schooling serves to perpetuate the social inequalities described in chapter one. The implications of this perspective are damning and make difficulties for educators, especially those with an interest in social justice. Yet, some academics have been less critical when using Bourdieu's theories; Nash (1990) suggests that "*...it is necessary to distinguish between the cultural arbitrary of the school and the scholastic necessary*", similarly Watkins (2018) poses the question: "*School knowledge: cultural arbitrary or social necessity?*". These questions allow nuance and social justice approaches in education, such as outreach.

On the basis of Bourdieu's work and these ideas, Zipin (2005) describes two approaches (or 'impulses') towards social educational justice. The first impulse is to *redistribute* valuable cultural capital to students who have not otherwise inherited it. For example, ensuring that all students receive an education on the work of Shakespeare. However, this approach risks reinforcing the value of otherwise arbitrary capital and continuing to disregard and devalue students' own forms of cultural capital. Therefore, Zipin proposes an alternative, whereby students' existing stock of cultural capital is *recognised* through education, challenging the hegemony of the cultural arbitrary. For example, allowing students to choose which pieces of literature they would like to study (e.g. allowing a Spanish student may wish to study Miguel de Cervantes, or a Scottish student may find it more relevant to learn about Robbie Burns). Yet, this approach is also problematic as it risks denying students the opportunity to accrue the cultural capital which is socially valuable. Thus, we reach an impasse between 'redistribution' and 'recognition'. Zipin describes the impasse as 'aporetic madness', suggesting that a socially just education system is impossible, yet it is one which must still be pursued (for the moral and economic reasons explored in chapter one).

2.2. Archer's theory of science capital

2.2.1. Science capital

Although the theory of cultural capital is typically applied to understanding patterns of participation in the arts (e.g. Burke & McManus, 2009), Louise Archer and colleagues' have developed Bourdieu's ideas further, identifying cultural capital which relates specifically to science (Archer, et al. 2015). The rationale is grounded in the increase in social standing of science in the 20th century. Having scientific resources, such as qualifications in science or access to scientists, can confer an advantage in educational and labour markets. Those holding this 'new' form of cultural capital may enjoy a higher cultural and social status in modern society.

The ASPIRES, ASPIRES 2 and ASPIRES 3 projects which longitudinally tracked students' science aspirations can be seen as the hub of the development of science capital as a concept. With various reports, academic papers, policy documents, practitioner guides, conference proceedings being produced by the research group and associated colleagues, the concept has become well utilised in the science education research community.

The initial ASPIRES project surveyed over 19,000 children (aged 10-14) and found that children broadly have high aspirations (challenging the idea that students from certain backgrounds have a 'poverty of aspirations') and also that generally they find science

interesting at school (Archer, et al., 2013). Yet, the majority of students still do not see science as relevant to them personally or do not have an interest in becoming scientists. Instead some students view science as a subject only for stereotypical ‘brainy’ scientists (*ibid.*). Archer et al. further found that families exert a considerable influence on students’ aspirations towards studying science further; children are more likely to aspire towards science if they are male, Asian, have a large stock of cultural capital, are in the top set for science and have a family member who works in science. Conversely, students are less likely to aspire to a science career if they are female, white, have little cultural capital, are in the bottom set and do not have family members who use science in their jobs (Archer, et al., 2013). The ASPIRES project used ‘science capital’ as a central concept and defined it as “*the science-related qualifications, understanding, knowledge (about science and ‘how it works’), interest and social contacts (e.g. knowing someone who works in a science-related job)*” (*ibid.*).

Science capital was further clarified as a distinct construct within the literature with Archer, Dewitt, & Willis (2014):

We propose that ‘science capital’ is not a separate ‘type’ of capital but rather a conceptual device for collating various types of economic, social and cultural capital that specifically relate to science- notably those which have the potential to generate use or exchange value for individuals or groups to support and enhance their attainment, engagement and/or participation in science (ibid.)

An individual’s level of science capital is seen as determined by eight different dimensions: Scientific Literacy, Scientific-Related attitudes, dispositions/references and values, Symbolic Knowledge About the Transferability of Science in the Labour Market, Consumption of Science-Related Media, Participation in Out-of-School Science Learning Contexts, Knowing Someone Who Works in a Science Job Parental Science Qualification and Talking to Others About Science (Archer, et al., 2015) (see below: Table 1: Eight dimension of science capital).

To advance their argument empirically and methodologically, the research group presented attempts to quantify and measure students’ (age 10-14) levels of science capital (Archer, et al., 2015; DeWitt, Archer, & Mau, 2016). Their science capital questionnaire showed that science capital is not evenly distributed across children in the UK. The majority (68%) were classified as having ‘medium’ levels of science capital and 27% were recorded as having low science capital. Just 5% were found to have high levels of science capital (*ibid.*). The level of science capital was found not to just be a matter of chance, but was found to be

strongly patterned by other forms of cultural capital, gender and ethnicity (Archer, et al. 2015) (reflecting the studies highlighted chapter one). The data also show that science capital is predictive of a child's intention to continue studying science. The more science capital they have, the more likely they are to want to continue studying science (*ibid.*)

The ASPIRES 2 project continued this work, tracking many of the same students to age 19, and found similar results. The report shows that students' career aspirations are relatively stable over time, that students still show interest in science, yet do not aspire to become scientists (Archer, et al. 2020).

Table 1: Eight dimension of science capital (adapted from Archer, et al., 2015; Godec, King, & Archer, 2017; Harris, Xanthoudaki, & Winterbottom, 2018)

Form of science capital	Dimension of science capital	Description
Science related forms of cultural capital	Scientific Literacy	This dimension comprises of an individuals' scientific conceptual knowledge, their scientific skills and knowledge of 'how science works'. Importantly, science literacy is more than learning disjointed facts and having uncontextualized skills. Considering the example of foreign language can be useful to explore this, although language acquisition requires learning words and grammar rules, to be considered <i>truly literate</i> requires fluency and embedding in everyday practice. Thus, to be truly scientifically literate requires an individual to use the language able to apply scientific skills and knowledge to their daily, personal and social lives, this is facilitated by scientific 'habits of mind' (being able to critically analyse data, discern how confounding variables may affect a study etc.). Brown (2004) considers the link between science literacy to be fundamental to developing science identities.
	Scientific-Related attitudes, dispositions/references and values	An individual's attitude towards science is as an important element of their science capital. Evidently, if someone feels positively towards science, they are likely to see its personal relevance, engage with other forms of science (e.g. science media below) and value science in their life. An individual with a positive attitude towards science also helps those with similar dispositions to see each other as kindred spirits and likely to get on.
	Symbolic Knowledge About the Transferability of Science in the Labour Market	Knowing how science qualifications can lead to employment, not only in science, but also to other jobs can confer advantage in the labour market is viewed as a distinct dimension. This dimension is significant because of the variable careers advice which students receive, both in homes and at school (Moote & Archer, 2018; Reiss & Mujtaba, 2017).

Science related behaviours and practices	Consumption of Science-Related Media	Engaging with various forms of media, such as TV documentaries and books relating to science, is seen as an important component of science capital as it is readily accessible (yet this is often the limit of science participation of those from low-income, minority ethnic backgrounds, Dawson 2018). This dimension also includes newer forms of media like social media and online streaming services.
	Participation in Out-of-School Science Learning Contexts	As science capital theory was originally conceptualised for investigating children's science aspirations, this dimension considers children's science experiences outside of school. Informal science experiences (described above in section 1.2.2), such as zoo visits, after-school science clubs and science at home, are seen as boosting students' levels of science capital.
Science related forms of social capital	Knowing Someone Who Works in a Science Job	This component introduces the social dimension of capital to the conceptual model. One's social network, if it includes scientists, adds science capital. This includes parents, other family members, neighbours and friends in one's extended network. VanMeter-Adams et al. (2014) found that social relations were amongst the strongest influences on students' decisions to pursue science subjects.
	Parental Science Qualification	This component captures the importance of parents as social science capital. Parent's ability to answer science related questions has been found to be a strong indicator of a child's interest in science (Alexander, Johnson, & Kelley, 2012).
	Talking to Others About Science	The final dimension of science capital described by Archer et al. concerns the frequency of science conversations. To actually derive value from social capital (above) one must actually leverage their contacts for some benefit. For example, talking to parents about science concepts over the dinner table normalises scientific dispositions and may bolster science literacy, or talking to a neighbour to gain an internship in a scientific organisation.

The fifth dimension of science capital theory (Participation in Out-of-School Science Learning Contexts) has been particularly influential in investigating informal education. As described in section 1.2.2 of this thesis, non-school (or informal) science is often presented as a solution to the failings of formal science education. When non-scientists are meaningfully engaged with the scientific community, they build science capital. Often participation in out-of-school science learning will provide students with other forms of science capital in a virtuous cycle. Edwards et al. (2019) argue that citizen science projects achieve this because:

...the more one is part of a culture of participation in science-related activities, the more one is likely to develop science learning outcomes and the disposition to participate further in science-related activities. In other words, developing science capital means developing a culture of participation in, and learning from, science-related activities (p. 382)

Equally, it has been argued that ‘tinkering’¹⁰ should be seen as science participation which might help build science capital (Harris et al., 2018).

Science capital has been an influential concept within science education and has shaped several studies. In recognising the importance of early experiences in science, Padwick, Dele-Ajayi, Davenport, & Strachan (2016a) investigated ways of measuring science capital in primary school children aged 7-11 years old. Using a simplified questionnaire, diamond nines and jobs card sorting activity they were able to determine that, regardless of gender, ethnicity or level of science capital, primary school children have positive perceptions of scientists. Yet, the self-identity of children as scientists was found to be strongly influenced by gender, ethnicity or level of science capital (*ibid.*). This suggests that aspirations towards science careers emerge early on, implying that earlier intervention may be important in helping address widening participation, rather than waiting till secondary school, when currently more interventions are targeted (Archer, et al., 2013; DeWitt & Archer, 2015).

Science capital theory has also been applied to subject specific domains. For example, Rüschenpöhler & Markic (2020) focussed their study towards chemistry education to create the concept of ‘chemistry capital’, Wilson-Lopez, Sias, Smithee, & Hasbún (2018) investigated which forms of science capital are mobilised by students during engineering projects and

¹⁰ Tinkering activities involve the making of objects through an iterative process, these activities are often dismissed as inconsequential, but frequently require the application of many dispositions associated with scientific thinking such as problem solving, perseverance and inquisitiveness (embodied science capital).

Cerrato, Rizzato, Tealdi, & Canel, (2018) investigated how a coding project may help build science capital in students excluded from mainstream schooling. Moote, Archer, Dewitt, & Macleod (2020) investigated the link between science capital and student aspirations in technology, engineering and maths; they found that science capital was strongly related to children's aspirations to go on to study physical sciences and engineering but not associated with a desire to study technology or maths. In recognising the importance of maths for participating in science, science capital has also been further reconceptualised into maths capital (Black & Hernandez-Martinez, 2016; Williams & Choudry, 2016). Evidently, there is capacity for the development of many other domain-specific capitals, yet Jensen & Wright (2015) caution against this proliferation.

Although science capital theory has gained wide recognition within the academic field, it is not without criticism. Jensen & Wright (2015) suggest that adding science capital to Bourdieu's existing range of concepts is unnecessary and perhaps even contrary to the social justice aims espoused by Archer et al. They argue that by identifying specific forms of capital which are valued within a field we risk further reifying them. Instead of increasing the focus on valuable forms of cultural capital they suggest we should instead "*zoom out and pan the camera side to side to see how science is just one element of a larger unjust sociocultural system*". Black & Hernandez-Martinez (2016) add to this critique and argue that science education should move away from institutional practices that reinforce the arbitrary nature of cultural capital (e.g. attainment scores).

Nevertheless, science capital theory has been widely accepted within the science education community and beyond (e.g. POST, 2013; Wellcome Trust, 2016). It has proved a useful conceptual tool to understanding patterns of participation with science. Importantly, in addition to understanding social inequality, science capital also has practical implications for pedagogy to help widen participation.

2.2.2. Implications for education

Much of the work described above forms part of the critical pedagogy literature and highlights many problems within formal (science) education. Yet in revealing difficult issues, theorists have been criticised for seldom offering solutions (Archer et al., 2018). However, one of the most significant developments of science capital theory is in moving beyond Bourdieu's critical perspective on educational systems and directly addressing how educational practice can be improved (King, Nomikou, Archer, & Regan, 2015). Evidently, some elements of science capital are fixed (e.g. parental science qualifications), yet science capital theory has been used to consider how education can build other dimensions of science capital in students

who are not exposed to it in the family. Thus, science capital moves from a critical theory to a practicable framework which aims to redress social injustices.

In collaboration with 43 science teachers, Godec, King, & Archer, (2017) pursued a series of action research projects and developed a ‘Science capital teaching approach’. This provides suggestions to educational practitioners to make their classroom practice more inclusive and, where it was absent, embeds social justice in their teaching.

The science capital teaching approach is summarised by a three-pillar model. At its foundation the science capital teaching approach suggests that educators should ‘broaden what counts’ as science. Science educators should acknowledge a larger range of experiences, skills, behaviours and identities which are legitimate and have relevance. Thus, they can challenge the ‘narrow’ conceptualisation of science that many students currently have (chapter one). Importantly, ‘broadening what counts’ changes the culture of science to be more inclusive rather than attempting to ‘fix’ young people to fit in.

The first pillar of the science capital teaching approach is: ‘Personalising and localising’. The guiding principle of this pillar is to contextualise science content so that it connects with students’ personal lived experiences, their interests, attitudes and values regardless of their background. The second pillar of the science capital teaching approach is: ‘Eliciting, valuing and linking’. In identifying students’ specific knowledge and experiences, personalising and localising becomes easier. Finally, the third pillar is: ‘Building science capital dimensions’. While some teachers are already applying these principles, the science capital teaching approach unambiguously builds on good teaching practice with “*an explicit focus on recognising and valuing students’ existing science capital whilst also helping them to build new capital*” (ibid.). Thus, the approach attempts to reconcile Zipin's (2005) redistribution/recognition dilemma (above).

The implementation of the science capital teaching approach has been a topic of research. The principles of the science capital appear to resonate with science teachers (King et al., 2015) and also improve student engagement, improve a range of science-related dispositions, as well as widening students’ participation in science classes (Archer et al., 2018). However, teachers also report the difficulty in applying the science capital teaching approach due to the systems of accountability systems in their schools, which “*are narrowly conceived and short- term in nature, and tend to focus solely on student attainment as determined by externally set measures*” (King & Nomikou, 2017). These findings suggest systems of formal education struggle with elements of social justice, thus reflecting findings of the studies referred to in chapter one.

Overall, Archer et al. (2018) suggest that the application of science capital theory to teaching practice may offer “...*ideas for how things might be ‘done differently’ in the ongoing struggle for a more socially just education system*”. Therefore, while the science capital teaching approach was published mainly as guidance for practitioners, it is grounded in academic research and has relevance to this current project in understanding the practices of outreach practitioners in the WROL.

2.3. Operationalising science capital to evaluate the WROL

As a sociological theory, one of the most significant challenges regarding Bourdieu’s work is the extent to which it can reasonably be applied to individuals and also whether it can be practicably applied to research and inform practice; can cultural capital theory be utilised beyond an explanatory framework for understanding how society operates? The lack of conceptual clarity and clear definition from Bourdieu has exacerbated challenges in operationalising cultural capital; raising questions of whether cultural capital can be meaningfully quantified/measured in individuals, making it difficult to determine changes in cultural capital over time and causing some to question whether it is a valid construct at all (Špaček, 2017). Nevertheless, the research community has developed strategies to meaningfully operationalise Bourdieu’s concepts (particularly Archer’s empirical developments in measuring science capital) and these are discussed below.

To begin, some of the less convincing attempts in operationalising cultural capital. Some have attempted to enumerate individuals’ cultural capital through proxy measures. For example, Graetz (1988) simply used the number of books as an indication of the level of cultural capital that might be expected (the higher the number of books, the higher the cultural capital). This measure has frequently been used since, but is obviously limited and has been rightly criticised, as Sieben & Lechner (2019) remind us, cultural capital is not a uniform construct, and the number of books captures a specific aspect of the concept (i.e., only objectified cultural capital). Another narrow measure of cultural capital previously used is that of attendance at cultural arts classes (Aschaffenburg and Maas 1997). Measurements that overly rely on one dimension are limited measures of cultural capital (Sullivan, 2002) and provide imperfect understanding to a deeply complex social construct.

Crook (1997) and De Graaf, De Graaf & Kraaykamp (2000) add some nuance to their operationalisation of cultural capital, where they separate the construct into two constituent components: the beaux arts and reading dimensions. For Cook (1997), reading items include the frequency of reading ‘serious’ books and practical books, library visits, and also the total number of books owned, and the Beaux arts items recorded the frequency of attendance at

ballet, opera, classical concerts, museums, theatre, and listening to classical music at home. Sullivan (2001) further breaks down cultural capital into four categories: reading (type and number of books read, library use, newspapers read), TV viewing (watching ‘highbrow’ programmes), music (listening to classical or jazz, playing an instrument), and ‘public’ cultural participation (art gallery, theatre, and concert attendance). These examples demonstrate a growing complexity in the understanding and approaches taken to measuring cultural capital, or at least measuring significant elements that contribute to cultural capital. These examples also speak to the importance of viewing cultural capital as a multi-factor construct, rather than a singular entity that can be easily quantified.

Indeed, Archer et al.’s (2015) conceptualisation of a science capital “score” is not to be considered a unitary construct, but a composite measure. It is operationalised through psychometric testing and correlation between items is used to infer the existence of the underlying dimensions of science capital (detailed in section 2.2.1). The strength of this approach is that factor analysis reveals the constituent constructs and does not overly rely on a singular measure (e.g. number of books at home). Furthermore, Archer et al. (2015) also takes care to acknowledge that their composite measure may yet be incomplete, leaving scope for future additions to the framework, as an iterative backbone that can be quantified, rather than a definitive one.

The challenge for practitioners therefore becomes one less of measurement, but whether cultural/science capital can be practicably changed by intervention. One of the key assumptions of Bourdieu is that cultural capital can be ‘transferred’. This is important for educationalists because, if true, then educational interventions can be used as a tool for increasing students’ cultural capital, potentially improving a student’s life chances. Indeed, Kalmijn and Kraaykamp (1996) found cultural capital was instrumental for disadvantaged ethnic groups, where a faster increase in cultural capital in black populations from 1900-1960 helped narrow the racial differences in educational outcomes. Archer et al., (2015) highlight that some dimensions of science capital are easier to influence and more amenable to intervention than others (they give the example of attitudinal dimensions, rather than behavioural or structural variables). Therefore, cultural capital theory moves from a conceptual sociological theory to a theory which can be utilised in practice – educational interventions can transfer certain forms of capital to students who might otherwise not have inherited them. However, because cultural capital is integral to the reproduction of inequalities, many sociologists regard capital as negative and problematic and question whether this redistribution is a ‘good thing’. This raises questions over whether increasing levels of science capital in students is desirable, or whether

this will simply reify capitals that are already dominant and perpetuate the *status quo* (Jensen & Wright, 2015). Evidently, formal science education and qualifications are important in the current system, but their dominance contributes towards reinforcing certain exclusionary practices. Claussen & Osborne (2013) ask: “*Whether the dominant cultural capital has an intrinsic justification... or whether it is simply a product of a sociohistorical context...*”. This study takes the perspective that students live in an existing system, and certain capitals have value within that system. Therefore, if students gain science capital as a result of visiting the WROL, this is a good thing for them. The wider sociological criticisms of cultural reproduction and cultural arbitrary (above) stand, but challenging the hegemony of dominant capitals and intergenerational social inequality is beyond the scope of the WROL and could be determinantal to the visiting students (depriving them of *currently* valuable science capital).

Finally, cultural capital theory has been criticised for its overly deterministic perspective (Sullivan 2002). Bourdieu’s concepts lean heavily towards ‘nurture’ in the ‘nature/nurture’ dichotomy. Considering the influence that Bourdieu gives to one’s upbringing and the significance that wider society has, cultural capital theory leaves little space for free will, individual agency or change. Bourdieu’s theories provide a model to explain observed social reproduction: cultural capital is inherited, and class/social position is maintained intergenerationally – those that are born into ‘upper’ class families will acquire cultural capital and therefore maintain their class position, conversely those from ‘lower’ class backgrounds will not inherit the requisite cultural capital to be considered middle/upper class and therefore remain in that position. Nash (1990) criticises this view as a “*vision of a life trajectory as something like a railway journey with strictly controlled socially permissible choice points at certain branch lines.*” Evidently this conceptualisation of cultural reproduction is flawed, even anecdotally we are aware of individuals who have little access to cultural capital from their parents/schooling or upbringing and have been incredibly successful. Likewise, it is quite possible to inherit a stock of cultural capital and reject it wholesale. To this point, I would argue that cultural capital and science capital should be seen as *highly predictive* of future behaviour, rather than *universal law*. As Brodeck (1962, quoted in McIntyre, 1993) says:

“Laws in social science, if we had them, would contain many more variables than those in physics. Yet we berate the social scientist for not being able to do what even the natural scientist cannot do. The multiplicity and complexity of factors in social phenomena impose limitations upon what we can reasonably expect to achieve” (p.47)

Again, this current research stresses the importance of viewing science capital as a multi-dimensional construct; a single element of one's science capital is not an outright determinant of science participation. For example, having scientists as parents does not automatically ensure science participation, nor does not owning any science books inevitably preclude participation. The cumulative effect of science capital is important, but not absolute.

In summation, cultural capital and science capital are useful in this project from two differing perspectives: sociological and educational. Firstly, Bourdieu's cultural capital theory is useful as a meta-level conceptual tool to frame this research, it has been used to describe society and critique the education system in perpetuating inequitable practices which explain differing educational outcomes between socio-demographic groups. This only gets us so far, and the educational perspective helps operationalise these concepts for empirical research. Archer's work has resolved factors that reasonably constitute elements of science capital and therefore, science capital can be measured. Finally, in the context of a WROL visit, increasing science capital is pragmatically a 'good thing' for these students.

Chapter two summary

In this chapter, I have introduced the theoretical resources which are applied in this study. I argue that Bourdieu's concepts of cultural capital, field, the cultural arbitrary and symbolic power allow us to understand social inequalities, particularly with regard to critical pedagogy. Yet, Bourdieu's framing of 'all pedagogic action' as symbolic violence left little room for practically addressing these social injustices. To resolve this impasse, more recent interpretations and developments of Bourdieu's work were described.

I have presented the work of Louise Archer and colleagues, who have furthered the work of Bourdieu to understanding science participation, with implications for understanding the WROL. Science capital theory has become a prominent conceptual tool for investigating science education. I argue that one of the most significant advances made by science capital theory is the movement from theory to practice. The methods and methodology used in this study are presented next.

3. Chapter three: Approach to this research- Methodology & Methods

This chapter describes the methodology and methods used to evaluate the school-university partnership programme in the WROL. Justification of chosen methodology and methods begins by exploring possible philosophical approaches to research. This project's critical realist approach is then described. This is followed by a discussion of the mixed methods single case research (MMSCR) research design used, as well as the constituent methods (interview, questionnaire and observation) and data analysis. The chapter concludes with an exploration of the ethical considerations made before data collection.

3.1. Methodological approach- Realist evaluation

In recent years demands to 'demonstrate impact' of science education interventions has increased (King et al., 2015). The rationale for evaluating WP programmes is multifaceted, Crawford, Dytham, & Naylor (2017a) suggest six key reasons:

- To see if programmes/projects 'work'
- To inform future practice and continue to develop programmes/activities
- To justify the money spent
- To demonstrate success
- To develop and contribute to the sector's knowledge
- Because they are required to (for example, by the OfS)

However, *how* to evaluate WP interventions has been a longstanding challenge for practitioners in the HE sector (Hayton & Bengry-Howell, 2016). There is little consensus to define 'evaluation', Glass & Ellett (1980) summarise:

*Evaluation- more than any science- is what people say it is; and people currently are saying it is many different things. Evaluation is a set of theoretical and practical activities **without a widely accepted paradigm**. Few people agree on the best way to evaluate. (p. 211) (emphasis added)*

The lack of consensus can be a problem for would-be evaluators. Indeed, much of the published WP evaluation has been criticised (Dytham & Hughes, 2017; EPI, 2020) and perhaps explains why "...most interventions have had no rigorous evaluation" (Gorard et al., 2006: 116).

In an attempt to define approaches to evaluation better, Kazi (2001) suggests three possible options: 1) the empirical (or positivist) approach, 2) the interpretivist approach and 3) a pragmatic, methodological-pluralist approach.

The first possible approach, positivism, is strongly associated with the philosophy of science. Positivists argue that reality can be directly observed and measured, creating objective knowledge. A positivistic approach to research therefore uses a highly structured research design, with methods that generate large-scale data-sets, statistical analysis and universal law (Henn, Weinstein, & Foard, 2006: 11). Regarding social research, positivists argue that the social world should be investigated using the hypothetico-deductive method and experiments (Henn et al., 2006: 16). Evaluation using this approach might determine the success of a programme by it achieving certain metrics. Scriven (1967: 40) summarises the positivist approach to evaluation as:

[Evaluation] consists simply in the gathering and combining of performance data with a weighted set of criterial scales to yield either comparative or numerical ratings, and in the justification of (a) the data-gathering instruments, (b) the weightings, and (c) the selection of criteria (quoted in Glass & Ellett, 1980 and Taras, 2013)

The second possible approach to evaluation suggested by Kazi (2001) is interpretivism and it is strongly associated with social science. Interpretivists argue that reality and social reality are different (Gray, 2014), two people's differing experiences of one situation are equally valid. Therefore, interpretivists reject the notion that complex social systems (such as the WROL) can be evaluated through reductive quantitative approaches alone. They suggest that knowledge is subjective and should incorporate multiple social perspectives. Interpretivism is most commonly associated with social science research methods, such as; grounded theory, ethnography, behavioural studies, case study or life history, to generate small-scale and intensive data (Henn et al., 2006: 15).

Both positivist and interpretivist approaches have previously been used to evaluate WP interventions (e.g. Banerjee, 2017 and Moss, 2015, respectively). Each approach has their advantages, but positivism and interpretivism are often juxtaposed (Vincent & O'Mahoney, 2018). For example, where a positivist might favour a multiple-choice questionnaire, an interpretivist might recommend an open interview. Using either approach is liable to criticism from the other perspective.

Critics of positivism argue that it is overly reductive for complex social phenomena. For example, while Bourdieu (1984: 95) condenses his extensive theory of cultural capital into the formula: [(habitus) (capital)] + field = practice, Davey (2009) describes this formula as

“pseudo-mathematical”. Each of the variables are unquantifiable because of their complexity. Brodbeck (1962) argues:

Laws in social science, if we had them, would contain many more variables than those in physics. Yet we berate the social scientist for not being able to do what even the natural scientist cannot do. The multiplicity and complexity of factors in social phenomena impose limitations upon what we can reasonably expect to achieve. These limitations are only a practical, though perhaps practically insuperable, difficulty and we simply do the best we can (p. 47, quoted in McIntyre, 1993)

Furthermore, when researching widening participation interventions it is difficult to control external variables (Crockford, 2019). For example, students’ lives outside of the intervention cannot be standardised. Therefore, supplementary qualitative data is needed to capture complexity.

Positivism is further criticised for its assertion that a researcher can be wholly objective. Even within science, it is well understood that the act of observation can change the outcome of an experiment, e.g. quantum mechanics. The act of observation is acutely relevant when researching social phenomena; objectivity when researching humans is challenging and the researcher’s presence may also alter the behaviour of the observed (discussed further in section 3.2.5).

Evaluation of the school-WROL partnership requires an acknowledgment of the complex social context and the potential subjectivity of the researcher. An interpretivist approach would help with this but is also liable to criticism by positivists.

Critics of interpretivism argue that the subjectivity of social science research methods weakens research. The ‘interpretation’ of qualitative data can be influenced by a researcher’s cultural background, individual beliefs and personal history which may result in biases. Campbell (1979) argues that evaluation of many previous programmes falls into an “overadvocacy trap” (p. 84), where internal evaluators have grossly exaggerated claims of programme success. This may be a result of subjective research methods or analysis.

The arguments between positivists and interpretivists were much rehearsed in the quantitative/qualitative ‘paradigm wars’ (Hammersley, 2008; Symonds & Gorard, 2008). With adherents of particular approaches becoming so dogmatic that Holmes, Murray, Perron, & Rail (2006) liken the dominance of particular ideologies to ‘fascism’. It is for this reason that Kazi (2001) advocates for a third, midway, approach to evaluation that combines positivism and

interpretivism. Pawson and Tilley's 'realist evaluation'¹¹ (Pawson, 2014; Pawson & Tilley, 1997) achieves this.

Realist evaluation acknowledges both the benefits and limitations of quantitative-dominant methods (positivism) and qualitative-dominant methods (interpretivism). This methodological agnosticism provides the middle ground approach required to holistically evaluate complex programmes, such as the WROL.

Since the 70s, realism has gained popularity as the guiding philosophical framework for conducting socio-scientific research (Fletcher, 2016; Kazi, 2001) and has previously been applied to WP and outreach evaluation (Dytham & Hughes, 2017; Harrison et al., 2019; Harrison & Waller, 2017).

Realist evaluation is often summarised as an approach which asks: 'what works for whom and in what circumstances and why?' (Pawson & Tilley, 1997). This is a direct result of the criticism of so-called 'black-box' evaluation (Scriven, 1994). The term 'black-box' refers to research which solely measures the effect of a programme, focussing on outcomes, *without* due consideration of the internal process that might cause any changes. The 'black-box' approach could be summarised as simply asking: 'does the programme work?'. While this might produce some important research and stands in its own right (Kazi, 2001), its findings can be limited, with reasons for success unclear. Critical realism helps deepen research and moves research to strive towards Scriven's (1994) 'white/clear box' evaluation which, not only, addresses the effects and outcomes of a programme, but *also* the inner workings and mechanisms of the constituent elements of a programme and how they are connected.

It is for this reason that the critical realist approach is applied to this project in the WROL. The intention of this research is not just to superficially determine whether the programme 'works' (or not). Instead, it aims to holistically evaluate the WROL. This requires a wider scope of investigation than superficially defining outcomes for the WROL and measuring them. Critical realists sometimes use the context-mechanism-outcome configuration, or CMO(C) (Blamey & Mackenzie, 2007; Dalkin, Greenhalgh, Jones, Cunningham, & Lhussier, 2015; Jagosh et al., 2015; Pawson & Tilley, 1997) as a model for their research to help. By explicating the three areas: 1) the context, 2) the mechanisms for

¹¹ There is some discussion over whether the term 'realist' or 'realistic' evaluation is preferable. Where 'realistic' was originally used by Pawson & Tilley (1997), 'realist' has become the preferred nomenclature in the evaluation sector (Kazi, 2001). Both 'realist' and 'realistic' evaluation are acceptable and can be considered synonymous (Pawson, 2014).

change, and 3) the outcomes, critical realist research intentionally moves to deeper understanding of the social phenomena under investigation.

The CMO configuration can be used to clarify how the critical realist approach is relevant to this project. Firstly, the immediate ‘context’ is perhaps clear: the WROL (section 1.4.1). However, the wider context in which the WROL operates is also important and due consideration has been given to the wider historical and political context to situate this research; sections 1.2.-1.4 of this thesis explores science education in England, both developments in the formal and informal sectors, the widening participation policy landscape and its rationale for the WROL in the context of Imperial College London.

Secondly, the ‘mechanism for change’ is considered by research question three (What are the features and pedagogical practices of the WROL? - Chapter six). The extended observations undertaken in the WROL are intended to understand the constituent features and inner day-to-day workings of the WROL, which may be causal factors in any outcomes observed, either positive or negative. Without the observation data collection and analysis this study would revert to Scriven’s ‘black-box’ evaluation- the assumption would be that any outcome is directly attributable and down to visiting the WROL. This would provide a partial understanding of the complex social and educational processes occurring *within* the WROL during a visit. Instead, this study critically analyses the inner workings of the WROL, with the intention of discerning which features or practices might be useful, and which can be improved. The extent to which mechanisms can truly be isolated and attributed to outcomes has been questioned (Vincent & O’Mahoney, 2018), nevertheless, to focus solely on outcomes and not even attempt to look at causal features in the WROL would lead to a limited study.

Finally, the ‘outcomes’ from the WROL are conceptualised and explored in two ways in this project; research question one (Chapter four) allows key stakeholders to describe what outcomes they expect from the WROL and research question two (Chapter five) operationalises science capital as one measure by which changes as a result of WROL visits could be quantified.

Realism is not overly prescriptive with regard to methods used in research and argues that the methods used should be determined by the context of the research problem rather than methodological purity (Mcevoy & Richards, 2006). The research methods described above are aligned with each of the research questions of this study, which are in-turn aligned with the CMO configuration and are therefore in keeping with the critical realist the approach applied to this project (Vincent & O’Mahoney, 2018). In recognising the complexity of the social context of the WROL and desire to understand both the wider context in which it operates and

the internal features which may result in positive outcomes (rather than just asking whether outcomes are achieved), the critical realist philosophy to evaluation is therefore justified over either strict positivist or interpretivist approaches.

3.2. Mixed methods single case research (MMSCR)

Onghena, Maes and Heyvaert (2019) define MMSCR as:

...research in which single case experimental and qualitative case study methodologies, and their accompanying sets of methods and techniques, are integrated to answer research questions that concern one case (p. 462)

MMSCR is not yet well established in the methodological canon, but as a distinct approach, it borrows the advantages of both quantitative and qualitative approaches (following the realist philosophy above), as well as the benefits associated with in-depth case-study research.

The combination of methods from both the quantitative and qualitative traditions is common within educational and evaluative research (e.g. Gorard, Siddiqui, & See, 2015; Hanley, Chambers, & Haslam, 2016). Henn et al., (2006: 20–22) argue that combining methods can be beneficial; the consideration of many perspectives concurrently broadens a study to create a more holistic picture of the system under investigation. Caruth (2013) further suggests several strengths in mixing methods: a) qualitative data can be used to bring additional meaning to numbers, while quantitative data can be used to add precision to words, photos, and narratives; b) mixed methods can help answer a wider range of research questions c) mixed methods can present more robust conclusions; d) mixed methods can enhance study validity; e) mixed methods can add insight and understanding that might be missed when only using a single method; f) adding quantitative data can increase the ability to generalize results compared to only using qualitative data. The use of mixed methods has become so ubiquitous that it is now considered a third paradigm in its own right (Johnson, Onwuegbuzie, & Turner, 2007; Symonds & Gorard, 2008). Furthermore, the Office for Students recognise the advantages of using mixed methods and their policy documents also advocate for this approach when evaluating outreach interventions (Office for Students, 2019a).

Case studies have also been particularly useful in educational research (Tellis, 1997) and bring advantages to this evaluation. Zainal (2007) suggests case studies have three main strengths; firstly, that data is collected within context, which means that evaluation is holistic. Secondly, although case study research is often seen as a strictly qualitative approach, mixed methods can be used. Finally, the advantages associated with mixed methods (as discussed) also apply to case study research. Evidently, the strengths of mixed methods and case studies

overlap somewhat. When using them together it is helpful to marry them under the MMSCR umbrella.

Although using MMSCR to evaluate the WROL brings several advantages, no research approach is without weaknesses. Onghena, Maes and Heyvaert (2019) suggest that attention should be given to the trustworthiness and validity of a study using MMSCR. To this end, a detailed exploration of the research methods and analysis used in this study is presented below. It is hoped this forms part of the ‘audit trail’ (Nowell et al., 2017) which demonstrates the validity and trustworthiness of this study.

3.2.1. Interview

The use of interview is a well-established method of data collection in educational studies and is an indispensable tool for most social science researchers. Pawson & Tilley (2004: 160-161) consider both ‘practitioners’ and ‘subjects’ as having useful perspectives which help evaluation. ‘Practitioners’ are considered experts in understanding how particular policies have been implemented, the challenges and opportunities involved, and immediate effects on outcomes including successes or failures. While the expertise of ‘subjects’ is narrower, they can still provide data on their immediate experience of policies and practices developed by others. In the WROL the academic leaders and teachers can be considered practitioners and students can be considered subjects; representatives of each group were interviewed and recorded digitally for this study.

In this study, academic leaders and teachers were interviewed to address research question one. They were asked what they wanted students to gain from visiting the WROL, and also asked supplemental questions which helped clarify how they thought this might be achieved and further explain their motivation for involvement, and the value of the WROL. Students were interviewed as a supplement to the science capital questionnaire (below) to answer research question two. They were asked about their experiences in the WROL and whether they thought it had any effect on their attitude towards science. Interview schedule development is discussed further below, and they are presented in appendices I and II.

Because the academic leaders and teachers form relatively small populations, it was possible to interview the majority of them and no sampling criteria were applied. Academic leaders were initially recruited for interview opportunistically. During my preliminary observations in the WROL, conversation would often present opportunities to invite leaders to participate. This approach worked well but required academic leaders to remain in the WROL after a long day of leading sessions. Subsequently, all academic leaders on the outreach teams’ database were emailed to invite them to an interview at a time and place convenient. This

elicited a good response, and 12 academic leaders were interviewed. Interviews with academic leaders lasted an average of 41 minutes

Science teachers from the partner school were ‘soft-approached’ for interview during the annual meeting between the partner school and the WROL staff. Teachers were then subsequently recruited opportunistically when they visited the WROL. All of the teachers in the science department of the partner school visit the WROL at least once a year, if not several times. Interviews with teachers were conducted in the WROL seminar space while the sessions with students were occurring next-door. Overall, nine teachers were interviewed, representing most of the science department, with each interview lasting an average 26 minutes.

Sampling and recruiting students for interview was more challenging. It was initially hoped that sampling based on levels of science capital (determined by pre-visit science capital questionnaire, below) could be used. However, the anonymisation of questionnaire data prevented the identification of individual students. Instead, a purposeful sampling technique (Palinkas et al., 2015) was employed. Purposeful sampling (sometimes referred to as ‘purposive’ sampling) is designed to identify the most information rich cases (Seidman, 2006: 52). In the context of the WROL, students were broadly identified as being engaged or disengaged with the session. Students from both groups were approached for interview with the view that they would have information regarding both engaging pedagogy in the WROL and practices which contributed to disengagement. Evidently, this is an oversimplification of students’ enjoyment of the session; disengagement may be completely unrelated (for example, one student was simply ‘*having a bad day*’ because their transport to reach the WROL was delayed and it was raining). Nevertheless, this purposeful sampling was intended to ensure a cross-section of perspectives were considered, with sampling alternating between engaged and disengaged students.

Students identified as potential participants were either approached towards the end of the morning session, or during lunch. In the interests of not depriving students important time in the WROL, all interviews with students were conducted during lunchtime. However, lunch in a HE environment is also part of the day’s experience for students. At lunch students are accompanied by mentors and the informal conversations which occur during the ‘lulls’ of a day are valuable (see section 6.2.1). Lunchtime was therefore considered as much an important part of the day as any time spent in the lab itself. Consequently, interviews with students were subsequently limited to 20 mins.

While interviews are traditionally conducted one-to-one, these can be intimidating, especially for children. Students may see adults as figures of authority to whom ‘correct’

answers should be given. It was therefore deemed prudent to invite peers to contribute concurrently to group interviews¹² (from pairs to four students), in the hope they would be more inclined to give frank and honest opinions. In total, 41 students were interviewed as part of this research, across 20 data collection sessions.

Most methods textbooks present two approaches to conducting an interview. At one extreme, there is the ‘structured’ interview in which participants are asked questions sequentially, exactly as they are phrased on the interview schedule (e.g. Korpan et al. 1997). This approach is typically associated with inductive reasoning, where established theory is tested in a ‘theory-driven’ or ‘bottom-up’ manner (Braun & Clarke, 2006). At the other extreme, interviews can be unplanned, organic conversations (e.g. Varelas et al. 2011), which are typically analysed using deductive logic to create new theory in a data-driven or ‘top-down’ approach (Braun & Clarke, 2006). The bottom-up approach is strongly associated with grounded theory, which was previously used to evaluate the work of the WROL, where Moss (2015) took an agnostic approach to existing theory and instead used data and deductive reasoning to develop his own heuristic model of university STEM outreach.

While approaching data collection in a data-driven ‘theoretically agnostic’ manner may be appropriate in some studies, this project considered the theory of science capital (section 2.2). Pawson & Tilley (1997) argue that ‘data-driven’ strategies give undue weight to the perspective of the interviewee and fail to fully account for existing theory. Realists make the case that interviewees are “*there to confirm or falsify and, above all, refine that theory*” (Pawson, 2006: 299). Therefore, it was necessary to create a interview schedules (appendices I to III) informed by key concepts found within the literature.

However, conversations are dynamic interactions, where it may make sense to follow themes introduced by participants and ask questions in a different order. Indeed, it can be helpful to ask a completely new question. For these reasons the schedule was not followed in an overly draconian manner. Thus, the “*much used but little celebrated pluralist midway compromise*” (Pawson, 2006) of semi-structured interviewing was used. This meant that the same questions were given to participants, but deviation or elaboration were permitted.

Although difficult to quantify (Goudy & Potter, 1975), ‘rapport’ is often cited as one of the defining features of a good interview. Rapport between interviewer and interviewee helps elicit frank and open responses from participants (Henn et al., 2006: 163). Creating a

¹² Group interviews are not to be confused with focus groups. In focus groups the role of the interviewer is transferred to moderator and the data collection is more observational.

friendly non-threatening atmosphere facilitates honest accounts from participants, but requires tact. Dean, Eichhorn, & Dean (1967) compare this to feeding pigeons, a few ‘crumbs’ are required, but too much enthusiasm will ultimately alarm the pigeons/participants. Under-developed rapport means interviewees are likely to be unresponsive and data will be ‘shallow’. Conversely, over-developing rapport means the data collection may not be made with adequate objectivity (O’Reilly, 2012). Rapport, in this project, was developed with each of the interviewees through genial conversation with participants at given opportunities. For example, teachers from the partner school come to the WROL at the beginning of each academic year for a ‘meet-and-greet’ session, which I made sure to attend. Rapport was built with students during their WROL session, as well as asking them general questions while walking them from their lunch back to the WROL for the interview. Finally, rapport was developed over an extended period with the academic leaders throughout my observation in the WROL.

After seeking permission from interviewees, all interviews were recorded using a digital voice recorder (SONY ICD-PX370) which allowed for perfect recall during transcription and analysis. Given the risks of technology failing at inopportune moments, Burnham et al.’s (2008: 239) advice was followed and handwritten back-up notes were also taken during the interviews (although these were never actually required).

3.2.2. Analysis of interview data

Thematic analysis (Braun & Clarke, 2006) was used to examine the interview data. The first step in thematic analysis is familiarisation with the data and begins during data collection. Because notes were being taken during interviews, key ideas were underlined and being considered, even at a subconscious level; each interview adding to the mental schema of thoughts and significant ideas. Familiarisation continues in the transcription phase.

Although converting audio data into written text is an integral part of analysing qualitative interview data, transcription is considered a neglected area within each the academic literature, methods textbooks and training for students (Bird, 2005; Davidson, 2009; Weinbaum & Onwuegbuzie, 2016). While some academics consider transcription a transparent process, requiring no more than a passing comment or often being left unspoken, transcription should be seen as a process where researchers make choices that need explanation (Ochs, 1979). The choices a researcher makes in transcribing data typically revolve around 1) who does the transcription and 2) how much detail is captured.

Considering the time required to transcribe interviews¹³, transcription is often outsourced to professional transcribers (e.g. Godec, 2017). Although confidentiality agreements help safeguard anonymity of participants, transcripts still require checking alongside the recordings to ensure the accuracy. Richman, Weisband, Kiesler, & Drasgow (1999) suggest that computers might provide some resolution in automatically transcribing spoken word and reduce transcription errors. Automatic transcription was trialled in this study using the NVivo Transcription Beta Program, however the resultant transcript was so inaccurate that it took even longer to remedy the programme's interpretation than it did to transcribe manually.

Subsequently, the transcription for this study was conducted manually in NVivo 11 and 12¹⁴. Although time consuming, there is some benefit to researchers transcribing their own audio recordings. Bird's (2005) wonderfully titled paper: *'How I stopped dreading and learned to love transcription'* suggests that researchers should embrace the extra opportunity to engage with their data in a more holistic manner adding to their depth of understanding. Thus, transcription becomes part of the important familiarisation process in thematic analysis (Braun & Clarke, 2006).

The other consideration for researchers, during transcription, is the level of detail they include. Humans communicate with their face and particularly with their eyes, body movement can also convey information. Evidently, in converting interviews into written word some information is lost, for example intonation, sarcasm, pauses, overlapping talking and physical gestures. Previous researchers, have created textual codes to capture such information, for example square brackets, [], used to indicate cross-talk, arrows, ↑↓, to indicate changes in pitch and musical notation has been borrowed to convey volume <<p>>, <<pp>> (piano-, softly or low volume and pianissimo- very softly or very low volume) (Roth, 2009). These notations have previously been used for in-depth conversation analysis, discourse analysis and linguistics methodologies (Bird, 2005). However, thematic analysis does not require the same level of detail (Braun & Clarke, 2006). Rather than trying to capture all information, selectivity in transcription should be understood as a theoretical and practical necessity which can be justified in relation to the goals of a study (Davidson, 2009). This study does not aim to examine

¹³ Evidently several factors affect the speed at which transcription can be done; the clarity of recording (including accents), number of interviewees and the proficiency of the transcriber. However, as a rough guide transcription takes four times as long as the recording, so 15mins of interview would an hour to transcribe.

¹⁴ NVivo 12 was released in 2018.

language patterns or conduct deep linguistics analysis, instead transcription is used as interpretive analysis of broad themes (Bird, 2005). Indeed, Ochs' (1979) advice that “*A more useful transcript is a more selective one*” (p. 44) was followed and transcription focussed on capturing the participants comments verbatim, without extraneous information.

The next stage of thematic analysis involves coding the data (Braun & Clarke, 2006). Coding is an adaptable process, with inductive ‘data-driven’, deductive ‘theory-driven’ orientations or a hybrid of both being permissible (Fereday & Muir-Cochrane, 2006). Initial coding of the transcripts was informed by existing science capital theory, with codes being determined *a priori* from the literature. The initial coding framework used key concepts from the literature, including the science capital framework (Archer et al., 2015) and science capital teaching approach (Godec, King, & Archer, 2017). Using the coding framework, the germane segments of the transcript were labelled in NVivo. Coding is an iterative process, so several ‘passes’ were made over the data both to ensure that the coding was thorough, the framework was consistently applied, and new codes being added as new commonalities between interviews were determined.

The next stage in thematic analysis gathered together codes with commonalities into ‘themes’ and reviewed clusters of data for patterns. Codes which appear frequently suggest a common theme across data streams and therefore theoretically significant areas are identified. Equally, themes that have insufficient data are discarded or merged. Themes are comparable to ‘demi-regularities’ from the realist evaluation tradition (Fletcher, 2016; Kazi, 2001), where events occur with such regularity (although not universally) that, given the same setting and context it becomes reasonable to predict its repeated occurrence. Indeed, ‘thematic saturation’ describes a point in research where the collection of more data would not bring any further understanding (Ando, Cousins, & Young, 2014; M. O’Reilly & Parker, 2013).

Although frequently presented as linear process, thematic analysis should be considered a reflexive and iterative process where the data is passed over several times, moving across the data, codes and themes and between the empirical and theoretical (Fereday & Muir-Cochrane, 2006). Therefore, although analysis began with a deductive approach, the actual approach taken in this study is better described as using abductive reasoning. Abductive logic is a pragmatic hybrid approach that moves back and forth between induction and deduction (Venkatesh & Brown, 2013). Evaluation is very much guided by abductive logic (Levin-Rozalis, 2003) and aligns with the realist philosophy underpinning this research (Kazi, 2001). Abductive reasoning is typically illustrated by its use in medical diagnosis (Porębski et al. ; where several symptoms may be present, a doctor can still make an informed diagnosis (using their knowledge of

established theory). This is comparable to the thematic analysis conducted in this study, where several potential views on the WROL were presented in interviews, the use of abductive reasoning brings the most logical perspectives to the fore (supported by prior research). Fereday & Muir-Cochrane (2006) argue that the iterative use of inductive and deductive logic helps ensure rigorous research. However, Braun & Clarke (2006) caution that coding data and grouping in themes could go on *ad infinitum*, comparing gratuitous fine-tuning of themes and codes to rearranging hundreds-and-thousands on a cake — they suggest that after a few editing turns further refinement becomes unnecessary. The coding and thematic framework for this study is presented in appendix IX.

The results from thematic analysis of the interviews are presented in chapters 4 (teachers and academic leaders) and 5 (students). It is important to note that not all quotations relating to themes are presented in results chapters, to do so would present too much raw data. Braun & Clarke, (2006) suggest using “*particularly vivid examples, or extracts which capture the essence of the point*”, therefore (unless noted otherwise) the example quotations are indicative of the sentiment of several participants, their importance determined by thematic analysis rather than simply choice anecdotes.

3.2.3. Questionnaire

Surveying participants via questionnaire is commonly advocated for evaluating programmes, including WP and science outreach interventions (Crawford et al., 2017a; Crawford, Dytham, & Naylor, 2017b; Cullen, Sullivan, & Junge, 2007; Fort, 2011; Friedman, 2008; Laing & Todd, 2015; Research Councils UK, 2011). Questionnaires are useful for several reasons, but perhaps the greatest advantage is being able to collect data from multiple participants concurrently (Kelley et al., 2003).

Using a post-intervention questionnaire is one of the most common means of capturing a ‘snapshot’ of participants’ immediate reactions to an intervention and ‘measuring’ the success of a WP activity (Hayton & Bengry-Howell, 2016). However, this approach lacks the ability to demonstrate causal links between the intervention and the outcome (Friedman, 2008) and the use of ‘happy/ smile’ sheets for evaluation has been widely derided (Hanley et al., 2016; Hayton & Bengry-Howell, 2016; Kirkpatrick & Kirkpatrick, 1975). This approach also risks incentivising ‘fun’ activities over more mundane, but more meaningful alternatives.

Instead, applying the same questionnaire twice, both before and after the intervention is a better approach. The determination of a baseline response is established so that any observed changes can be attributed to the programme (Harrison et al., 2019). Although two data collection points are considered the minimum, if a change is observed, it is advisable to apply

the questionnaire a third time to assess the longevity of the change, (Office for Students, 2019). This study therefore employed a pre-post research design for the questionnaire, with the contingency for applying the questionnaire a third time for longitudinal tracking if any effect was observed.

As for the survey instrument itself, the science capital questionnaire designed by Archer et al. (2015) was modified and used in this study. Archer et al. (2015) and DeWitt, Archer, & Mau (2016) describe how their survey instrument was developed. Based on their science capital theoretical work and principal component analysis (PCA), they determined nine components of science capital:

- Everyday science (media) engagement.
- Future science job affinity (aspirations).
- “Informal” Science activities.
- Parental attitudes and practices (including attitudes to science).
- Science teachers and lessons.
- Self efficacy in science.
- Utility of science qualifications.
- Valuing museums/museum experiences.
- Valuing science and scientists.

While the Archer, et al. (2015) questionnaire resulted in a final index score between 0 and 105, the research group has taken care to not over-emphasize their scale as the ultimate measure of science capital. They conclude their paper by asking whether their index truly captures the complexity of science capital and they question whether they have missed any dimensions of science capital. They also stress the multidimensionality of the index, Moote et al.(2019) summarise:

We do not claim that science capital is a single/unitary construct/factor [...] but rather [it] has a number of different dimensions which, together, influence an individual's relationship with science and are connected to the extent to which people feel that science is 'for me'. Correspondingly, our measure, or index, of science capital is a composite measure that captures these different facets of the construct (p. 6)

It is self-evident that addressing the complex multidimensional nature of science capital through a single outreach programme is near impossible. For example, there is little chance that the students visiting the WROL would have influence on the ‘Parental attitudes and practices’ (unless an intervention to engage parents was added). It was therefore considered important to focus this research on components of science capital which can be reasonably expected to be influenced by the WROL. As Archer, et al. (2015) suggest:

...some attitudinal aspects may be easier to influence and more amenable to intervention than behavioral or structural variables. To this end, the aspects of science capital concerned with “valuing science/scientists” and “utility of science qualifications” may be obvious first targets. (p. 942)

Indeed, these two dimensions (‘valuing science and scientists’ and ‘utility of science qualifications’) were considered as the first potential components of the students’ science capital which might be changed. The components ‘Future science job affinity (aspiration)’ and ‘self-efficacy in science’ were also considered liable to be influenced by WROL intervention.

Subsequently the questionnaire used in this study was produced using the items from Archer, et al. (2015) which pertained to each of the four components above. This resulted in 16 questionnaire items, feeding into four components. These four components in turn constitute a partial measure of science capital, i.e. those considered most likely to change because of visiting the WROL. Each of the questionnaire item asks respondents how much they agree with a proposition, on a Likert scale of 1 to 5 (1 being strongly disagree and 5 being strongly agree). The original 16 items are shown in Figure 3 below.

Harrison et al. (2019) suggest that using established theories is advantageous not least because of the pre-existing evaluation tools and metrics. Indeed, science capital resources have been validated across multiple populations, as well as science capital theory.

Thought was given to the best medium through which to distribute questionnaires. The relative advantages and disadvantages of both hard paper copies and online questionnaires have been discussed in methods literature (Ebert et al., 2018; Greenlaw & Brown-Welty, 2009). Overall, online distribution was considered most appropriate. The advantages of online distribution are primarily pragmatic rather than theoretical; firstly, it is cheaper, secondly, it removes the chance of transcription errors, finally, the questionnaire can be distributed and forwarded multiple times, where paper copies may be lost by students (or even researchers!).

A hyperlink to the pre-visit questionnaire was given to students one week before visiting the WROL in three different ways; a link was posted to the class’ Virtual Learning

Environment (VLE), a link was emailed to the students by the school's laboratory technician and a link was also given to students on a slip of paper during class alongside the trip permission forms. The 'belts and braces' approach to pre-visit questionnaire distribution was intended to increase the response rate. A further benefit of giving students a paper copy was in introducing myself and the research to students, helping them understand the rationale and importance of this work, as well as starting the rapport building process (above) for group interviews. The post-visit questionnaire was given to students to complete on iPads at the end of the WROL day (bar one class, who had the post-visit link emailed to them by their teacher). Overall, 272 responses to both pre and post questionnaires were received and analysed.

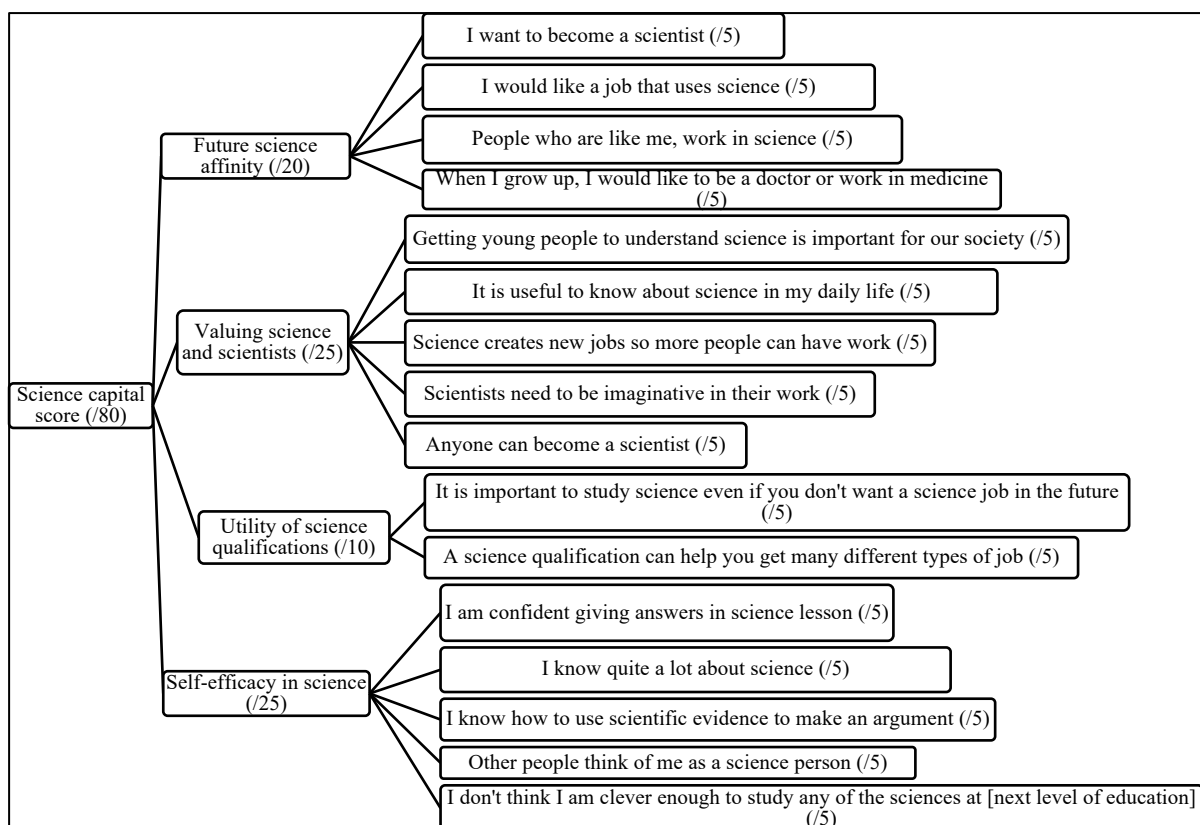


Figure 3: Original science capital questionnaire items and components

Again, while the use of questionnaires is justified in this study, this is not without faults. As described in section 3.2.3, the use of questionnaire is liable to criticism for reductionism. Archer, et al. (2015) pose the question “...can a quantitative tool, such as this survey, really capture the complexity of capital?” and stress that quantitative work into science capital is complimentary, and not a substitution, to qualitative work. It is for this reason that the science capital questionnaire in this study is supported by interviews with the students (described in section 3.2.1).

Consideration was also give to the accuracy of questionnaire responses. Fan et al. (2006) consider two key sources of inaccurate data when adolescents respond to self-report

surveys: firstly, inaccurate responses due to carelessness or confusion, secondly, intentional false response by ‘jokesters’. To help mitigate the risk from inaccurate responses through confusion or carelessness the questionnaire was designed to be as user friendly as possible. The online questionnaire was designed with clear signposting for students to follow instructions and phrasing of questionnaire items followed Archer, et al.'s (2015) original diction, as this was considered to be clear for children.

Unfortunately, dealing with respondents who reply flippantly with a joke is more difficult. Alexander (2013) humorously presents the ‘lizardman constant’ concept, which apportions four per cent of respondents as ‘jokesters’ who agreed when asked: "*Do you believe that shape-shifting reptilian people control our world by taking on human form and gaining political power to manipulate our society, or not?*" (Jensen, 2013). While statistical techniques exist which screen and remove a certain proportion of extreme answers (Robinson-Cimpian, 2014), the use of such techniques cannot discern between deliberately malicious responses or legitimate and sincerely held extreme responses. The students were asked to complete the questionnaires as truthfully as possible, stressing the importance of accurate responses for the study, but no other techniques were used to counteract joke responses.

3.2.4. Questionnaire data analysis

Questionnaire data analysis began with reliability and validity testing. Although Archer, et al. (2015) derive their components using principal component analysis (PCA) and used Cronbach’s alpha to check the internal consistency of their questionnaire, PCA was repeated with the data from this study.

PCA is used to determine latent variables i.e. variables that cannot be directly observed, and shows how well questionnaire items ‘load’ together as components (Beaumont, 2012). Before applying PCA, it is recommended that measures of sampling adequacy are used (*ibid.*) Both the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy and Bartlett’s Test of Sphericity were applied to the data to test whether PCA was appropriate. As the questionnaire being tested in this study had four existing theoretical components, the PCA was fixed at four factors. The reliability of the responses to the components, and the scale overall were tested using Cronbach’s alpha. The PCA assumption tests, PCA results and Cronbach’s alpha results are reported in section 5.1. As a result of this analysis, some questionnaire items were moved between components and others removed, this is also discussed in chapter five.

Composite scores for each of the four science capital components were calculated by totalling the Likert scale responses for corresponding questions (Figure 3: Original science capital questionnaire items and components). The four science component scores were then

tallied to give an individual's overall science capital score. The mean pre-visit values were then compared with the mean post-visit scores. To determine if any statistically significant changes resulted from visiting the WROL a paired t test (sometimes known as a dependent sample t test, or repeated measures t test) was applied to each of the four components and the overall score. Results of this test are presented and discussed in section 5.2.

Finally, responses to individual questionnaire items were analysed. How to analyse Likert scale data is debatable (Derrick & White, 2017). Reviewers frequently argue that data must be normally distributed for parametric techniques to be appropriate (Norman, 2010). Because Likert scales produce ordinal data that cannot, by definition, be normally distributed parametric tests cannot be used (*ibid.*). Further problems can arise when applying simple descriptive statistics, such as the mean which can be unclear with ordinal data. For example, what is the average of "agree" and "strongly agree", "agree and a half"? (Sullivan & Artino, 2013). For this study, it was considered most appropriate to apply Wilcoxon's signed rank test. Wilcoxon's signed rank test is often considered the non-parametric equivalent to the t test and is used to compare repeated measures (such as the pre/post questionnaire used in this study). Wilcoxon's signed rank test can be applied to ordinal data and determines whether the distribution of two measures are significantly different (or not). Results of this analysis are presented and discussed in chapter five.

3.2.5. Observation

Observation was also used to evaluate the WROL. We are all in a constant state of observation, however, the personal event of 'just looking' is transformed into research by the systematic recording, analysis, interpretation and reporting of what has been observed (Simpson & Tuson, 2003). Observation was used as the primary research method to help answer research question three: 'What are the features and pedagogical practices of the WROL?'.

Participant observation in the WROL was used extensively to collect data in a naturalistic context. Such observation is helpful as it allows researchers to become more in tune with the social setting and gather data *in situ*, as Kahn (2011) says:

To stand outside people, looking in at their lives as if they were in some laboratory or snow globe, is not to understand them... The study of human relations is necessarily an embedded one; to pretend otherwise obscures more than it illuminates (106-107).

Observation helps move evaluation beyond merely relying on second-hand reports of what people say they do or what they deem significant in an interview. Furthermore, observation allows researchers to look in detail at the environment, people and their relationships, their behaviour, actions and activities, histories and physical objects (Cohen, Manion, & Morrison, 2011: 221). By using observation in natural environments, researchers can counter criticism typically levelled against experimental methods, where the artificially constructed setting of laboratory experiments often lack ecological validity (Gouvier, Barker, & Musso, 2012). It is for these reasons that observation was used in this research project to understand the pedagogical practice occurring in the WROL.

The extent to which a researcher embeds themselves into a social system requires consideration. Gold's (1958) oft cited taxonomy helps consideration of the personal involvement an observational researcher may employ. A '*complete participant*' uses a completely covert ethnographic approach; '*participant-as-observer*' where the researcher integrates themselves into a group, but participants are aware of the researcher's role; '*observer-as-participant*' describes researchers who are considered outsiders by the participants, yet participants accept the researchers' presence to conduct research; and finally- '*complete observer*' where a researchers' position is completely detached from this subject under investigation and is typically a one-off. A 'participant-as-observer' role was used in the WROL.

Although an overt approach to observation was used in this research, consideration was given to the potential use of covert techniques. One criticism of overt research is that because participants are aware they are part of a study they may modify their behaviour (sometimes referred to as '*Hawthorne effects*'¹⁵ or 'demand characteristics' (Cohen, Manion, & Morrison, 2011: 473). Covert observation has the distinct advantage of participants not knowing they are part of a research project, so they are therefore likely to act naturally. Indeed, previous doctoral research in the WROL suggests that using video and audio recording may be a new avenue for research to counter this effect (Moss, 2015: 240-241). Furthermore, the WROL is also already equipped with a CCTV camera which is capable of observing sessions remotely or recording

¹⁵ Named after a study into working conditions and levels of worker productivity at Hawthorne Works in Illinois. It was found that when working conditions were altered, productivity would increase, regardless of whether the change was predicted to increase or decrease productivity. It is argued that the positive changes in productivity were a result of factory workers being aware they are being observed rather than any of the other manipulated working conditions. Productivity subsequently dropped once the study was over.

them for analysis at a later date, so no extra equipment would be required. However covert, the researcher may still induce unwanted or extraneous effects on those being observed.

Despite the benefits of covert observation suggested above, it was decided that overt observation would be preferable. Firstly, covert observation has serious ethical implications regarding informed consent. If participants are unaware that they are part of a study, it is impossible for them to consent to participation. Secondly, the physical situation of the CCTV in the WROL is such that it doesn't allow for a very naturalistic observation into a session, the camera itself is limited to a fixed point on the ceiling. The CCTV can be controlled remotely and rotated to aim the camera into a new area of interest, this 'movement' however risks alerting students to the fact that they are being observed remotely, negating the original purpose of covert observation using the CCTV. Equally, the microphone is fixed, so discerning individual conversations in the WROL during large group activities would have been impossible. By being physically present in the WROL it was possible to circulate and easily move to areas in which significant events were occurring for a better observational vantage point, which the CCTV would not have allowed.

Observation using such an ethnographic approach is not without its detractors. One of the main criticisms typically levelled against observation is its susceptibility to observer bias (Simpson & Tuson, 2003: 18). The extent to which a researcher can remain objective when involved in close inter-personal relationships can be a problem. Indeed, the concept of 'over-rapport' has been proposed (O'Reilly, 2012) as term to describe when a researcher becomes excessively involved in the lives of their research participants and lose objectivity (previously termed 'gone native'¹⁶). Equally, the researchers' own ethnocentric perspective may cloud observation, overlooking what might otherwise be significant (Cohen, Manion, & Morrison, 2011: 473; Lincoln & Guba, 1981). Further criticism against observation, as a method of research, is that it requires considerable time and resources (Simpson & Tuson, 2003: 18). The effort needed to observe in a meaningful manner (as compared to 'just looking') may also lead to observer fatigue or attention deficit (Cohen, Manion, & Morrison, 2011: 473).

To address each of these potential criticisms, it was decided that an observation schedule would be used to aid data collection during these studies (appendix V). The use of such a schedule guides data collection in a theoretically informed manner rather than

¹⁶ 'Going native' is a term associated with early colonial ethnography, now considered offensive (O'Reilly, 2012), 'over-rapport' serves a useful replacement term where the sentiment remains, without using problematic connotations.

attempting to record everything that happens. Selective observation, using a schedule, aims to capture pre-determined ‘*significant events*’ (Simpson & Tuson, 2003: 25) or ‘*critical incidents*’ (Cohen, Manion, & Morrison, 2011: 464).

The concept of critical incidents is defined and operationalised differently by various researchers (Spencer-Oatey, 2013). Flanagan (1954) originally developed the ‘Critical Incident Technique’ to identify important incidents whose “consequences are sufficiently definite to leave little doubt concerning its effects” (p.257). This definition of ‘critical incident’ is sometimes understood using the ‘Road to Damascus’ idiom, which describes an important turning-point in an individual’s life where a great change takes place. Norman et al. (1992) suggest that ‘revelatory incident’ would be a better turn of phrase. This conceptualisation of ‘critical incidents’ could, for example, be used in a retrospective study which asks successful scientists to recall the most important moment that determined their career direction and success.

Others have, however, interpreted the use of ‘critical incident’ slightly differently; where the ‘criticality’ is determined by the importance in helping researchers’ understanding, rather than the importance to the individual(s) being investigated. Cohen, Manion, & Morrison (2018) write:

“...critical incidents ... are crucial to the understanding of the case. ... sometimes a single event might occur which sheds a hugely important insight into a person or situation” (p.384)

In this study, ‘critical incidents’ are operationalised in this manner. Critical incidents recorded during observation in the WROL were events which offered important insight, warranting greater detail and recording than other events. The critical incident data collected were those moments which are necessary to advance our understanding of the workings of the WROL.

The use of a schedule for observation is not infallible but helps increase objectivity during observation. Instead of deciding spontaneously, in the field, which events are significant thought is given to how data is collected and aids consideration of which potential instances may be pertinent. Observation schedules also help prevent observation fatigue because the researchers are required to observe selectively, rather than attempting to record everything.

Although observation schedules were used in this research, it must also be noted that they are not so restrictive that there was inadequate scope for additional impromptu records.

3.2.6. Initial observation using the PAAI

Observation in the WROL began during the 2017/18 academic year. The focus was initially on what students were learning during practical science activities. The rationale for focussing on science learning was twofold; firstly, the WROL's specialist remit was to enable students to complete practical work. Secondly, I, as the principal investigator have a background as a qualified schoolteacher. Data collection, at this point, was guided by Millar's (2009) Practical Activity Analysis Inventory (PAAI). It is a tool designed to allow researchers and practitioners to understand three key things: 1) what learning outcomes the practical activity aims to achieve, 2) whether these are achieved and 3) *how* the practical might achieve the aims. The PAAI allows for a very structured observation. Systematic observation of the elements surrounding the practical activity uses a combination of event sampling and rating scales (Cohen, Manion, & Morrison, 2011: 462) to produce numerical data and the frequency of events.

In total, 41 sessions (~205 hours) were observed using the PAAI. These observations included *all* school visits to the WROL, not just the case-study partner school. Results from these observations are presented in section 6.1.

However, as data analysis for Research Question One began, it became apparent the outcomes desired by the teachers visiting the WROL extended beyond the information captured by the PAAI. As a tool developed largely for *classroom learning* the PAAI's focus was on cognitive outcomes and skills acquisition. Teachers, who visit the WROL with their students, largely rejected formal conceptual learning as the primary outcome. They wanted their students to learn about university life and other elements of the science community (discussed in chapter 4), dimensions of science education which the PAAI was never designed to capture.

3.2.7. Observation using science capital schedule

Although the data collected using the PAAI was informative (section 6.1) because of restrictive nature of its focus, it was decided that a broader focus during fieldwork would be required to capture elements of the work occurring in the WROL faithfully. These considerations related to dimensions of science capital beyond conceptual learning. A new observation schedule was developed to focus the attention on the science capital dimensions originally described by Archer, et al. (2015) and the pedagogical principles found in Godec et al.'s (2017) science capital teaching approach.

The development of the observation schedule began with Archer, et al.'s (2015) eight dimensions of science capital:

- Scientific literacy

- Science-related attitudes, values and dispositions
- Knowledge about the transferability of science
- Science media consumption
- Participation in out-of-school science learning contexts
- Family science skills, knowledge and qualifications
- Knowing people in science-related roles
- Talking about science in everyday life

Consideration was given to *how* the WROL may help build each dimension of science capital for the visiting students. For example, ‘science media consumption’ may be encouraged in the WROL by showing students new science-related media, or alternatively demonstrate to students how their existing media consumption is related to science. Subsequently 15 potential practices which might be used in the WROL to build science capital were determined:

- Delivering content from the curriculum
- Developing skills from the curriculum
- Showing the nature of science/ How science works
- Non-curricular science literacy
- Show the applicability of science in everyday life and ‘broadening what counts’
- Building positive attitudes towards science
- Giving students the opportunity to embody/ imitate scientific dispositions
- Showing what scientific jobs there are
- Showing how to get scientific jobs (knowledge about the extrinsic value and transferability of science qualifications)
- Showing how science can be relevant to non-scientific jobs
- Highlighting new science media for students and valuing existing media-consumption as scientific
- Signposting other out-of-school science learning opportunities
- Linking existing (familial) knowledge/practices to science.
- Mentor and academic leader introduction and interaction
- Encouraging students to talk about science in all contexts

Observation of these practices might be considered what Cohen, Manion & Morrison (2011: 464) describes as ‘critical incidents’. The observation schedule was developed, allocating space for noting occasions when any of instances where these pedagogical practices were observed. Equally, the schedule allowed for the observation and recording of instances where these were *not* observed. For example, if academic leaders missed an opportunity to

signpost other out-of-school science learning experiences, this could be recorded in the field notes in a different colour (appendix V).

To test the external reliability of the new observation schedule, peer observation was undertaken with Imperial College's Outreach Evaluation & Impact Coordinator. The session observed together was discussed in depth and observation notes compared. Many of the critical instances were noted by both observers and comments aligned on the interpretation of these events. Where the discussion diverged was on critical instances not observed by both parties. This divergence was not a result of the observation schedule, but instead that both observers circulated around the WROL and were not always studying the same group of students or interactions.

Detailed field notes were taken during each of the sessions with the partner school, guided by the new science capital observation schedule. Notes were made using a combination of printed observation schedules and digital versions using a laptop or tablet. The initial paper form was generally too small to make comprehensive notes and a digital medium allowed for greater flexibility in note taking, as the table size could be adjusted. Using a laptop also allowed for verbatim notes of conversations to be taken.

All sessions where the partner school visited the WROL during the 2018/19 academic year were observed using the new framework; in total, 26 sessions were observed, 22 with the partner school and four with primary schools (the partner school 'donates' some of its allocated WROL days to their feeder primary schools). In total, this represents approximately 130 hours of observation using the science capital schedule and associated fieldnotes.

Table 2: WROL & Partner school sessions 2018/19

	Date	Year group (Age)	Science domain	Session topic(s) or practical activity(ies)
1	5/11/18	13 (17/18)	Biology	Biology carousel: Blood type testing, garlic root tip squash (mitosis), cuttlefish dissection
2	13/11/18	7 (11/12)	Physics/Chemistry	‘Science busking’ workshop
3	15/11/18	7 (11/12)	Physics/Chemistry	‘Science busking’ workshop
4	21/11/19	13 (17/18)	Physics	Diodes & breadboard circuits
5	28/1/19	12 (16/17)	Biology	Genetic Modification and Biotechnology- DNA Replication
6	31/1/19	13 (17/18)	Astronomy (BTEC)	Lenses & optics,
7	5/2/19	12 (16/17)	Chemistry	Enthalpy change, Hess’ law & Calorimetry
8	14/2/19	12 (16/17)	Physics	Ideal gas law, standing waves, speed of sound
9	25/3/19	8 (12/13)	Physics/ engineering	Newspaper bridge engineering
10	28/3/19	9 (13/14)	Physics/ astronomy	Lenses & refraction, spectrosopes, planispheres
11	29/3/19	13 (17/18)	Forensic science	Crime scene investigation (fingerprinting, blood type testing, blood spatter analysis DNA analysis, chromatography)
12	30/4/19	10 (14/15)	Physics	Physics carousel: Wave Tank, Weights & Forces, Speed of Sound, Radiation
13	2/5/19	10 (14/15)	Physics	Physics carousel: Wave Tank, Weights & Forces, Speed of Sound, Radiation
14	7/5/19	10 (14/15)	Physics	Physics carousel: Wave Tank, Weights & Forces, Speed of Sound, Radiation
15	8/5/19	10 (14/15)	Physics	Physics carousel: Wave Tank, Weights & Forces, Speed of Sound, Radiation
16	14/5/19	10 (14/15)	Physics	Physics carousel: Wave Tank, Weights & Forces, Speed of Sound, Radiation
17	16/5/19	10 (14/15)	Physics	Physics carousel: Wave Tank, Weights & Forces, Speed of Sound, Radiation

18	17/5/19	10 (14/15)	Physics	Physics carousel: Wave Tank, Weights & Forces, Speed of Sound, Radiation
19	20/5/19	7 (11/12)	Physics	Space, aerodynamics and rocket engineering
20	10/6/19	12 (16/17)	Environmental systems and societies	Ecology, trophic levels & biomass
21	11/6/19	10 (14/15)	Physics	Space, light (refraction, reflection, lenses), spectroscopy
22	13/6/19	8 (12/13)	Physics/ engineering	Newspaper bridge engineering
23	18/6/19 †	5 (9/10)	Primary science	Properties of Light and States of Matter
24	19/6/19 †	6 (10/11)	Primary science	Electromagnetic spectrum and States of Matter
25	26/6/19 †	5 (9/10)	Primary science	pH, acids & alkalis and States of Matter
26	27/6/19 †	5 (9/10)	Primary science	pH Indicators and States of Matter

† Denotes days which the partner school allocates to their feeder primary schools.

Representative classes from all years from the partner school visit the WROL, apart from year 11. Some groups visited more than once, for example the Year 13 BTEC group who had two practical sessions which coincided with two of the units for their qualification: astronomy and forensic science. Year 10 was the only year group in which every student was given the opportunity for a visit. Students in other year groups had to be selected by the teachers to be allowed to attend the WROL.

To prevent selective memory, field notes were always completed on the day of observation. Sessions in the WROL typically conclude at 16.00 allowing ample time to consolidate written data.

3.2.8. Observation data analysis

Qualitative data collected during observation is typically analysed using inductive logic; through a series of iterative coding and re-coding steps new theory is expected to emerge from the data (Corbin & Strauss, 1990). For example, in research which has been undertaken in the WROL previously, Moss (2015) used an iterative grounded theory approach. Advocates of a ‘hard’ grounded theory approach suggest adopting a ‘theoretically agnostic’ view, which warns against using existing theory during analysis, lest it biases the formation of new

knowledge. Because the science capital observation schedule was created using existing concepts, this ‘theoretical agnostic’ approach was impossible. Therefore, in keeping with the realist evaluation approach of this research (Pawson & Tilley, 1997), abductive thematic analysis (Braun & Clarke, 2006) was used instead.

As with the interview data (section 3.2.2, above), analysis of the observation data actually began *during* the data collection process. The use of the science capital observation schedule enabled critical instances to be instantly coded using the concepts determined from the science capital literature.

The critical instances which occurred most frequently were considered to be ‘demi-regularities’ (Fletcher, 2016) where an event occurred with such regularity that it became reasonable to predict its repeated occurrence within the WROL. For example, mentors were frequently seen teaching students how to access science in HE institutions. These demi-regularities were considered thematically significant practices in the WROL and therefore became key themes. Following Braun & Clarke's (2006) approach to thematic analysis, the nascent themes were reviewed for commonalities and expanded upon across several iterative passes through the data. Subsequently, although the observation schedule initially suggested initial themes to the data, theoretical re-description re-grouped these clusters, according to salient connections between findings and presented the most significant themes. For example, observation noted that science media was regularly used in the WROL and became a key theme, but analysis showed the use of media in the WROL could be split two way; instances where the academic leaders suggested the media reference or when students were the ones to introduce their cultural references.

The results and discussion from the analysis of the observation data are in section 6.2. Again, it must be highlighted that (unless otherwise noted) Braun & Clarke's (2006) advice to present “*particularly vivid examples, or extracts which capture the essence of the point*” is followed. Although perhaps only one or two vignettes for each theme are described in section 6.2 they are representative of instances that are common occurrences in the WROL.

3.3. Ethical considerations

This project was planned and conducted initially with reference to the British Educational Research Association's 2011 guidelines for ethical research (BERA, 2011), and subsequently guided by BERA's updated 2018 guidelines (BERA, 2018). The project plan was also reviewed by Imperial College's Joint Research Compliance Office (JRCO) before being referred to Imperial College Research Ethics Committee (ICREC) for external validation. Three potential issues were identified with this research:

- The use of children and their capacity to consent to participation
- Anonymity and confidentiality of participants
- Potential negative effect on teaching and learning due to researchers' presence in the lab

Each of which required discussion and some mitigating action before data collection, to ensure ethical evaluation of the WROL.

Informed consent is considered a cornerstone of human autonomy and therefore is required for ethical research. To give informed consent, a participant must be provided with enough information and have the capacity to make a meaningful decision to agree to take part. It is commonly assumed that vulnerable groups (e.g. children or those with learning disabilities) are considered to be less able to evaluate any risks of participating in research adequately and cannot consent to participate. This does not preclude research into vulnerable groups, where instead proxy consent is sometimes used (Shuster, 1997; Wiles et al., 2005). Informed parents or caregivers are considered to have a vulnerable person's best interests in mind and are may be deemed competent enough to consent on their behalf.

Coyne (2010) highlights several issues with proxy consent. Blanket proxy consent fails to recognise a child's capacities, removes any agency they have in their own right and disenfranchises them from research processes. This is all contrary to the United Nations Convention on the Rights of the Child (United Nations, 1989) which advocates the right of every child to self-determination, dignity, respect and the right to make informed decisions. Furthermore, and perhaps most importantly, dissent by a child should be considered binding, positive proxy consent cannot override the wishes of a child to not participate in research (Broome, 1999)

Researchers find that children are capable of providing valid consent to research participation and medical procedures (Coyne, 2010). For example, Alderson, Sutcliffe, & Curtis (2006) report that children as young as four, begin to understand the principles of controlling diabetes, making informed and 'wise' decisions in their own best interests. Levine (1995) suggests that children should be able to authorise participation, for anonymised surveys and other risk free research, without the permission of their parents or guardians. Broome (1999) points out that adolescents are considered to be cognitively capable of a level of comprehension and have sufficient autonomy to provide informed consent where low risks are involved.

Considering the ambiguity of the literature surrounding research consent and changes in legislation (the impending introduction of GDPR) occurring at the same time as this project

was being planned (Macenaite & Kosta, 2017), it was appropriate to use a hybrid approach, consent being required from students, parents/caregivers and gatekeepers who control access to potential participants (Seidman, 2006: 45). The headteacher of the partner school was asked to approve that their school and students were included in this research. Parents and carers of students visiting the WROL were then given the opportunity to refuse participation. The WROL staff were asked for their assent to observing the session they were leading. The teachers accompanying students from the partner school were consulted when asking students to participate in interviews. Finally, the students themselves were asked to opt-in to this project. Overall, there were five opportunities for parties, with a duty of care, to scrutinise the students' role in this research and potentially prevent their participation. This is depicted as a logic tree in *Figure 4*, below.

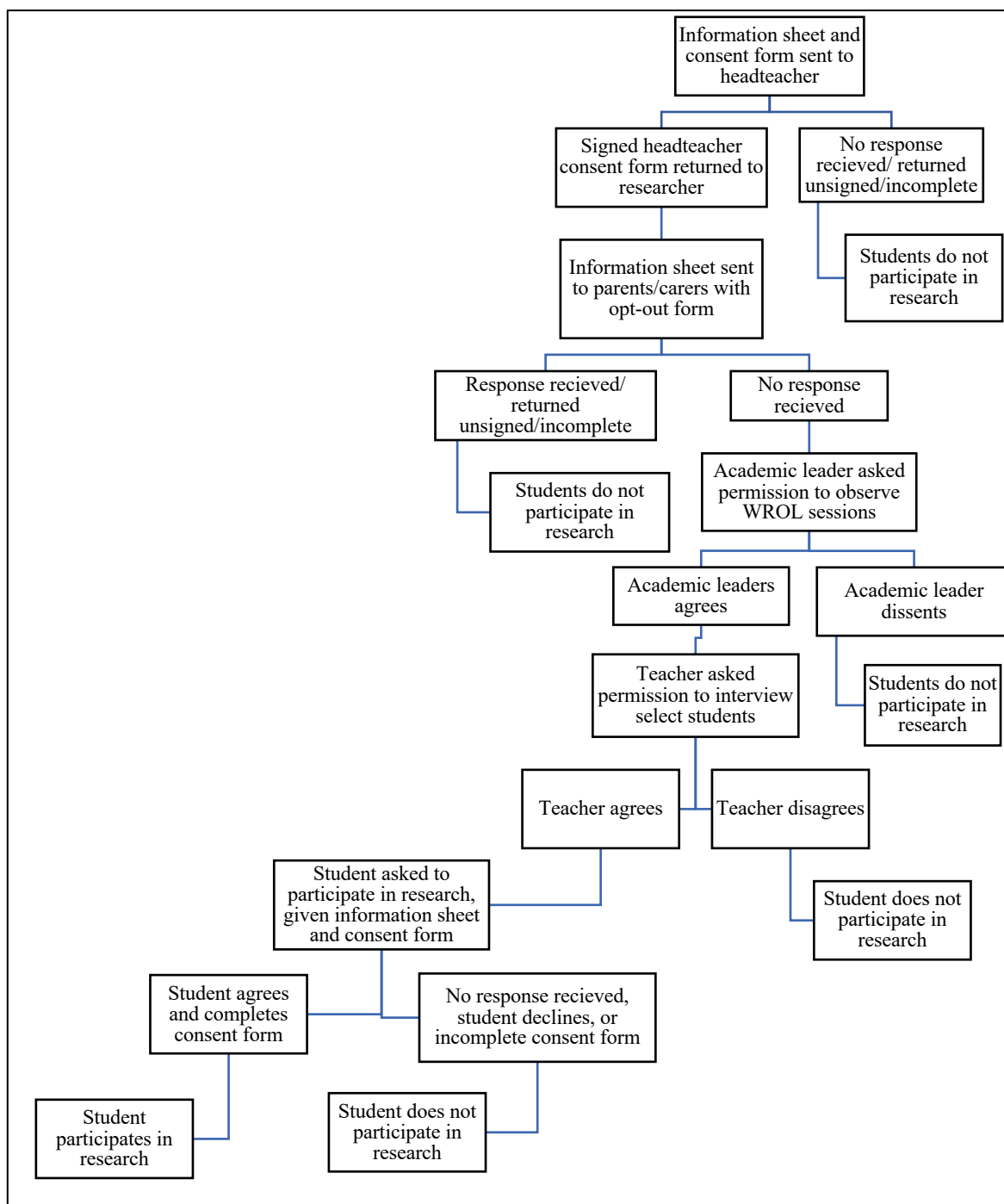


Figure 4: Consent cascade

Although consent was sought from several parties before data collection, these discreet events do not safeguard continued consent. Processual consent is advocated by Rosenblatt (1995); throughout the data collection process researchers should periodically check that participants are still willing to participate, typically by a verbal prompt: “*You don’t have to answer this question if you don’t want to*”, “*Are you happy to continue with the interview?*”. Processual consent was employed in this study and all participants were able to withdraw participation, without giving a reason.

Careful consideration was also given to the level of detail provided on the consent forms. Providing inadequate information to gatekeepers or potential participants risks misleading them and thereby coercing participation by omission. However, although ethics boards insist on the use of consent forms and often stipulate inclusion of certain information, presenting potential participants with too much information is also problematic. The presentation of a document containing Terms and Conditions written in ‘legalese’ may be scrolled to the end and a participant may accept what is written without proper attention. Douglas, McGorray, & Ewell (2021) found that the majority of participants could not recall a deliberately unusual sentence (“*Some researchers wear yellow pants.*”) placed in various locations in a consent form. Finally, some have argued that it is impossible to give full information before the research begins, as the research process may take unexpected directions, particularly in qualitative research (Larossa, Bennett & Gelles, 1981). Considering these points, a pragmatic level of information was deemed appropriate. Information sheets and consent forms were written in plain language (Green et al., 2003), outlining the research project, informing participants and gatekeepers of their rights and highlighting any possible negative impacts participation might lead to. Participants (and gatekeepers) were also afforded the opportunity to ask further questions. Exemplar information forms and blank consent forms are presented in Appendices V and VI.

Some concerns were raised as to the effect that research would have on the teaching and learning occurring in the WROL and whether a researcher’s presence would be a disruption. While this is not strictly an ethnographic project, ethnographic researchers have long considered the impact their presence has on the systems they study (O’Reilly, 2012); critics might suggest researchers will alter outcomes, but proponents would argue that the closeness to the systems under investigation allow a greater depth of understanding. As explained in section 3.2.5 a ‘participant-as-observer’ (Gold, 1958) role was taken during observation, helping mitigate any negative effect of my presence. Firstly, efforts were made to avoid being intrusive, academic leaders were always asked from where observation might best be made (perhaps from either the back of the room or a table without students). Circulation during the session meant that no particular group of students or mentors were over-burdened with the presence of a researcher for too long. Rapport developed with various stakeholders (mentioned above, section 3.2.1) helped further safeguard against my research being seen as a detriment. Interviews with students were also held during lunch, rather than during WROL sessions. Finally, visiting students often treated me as a mentor, asking questions about the

practical or about life at university, conversations I was happy to oblige with in the pursuit of mitigating any negative effect my presence may have had and further aiding rapport.

While the initial plan submitted to ICREC proposed that all participants would be anonymised, the committee was concerned about the study collecting potentially identifiable or sensitive data from students. The science capital questionnaire originally asked students their racial/ethnic origin and their parent's occupations. While the racial and classed dimensions of science participation is of significant interest for WP (section 0), ICREC considered the collection of this data to be inappropriate and questionnaire items relating to ethnicity and parental occupation were subsequently removed. To further safeguard the anonymity of participants, the questionnaire data was anonymised at point of collection. Interviews were also anonymised at the first possible opportunity, any identifiable information in the interviews was omitted in the transcripts and the transcripts were disaggregated from the raw audio files in NVivo. BERA (2018) consider that, as well as individual participants, institutions are entitled to privacy and should be afforded anonymity and confidentiality. For this reason, the partner school has deliberately not been identified in this thesis and specific details, which might otherwise be useful or interesting to the reader, but would make the school identifiable, have been deliberately omitted.

Considering the safeguards made to conduct ethical research, ICREC approved the study (ICREC reference:17IC4316) (appendix VIII)

3.4. Positionality and a reflexive turn

To make sense of their world, an individual relies on thoughts, processes and knowledge informed by the myriad of experiences from their own life. However, when conducting social research, a researcher is almost inevitably part of the social phenomena being explored. Therefore, complete detachment from the social system they are investigating is impossible for a social researcher. Malterud (2001) argues the researcher's background can influence an investigation in six ways: the topics chosen, the perspectives taken, the methods employed, the findings considered, the framing of arguments and finally the means through which conclusions are communicated. The relationship between a researcher's identity and research can therefore raise questions of emotional connection, bias and subjectivity. For example, Oakley (1981) problematises the concept of 'an interview', with regard to gender. From a feminist perspective, she argues that methodology textbooks construct interviews as a masculine practice and argues that, even when a woman interviews another, the interviewee is depersonalised and objectified. Similarly, Chadderton (2012) uses critical race theory to

problematised white researchers undertaking research into race and social justice. Thus, a researcher's position in relation to the research can be problematic.

To counter this, Dean (2017) suggests that researchers should “*account for our humanness*” (p.1). However, this can be challenging as it exposes a researcher's origins, biography, locality and ‘intellectual bias’ and brings to the foreground potential accusations of partiality, or even accusations of illegitimacy (Blackman, 2007). Despite this, Dean (2017) goes on to argue that “*reflexivity offers us a route out*” (p.1). Reflexivity is the explicit evaluation of self, including examination of one's own beliefs, judgments and practices and how these may have influenced the research process. Indeed, Malterud (2001) agrees that acknowledging a researcher's positioning should not weaken research: “*Preconceptions are not the same as bias, unless the researcher fails to mention them.*”(p. 484). Therefore, explicit reflexive disclosure enables practitioners to acknowledge their position and this moves from a potential criticism to becoming a valuable source of knowledge.

Beyond a general commitment to reflexivity (Price & Martin, 2018) critical realism does not prescribe any methods to actually achieve reflexivity. However, Malterud (2001) suggests two techniques: Firstly, establishing ‘metapositions’. This is achieved by creating distance from a study setting. This chapter has already described techniques for maintaining detachment from the WROL (e.g. consideration of ‘over-rapport’ in interviews, or the use of schedules for observation). Secondly, researchers should share preconceptions. To achieve this, I present a transparent and critical analysis of my identity and positioning with regard to this research to acknowledge my preconceptions below.

I am a white male, born and raised in a small, picturesque village in Cambridgeshire. My father was a self-employed optician (now retired), and my mother is a housewife (both attended university). I have two siblings and, during my childhood, lived in a four-bedroom semi-detached house. I performed well academically in my local state primary and secondary schools, and then also at one of the country's highest performing state sixth forms (Hills Road Sixth Form College). I have a university education, firstly studying Environmental Science at the University of East Anglia (UEA), which allowed me to work briefly as an aquatic ecotoxicologist. Consequently, I completed my PGCE at the University of Cambridge and worked as a science teacher, also in Cambridge. Despite some of the traditional indicators of privilege, it may be pertinent to acknowledge I am also a second-generation immigrant; whose grandparents came to the UK from Latvia after World War Two. This may have also informed my general sense of social justice, where the concepts of ‘opportunity’ and social assimilation are important in my family.

I would suggest that my background and personal characteristics indicate a middle-class upbringing, with the associated qualifications, knowledge, ways of thinking and behaviours. In retrospect, I concede I was a rather ‘passive observant’ of my own schooling. Without any significant barriers, my family and immediate social structures allowed me to ‘succeed’ with relative ease, rather than any intentional and concerted effort by me. My progression from school, to sixth form, to university seemed very ‘natural’ and expected. My thinking throughout those stages, regarding formal education, could perhaps be best described as ‘naïve’, where I thought that the life-chances for all students in the UK were the same, because of state education, anyone who tried hard enough could receive their GCSEs, move onto their state funded A levels etc.

I did not actively or critically consider my own privileged upbringing until my teacher training. During my teacher training I was given two ‘lower’ sets to work with. The experiences of teaching these two classes were starkly different to my own experiences as a student in the top sets (I was in the top set for almost all my subjects, apart from P.E.). The schools had identified and created sets of particularly low attaining students, with the rationale of giving them more concentrated teacher intervention (both of these classes had only ~6 students). Despite these efforts, these students were often ‘disengaged’; both from their education and sometimes from society. With some introspection, I understood why they were disengaged; they were identified early in their education as ‘low-ability’. They were physically separated from their contemporaries, and not so subtly labelled as ‘different’. These students often had low self-concept of their own abilities, difficult home-lives and would have significant difficulty in exams. I thoroughly enjoyed my time working with these students, they gave me a great deal to think about regarding my own pedagogy. I reasoned that teaching top-set classes might be quite ‘forgiving’ – that these students have a lot of advantages and privilege and they will likely do well in their exams, perhaps regardless of the teacher. In contrast, the bottom set students required deep thought for their lessons to be effective. These experiences were integral to my thinking regarding social determinism and provides my personal rationale for pursuing this research project. I now recognise my own academic attainment is likely a reflection of my upbringing or social class, rather than my innate ‘ability’. I understand that replicating my experiences of school will likely not work for students from different backgrounds and this motivates my pursuit of a ‘different’ and better pedagogical approaches.

My background is different to that of the participants of this in many ways. While I am reluctant to homogenize them, the fact remains that the partner school the WROL works with has been identified deliberately as it serves a high proportion of lower socio-economic status

students (as measured using several metrics, including % pupil premium). The school also broadly serves a racially diverse cohort of students, with a significant portion of black students. I recognise and struggle with the sense of irony of ‘me’ researching this student population. It has previously been suggested, for example, that it is better for women to interview other women (Finch, 1984). Chadderton (2012) further questions white researchers conducting research into race. Because I come from a different background to the study participants and likely experienced a radically different upbringing, it is pertinent to ask, whether *I* can truly understand the students I am researching. Will I misinterpret or misrepresent interviewees’ perspectives? Will I overlook important elements during observation in the WROL because I am ‘blind’ to their significance to certain students? Godec (2017) considers the same issues in her study and tentatively explores matching researcher identity to research participant as a means to overcome this problem. However, ultimately concludes: “*given the complexity of social identities ... it would be impossible to think that researchers and participants could be matched in a way that does not exclude any aspects of their identity/positions*” (p.81). It is hoped that my acknowledgment of my concerns here, in the pursuit of reflexivity, may go some way to ameliorate these issues.

At this stage it may also be pertinent to acknowledge my preconceived notions of outreach and recognise my research affiliation. Both of these may lend themselves to accusations of biasing my perspective. It would be fair to suggest that I am convinced by the benefits of science outreach, I enjoy teaching the subject and want to share this with students. I believe that the WROL and similar programmes have a distinct role to play in the informal science education sector. Furthermore, I am an Imperial College student, investigating Imperial College’s outreach space. One of my supervisors is the founder and patron of the WROL, another is the Head of Outreach at Imperial. It would therefore be reasonable to assume that my research would treat the WROL favourably. Indeed, the outreach sector has fallen into an “*overadvocacy trap*” (Campbell, 1979: 84) where many evaluators have exaggerated claims of programme success because they want them to succeed. However, I suggest that my awareness of these preconceptions and pressures goes some way to counter any bias. Regardless of my institutional or personal affiliation to outreach, I am also committed and convinced of the benefit of ‘critical’ approach to ‘pedagogy’; sharing negative, or negligible results means that educational interventions can be improved. Intentionally looking for positive results does nothing to further our understanding of the informal science outreach sector.

Overall, I would broadly conceptualise my background as moving from ‘doing science’, to ‘teaching science’ and now ‘researching social justice in science education’. This trajectory

brings ‘baggage’ and the intention of the open discussion above is intended to pro-actively present and critique my preconceptions and potential biases.

Chapter three summary

In this chapter, the methods used to evaluate the WROL were presented. Guided by a realist philosophy, a mixed methods single case research approach was justified and described. The methods applied to evaluate the WROL were discussed and several potential criticisms were addressed. Ethical issues with the study were also described, as well as the techniques used to mitigate any ethical concerns of the study. Finally, my own position to this research was described, and a reflexive exploration of this was used to critically analyse my preconceptions and biases.

The following three chapters present the results obtained using the research project described above, starting with results from the interviews with teachers and academic leaders.

4. Chapter four: Research question one- What are the desired outcomes of the Wohl Reach Out lab?

The success of school/university partnership programmes relies on several factors, but perhaps the most important is an alignment of shared goals of stakeholders (Kim et al., 2013). This chapter presents data gathered from the interviews with two key groups that interact in the WROL: the visiting teachers and the academic leaders running the sessions. The intention here was to distinguish what each group wanted to gain from work in the WROL and to determine whether opinions of the two groups were in agreement.

The interviews conducted (as described in section 3.2.1) were semi-structured, with stakeholders being questioned on pre-determined areas of interest, but also with the freedom to cover topics that interviewees thought important. Interviews were transcribed verbatim in NVivo. The transcripts were thematically analysed (Braun & Clarke, 2006). Initial codes were derived from the literature, with the contingency of adding further codes during the coding process if other salient concepts emerged. The coding framework was applied to both the academic leader and teacher interview transcripts. The two data-streams were then combined, codes were clustered together to produce themes that were discussed across both stakeholder groups (Appendix IX). While these two groups had distinct, and sometimes contrary perspectives, by combining the two datasets, the iterative process of refining significant themes allowed greater understanding of the similarities and differences. For example, as the teachers would often discuss the limitations of practical equipment in their labs, and some academic leaders recalled the same experiences in their school (and thus formed part of their motivation for working in the WROL) it made sense that these would align conceptually. Similarly, where some academic leaders focussed on academic outcomes and no teachers did, it was germane to compare the transcript sections from both groups concurrently to explore those differences.

This chapter is divided into three sections, reflecting the themes commonly discussed by stakeholders. Firstly, stakeholder's criticism of practical science in school and the expectation that the WROL provides practical experiences for students with the equipment available and the time needed. Secondly, the rebuff of the singular focus to curricular outcomes in school and importance of students receiving non-curricular, or science enrichment experiences in the WROL. Finally, the lack of opportunity for students to interact with scientists in their lives and therefore the value of student-mentor conversation in the WROL in challenging science stereotypes and also giving practical advice. Unless stated otherwise, the

quotations presented are indicative of views frequently expressed and used to exemplify sentiments commonly shared interviewees.

4.1. Experience of practical science

Interviewees commonly discussed their desire for students to complete practical science activities when visiting the WROL. As section 1.2.1 of this thesis described, practical science is a key feature of the UK science education system. However, school practice has several shortcomings. Interviewees cited two key factors that limited the provision of practical work in school: equipment and time. Each of these are provided in the WROL.

4.1.1. Science equipment in school and in the WROL

Suitable science equipment is vital to pupils' science education. Unfortunately, science teachers in this project frequently complained that practical activities in their lessons were limited by the lack of suitable equipment:

I think one of the biggest ones... is the idea that we just don't have a lot of the equipment... We just don't have a lot of the equipment, so we don't have as good a set of rails as you guys have for the mass times acceleration [experiment], we don't have the light gates, the temperature probes for specific heat capacity, they're always just not quite as in good shape.... (T8)

and

...with things like PCR and electrophoresis, we don't have the equipment, so we couldn't do it. (T7)

While the teachers often referred to specific pieces of kit or specialist practicals for A level/BTEC courses, the academic leaders spoke more broadly about their perception of science equipment in many schools (rather than specifically the partner school). One academic leader explained how a lack of equipment in schools can make it difficult for students to understand scientific phenomena:

Lots of students won't have the equipment or facilities within their own schools, to do different experiments, I think lots of concepts within physics are quite vague and until you see them happening, like the photoelectric effect, you can explain it as much as you want...but until you actually see it happening it's incredibly hard to believe it... and there are lots of things like that. (AL6)

The concern over science equipment was further linked to wider deficiency in the school environment. Another academic leader went on to suggest that schools serving disadvantaged groups not only lacked specialist kit, but also basic infrastructure:

When you get these WP [Widening Participation] groups, they tend to come from schools with not a lot of equipment, they're not used to this kind of environment, their poor desks are 200 years old. (AL11)

It must be noted that the particular partner school was relatively new, and the facilities were not as dilapidated as this quote may suggest. However, the interviewees' assertions were supported by previous research; schools in less affluent areas tended to be materially disadvantaged (Lupton, 2003). Indeed, evidence submitted to the House of Lords Science and Technology Committee's (2006) report showed that equipment is a common concern across the sector. Furthermore, The Wellcome Trust (2017) also found that students from more deprived background had less experience of frequent practical work. This may have related to the availability of equipment.

Following the criticism of science equipment in schools, interviewees often contrasted the provision in the WROL. Interviewees were keen to highlight that students visiting the WROL can see, handle and use specific science equipment that they would not have at school:

It's super important, and what we can celebrate from here [the WROL] is, there's so much cool equipment! (AL6)

and

[the WROL] doesn't really look like most science labs that you have in schools, it's far better equipped, it's a nice place to work, it has all the technology that usually works [referencing an earlier comment about school technology not working] (AL11)

One academic leader added a further issue by comparing the provision of equipment in private school. They suggested that students from these two school contexts would experience the WROL differently:

...if you get kids from private schools... they generally have access to more of this sort of stuff... not so different from what they might see in school, they often have labs that look a bit like this [the WROL], private schools are set

up very nicely, they've got lots of equipment, that sort of stuff... to me it feels like WP kids get a bit more out of it than other students may do. (AL11)

This academic leader raised an important point regarding the targeting of interventions to those students from under-resourced communities, such as the partner school.

Overall, the interviewees' comments on equipment were reminiscent of Braund and Reiss' (2006) case for informal learning; they argue that an informal learning environment can provide access to rare or 'big' science (science requiring specialist or large equipment). The evidence from the interviews in this study support Braund and Reiss' assertion.

However, praise for provision within the WROL was not limited to specialist scientific equipment. The more 'mundane' science objects were also deemed important, e.g.: *'The children, when they put on the labcoats and go into the lab, they know that it's now professional time'* (T7). Here the teacher highlighted how the students recognised the professionalism associated with labcoats, and their symbolic value (Bourdieu, 1986). Therefore, it is not just objects with high material value or scarcity that are important in the WROL, but those with high symbolic scientific value. The symbolism associated with labcoats has been well recognised (Gillon, 2000; Ruiz-Mallén et al., 2018; Veatch, 2002) but stakeholders in this study suggested that goggles and the lockers (in the shape of the periodic table) were important elements of a WROL visit. Calabrese Barton et al. (2013) describe how 'identity artifacts' are materials or tools which help students form connections between their own identities and science. Students in the WROL using scientific equipment (no matter how commonplace) may position themselves mentally within science and develop their own science identities.

Overall, the opportunity to use equipment in the WROL was seen as an important outcome from the visit by the stakeholders interviewed.

4.1.2. Time for practical science in school and the WROL

Teachers felt in school there was lack of adequate time and that short lesson periods meant that practicals were completed hastily:

...there's the time element, you need more than an hour or hour and a half lesson to do them [practicals] properly... I hate that, I hate a practical being rushed and hate it not being done properly. (T3)

Another teacher went on to explain their struggle in deciding how to allocate lesson time, either for practical work or for exam material:

...there are just so many demands made on teachers... when I'm looking at KS3, which you would think would be a point where there would be time to explore things and I'm expected to be able to do a practical and all of the theory and do all of the stuff that is supposed to go along with the practical like predictions, methodology, conclusions etc. in 50 minutes, with Year 9 students and that's just not happening and so I haven't done a practical lesson with my Year 9s in a very long time... there is a limit to what I can realistically do. (T10)

This teacher then stated that theoretical content is prioritised because this is how students are tested and the teachers' performance is measured:

...if they [the students] don't answer the questions in the tests, that's a more obvious bad reflection on me than [if] they haven't done a particular practical... I have this conflict [between the test and the practicals]. (T10)

These comments were reminiscent of both Nott & Wellington's (1999) and Hodson's (1992) views that “...the assessment tail is definitely wagging the science dog” (p.17) and that “It is inevitable that both teachers and students will put most value on that which is examined and for which academic credit can be gained.” (p.116). The WROL therefore represented an opportunity to dedicate time towards practical science, without time-pressure to focus on assessment.

Another teacher was candid in admitting that time constraints in school limited the ability to plan lessons:

Because [as a teacher] your time is so limited, you don't have time to prepare resources or plan exciting lessons as much as you like. You do your best, but I'm gonna straight-up honestly tell you I don't think my lessons are as great, as well-planned, as I would love to every single time because of those limitations (T9)

This limitation was in contrast to time provided in the WROL for students to complete practical activities. Two academic leaders recognised the advantage they had over schoolteachers in being able to extend practical exploration during the length of a WROL visit:

Sometimes at school, I think that's [exploration of practical work] lost because there isn't the time. Here, [in the WROL] we've got eight hours.
(AL12)

and

In schools you might only have a 50 minute lesson and if you're trying to do an investigation in that 50 minutes, by the times you've got all the kit out and set up it all up, you don't have very long to actually to do stuff. So, we tend to do sessions that are a bit longer, two hours sometimes three and it enables them [students] to look at things a little more deeply than they would at school. (AL11)

Another benefit of the extended length of time the WROL was supplemented by the staff: student ratio. By having so many mentors, the students each had opportunity to discuss their practical work in detail, whereas in school they would not. One teacher lamented that they didn't get a chance to speak to each student every lesson:

[at the WROL] you get time to speak to the students and have a little chat to them. As a teacher I wouldn't be able to do that, if you're in a class and you're teaching the class of 30 students you don't get time to talk to them individually (T7)

The time available for practical activities in the WROL was a significant theme in the interviews and thought a key element of the WROL experience. This is important as practical science is often seen as an intrinsic part of science education (section 1.2.1). Yet, teaching students 'how science works' in the classroom has previously been highlighted as an area of particular difficulty (Claussen & Osborne, 2013; Millar & Osborne, 1998). Hodson (1998) argued practical science is surrounded by the following misconceptions that are commonly distributed in science education, either consciously or unconsciously:

- "1. Observation provides direct and reliable access to secure knowledge.*
- 2. Science starts with observation.*
- 3. Science proceeds via induction.*
- 4. Experiments are decisive.*
- 5. Science comprises discrete, generic processes.*
- 6. Scientific inquiry is a simple, algorithmic procedure.*
- 7. Science is a value-free activity.*

8. *The so-called 'scientific attitudes' are essential to the effective practice of science.*

9. *All scientists possess these attitudes.*" (p. 95)

The comments by stakeholders' in this study suggest that some of these common misconceptions may be challenged with the extended practicals in the WROL. Interviewees argued that, in school:

There is a level of doing experiments because they're part of the syllabus and they [students] have to do them...to tangibly demonstrate an aspect of content you are teaching and it's not so much about discovery as demonstration (T1)

This academic leader's comments align with point 4 above, that children and teachers are pushed toward producing decisive experiments that 'prove' well-established phenomena, students need results to analyse for coursework. If the experiment is not conclusive then it is problematic for both student and teacher. This does not reflect true practical science. Whereas, in the WROL misconceptions like these can be challenged. Another academic leader commented that practicals frequently go wrong in the WROL, but that it not an issue:

Everyone gets to see it [practical science] in action, do it, try it and it will go wrong, because practicals always go wrong but I think that's the point of it and that they [students] need to know that things go wrong and understand why things go wrong, to learn how to improve it (AL1)

Ultimately, "*it's more like research than school*" (AL2). Braund and Reiss (2006) concur, they suggest that one of the benefits of informal learning is that it can provide 'extended' practical experiences which, importantly, more closely reflect the real work of scientists. This, indeed, is what the interviewees in this study said that the WROL offers.

4.2. Non-curricular science experiences

Previous research in the WROL broadly categorised its various activities as either 'curriculum-based' or 'enrichment' programmes (Moss, 2015). In this study, interviewees wanted students to have enriching science experiences in the WROL, rather than curriculum-based effects.

Again, this desire was grounded in a criticism of school science. Teachers in the UK are accountable to their students achieving results in standardised national examinations, which creates a culture of 'performativity' (Clapham, 2016; Millar & Osborne, 1998; Nott & Wellington, 1999; Troman, 2000). Because of these pressures, it is almost inevitable that

teachers will put most effort towards “*that which is examined and for which academic credit can be gained*” (Hodson, 1992). Teachers in this study resented the performativity culture, not just in the partner school, but across the UK education system. Interviewees commonly criticised the pressures to focus all their teaching and learning efforts towards content in the curriculum:

...there is a danger within schools to focus on facts within the curriculum and that's how science ends up being perceived [by students] (T2)

The focus on the curriculum in schools was described by one teacher as hindering their ability to teach science in an authentic manner:

...because there is so much theory and content and the pressures on the A-level courses is very much based on learning and that can take away from the real... aspects of science that maybe get lost. (T6)

Equally, when referencing their own experience, academic leaders were critical of the rigidity of formal education relying on a focus on examination results:

the general problem that I find with British education is that everything tends to be formulaic and, whether it's practicals or written exams, you're taught to answer questions in a specific way and if you learn your method, you'll pass your exam whether or not you've understood the topic (AL1)

Another noted that students, like their teachers, also focussed their learning purely towards formally examined content:

A lot of students at A-level seem to just want to know what's on the syllabus, I often get asked [by students]: 'Do I need to know this?' (AL9)

These findings concur with previous research; Clapham (2016) found that: “*performativity had crept so far into the systems of their schools that it suppressed anything other than overtly exam-focused teaching.*” (p. 486). Despite the importance of curricular learning in enabling students to accrue valuable qualifications (institutionalised cultural capital), teachers in this study expressed a desire that their students should not be merely focussed on exams:

I don't think that all of the experiences that they [students] have should be linked to their exams, because they spend the vast majority of their times studying to work towards those exams. (T4)

Thematic analysis showed that teachers wanted the WROL sessions to avoid the normal pressures of formal schooling:

*...from my perspective [students] come to experiment, to find stuff out, **rather than just because it's part of their curriculum.** (T6)*

and

*I think that [visiting the WROL] really gets to the heart of science... **it's not really content.** (T2)*

Academic leaders were aware of the teachers' position and broadly supported them in rejecting curricular learning as the primary focus of the WROL:

What you tend to find is that the teachers that are in with the students, they are always quite happy for you to do that [not teach curricular topics] because they [teachers] can't. It's something that they [teachers] can't do... going off-piste and exploring these weird avenues...I think I find it quite hard to stick rigidly to the curriculum and I'm glad I'm in a position where I don't have to do that, and I'm allowed to [deviate from the curriculum]. (AL11)

One academic leader suggested they had a privileged position in being able to circumvent the 'normal' requirements of formal schooling:

I think we [academic leaders in the WROL] have a particular advantage, we're taking them [the students] out of their standard school system (AL1)

Another academic leader said they try to go beyond the school experience deliberately:

Ideally, a better, or a different experience to what they'll see in the classroom. A lot of the times, you'll do an experiment that hopefully they shouldn't have done in their own normal day-to-day school life (AL5)

Another academic leader said:

we don't want to just bring people [students] here and go through loads of theory for the whole day (AL7)

Interviewees therefore rejected curricular learning as an outcome and instead favoured experience from outside the curriculum. The rejection of curricular learning in the WROL was somewhat surprising. Science qualifications demonstrate the comprehension of curricular

knowledge of a student. The possession of a science qualification is equally necessary for progression to the next stage in our formal education system. Science qualifications carry other advantages in employability and often command some financial benefits (Greenwood, Harrison, & Vignoles, 2011). Science qualifications can therefore be considered important forms of institutionalised cultural capital (Bourdieu, 1986: 20). Nevertheless, both teachers and academic leaders rejected these advantages in their assessment of exposure to learning in the WROL. They tended to suggest that other *non-institutionalised* forms of science capital are significant in the WROL. It is these other forms of science capital, which are not captured in exam board syllabuses, that teachers and academic leaders allude to:

You [the WROL] do something that doesn't link directly to the curriculum but enhances their [students'] learning (T9)

and

...it was all those extra little bits, not the actual curriculum itself that inspired me that made me want to do this sort of stuff and made me want to pass it onto somebody else (AL11)

Teachers and academic leaders considered visiting the WROL as a learning experience, but not as one merely defined by the national curriculum or exam board syllabuses.

However, despite most interviewees rejecting curricular learning in the WROL, a few academic leaders were still evidently influenced by the school curriculum agenda. One academic leader said their primary aim in the WROL: “...is supporting their [students'] academic studies” and this is achieved “by very directly saying ‘we’re going to cover this content that’s in your curriculum’” (AL4). This academic leader’s approach to planning their WROL sessions acknowledged the pressures and primacy of exam outcomes rejected by teachers of WROL students.

Admittedly, this academic leader’s approach was anomalous. They directly pursued the curriculum, whereas other participants rejected this approach. Some other academic leaders, who wanted to go beyond the curriculum, remained concerned that their sessions didn’t cover enough formal academic content:

...there have definitely been some sessions that I've been involved with where I have thought 'ok are we actually teaching them enough science here? Are we doing just a bit too much of letting them [students] do this activity, which is fun ...but we're not really getting across to them... understanding a

scientific theory.... I think you do have to try and reinforce the theory as well as just saying 'lets have a play around with some kit' (AL7)

One academic leader remarked that the WROL was overly focussed on replicating ‘school science’:

I still think some of the sessions that run from here [the WROL] are a bit ... a bit heavily dependent on what the kids are currently doing in the school curriculum. That's my concern, that it becomes a glorified school science lab. (AL6)

This respondent went on to say later that ideally sessions “*would be research led, which Imperial is ace at, rather than 'here is some curriculum'”* (AL6). These comments show some tension remains between the pressures of curriculum and the desire to move beyond it to more enriching experience. When questioned about the balance, the academic leader estimated “*that about half of the sessions I teach stick strictly to the syllabus*” (AL9), suggesting that the other half does not stick to the syllabus. The influence of the school science curriculum in the WROL was still seen during observation element of this study, despite the majority of interviewees rejecting curricular learning; this is discussed further in Chapter 6.

The rejection of curricular outcomes may, in part, be due to concerns over the pedagogy used in the WROL:

The other thing is, they're [academic leaders] not teachers, they're not trained in pedagogy (T8)

Three teachers commented independently how the academic leaders often struggled to explain concepts clearly enough for their students and pitched academic content too highly:

...the presentation didn't make sense to the majority of students and that's because ... there was too much about this topic they don't know about. (T5)

...we find quite a lot when you get a PhD student presenting, they never break it down far enough...it's always been a case where it's not been broken down or pitched at the right level. (T3)

In the past we've had concerns over information being pitched a bit too high from the front, so when they did respiration last year with years 9 and 10 they [academic leader] started talking about the Krebs cycle, they start talking

about quite high level knowledge and we saw in the kids that they just started to switch off and it was hard to get back, we want to stretch them but don't want to go too far beyond and lose them. (T2)

Another teacher explained how the practical activity in the WROL did not align with the method prescribed by the exam board:

For example, the force [practical]...it's different to the curriculum we're teaching. The way its carried out [is different]... and so what they're learning here is something but doesn't actually coincide exactly [with] what we need to do in class in order for them to pass their exams (T1)

It must be noted that there are many ways to conduct 'required practicals'¹⁷ and exam boards stress that their suggested methods are not compulsory (AQA, 2018). However, this teacher thought that the WROL practical differed too much from the formal requirements.

These comments are supported by Bruce et al., (1997) who found that university students leading outreach activities often rely on their own experiences of education. Amateur educators, without pedagogical training, attempt to implement teaching methods they have experienced; they default to replicating didactic, textbook or lecture-based approaches because this is how they have been taught. However, this naïve pedagogy may not be the most effective approach to teaching in the WROL. As Gorard et al. (2006) notes: "*It may not be enough to 're-package' the current curriculum to make higher education more attractive to socially excluded groups.*" It is important that academic leaders do not simply attempt to recreate the classroom experience. One teacher summarises: "*we [the teachers] can teach the content*" (T2) with the insinuation that the WROL should focus on other outcomes via complementary teaching approaches.

4.3. Interacting with real scientists and university students

The interviewees also anticipated the benefits of the WROL where students interact with 'real' scientists and university students. One teacher said this was their primary motivation for coming onto campus with their class:

*They [students] get to, **number one**, meet different people, so they're not just being taught by the same teacher constantly (T7)*

¹⁷ 'Required practicals' are a series of practical activities stipulated in GCSE science specifications

Of course, simply being in the presence of scientists or undergraduate students is not enough to be a useful experience for visiting students. The interviewees thought these interactions were important for two reasons: firstly, challenging existing stereotypes about scientists and, secondly giving students information, advice and guidance on gaining access to higher or further education.

4.3.1. Challenging scientist stereotypes

It is well established that young people are aware of the social inequality within the science sector and they have a narrow view of who typically becomes scientists (Chambers, 1983; Miller et al., 2018; Ruiz-Mallén et al., 2018). This leads to students believing that science is ‘not for them’ (Archer et al., 2010). The interviewees in this study thought that the WROL challenges the limited view of who can participate in science:

I think that's [interacting with a diverse group of scientists] really valuable and students get such a variety of having role models and having a bit more diversity and that kind of thing...(T3)

This teacher then went on to say:

...you [the students] get someone to aspire to, or to see that they could potentially [be] that kind of person (T3)

While this teacher discussed diversity in general terms, another went onto explain how various aspects of identity could overlap with one of the mentors:

*the idea that being exposed to people who have taken a variety of different routes and different experiences to get to where they are is eye-opening and also means that students ... don't feel shoe-boxed into 'well this is my place and I have to do this', it can also be a case of just seeing people who are maybe closer... **maybe they connect with on some level, in terms of just being the same gender or age or ethnicity or whatever** [sic] (T6)*

This was a common sentiment. However, beyond a fairly general discussion of diversity, interviewees struggled to talk about specific socio-demographic identifiers. Participants largely appeared uncomfortable discussing matters relating to gender, racial or class participation explicitly. One academic mentor was particularly frank in admitting the avoidance of such topics:

I'm not going to be pushing, I don't want to dilute the science itself with socio-economic, political backgrounds. I don't want to get involved in those discussions, then people start focussing on the wrong thing, they might get upset or offended, I don't want to go down that route (AL12)

The reluctance of participants to discuss race, ethnicity and class was surprising. It was (perhaps naively) expected that because the stakeholders were engaged with a WP programme race, gender and class would be a significant area for discussion. Yet, beyond a superficial acknowledgment of the importance of diversity in science, interviewees avoided these and related issues.

While the most significant themes of identity in the WP literature were eluded, interviewees were happy to discuss one 'safe' aspect of students' identity, their age:

...as soon as they [students] see that that [undergraduate mentor] is just them in a couple of years' time, I think they can really relate and they suddenly grab on to that because they don't get to have those conversations with people who aren't family members very often, and so having that in situ, in the environment, can be quite a motivating thing for them and they often come away and say 'I really want to go to university'. (T4)

The closeness in age between visiting students and the mentors was usually guaranteed. The students were between 11-18 years old and their mentors mostly between the ages of 18-21. While these ranges may not overlap considerably, it may be useful to remember that their science teachers, with who they have most opportunity to discuss scientific topics, are likely to be older.

Indeed, two academic leaders were keen to disavow themselves as teachers. Both wanted to reject what they saw as the clichéd image of a schoolteacher:

I quite like the high energy; I see myself as quite an approachable person... I try not to be their stereotypical teacher... I can go slightly off topic and make it a bit interesting (AL9)

and

...the first thing I tell them [students] is: 'I am not your teacher'. (AL12).

One final consideration was raised by an academic leader who reflected on the perspective of students who have an established positive relationship with science, that they may have previously hidden from their family or peers:

they're thrust into Imperial college ...[and] all of a sudden they realise there are other people like them, thousands of other people, they are not unique and not weird and at lunch time they can have a chat about dark matter or dark energy and that's fine... they are surrounded by people who are passionate about science (AL11)

This academic leader is typical of the findings of Dowie, Barrow and Nicholson's, (2017), who reported that students from historically underrepresented backgrounds can sometimes feel they are 'outsiders'. Meeting 'like-minded individuals' may help secure both their own personal identity as a scientist, as well as their feeling of belonging to a community that shares a common interest. Furthermore, Shin, Levy and London (2016) found several positive effects of exposing students to role models. These included an increased interest in STEM, improved perception of their own identity as a scientist and increased academic sense of belonging.

Again, the stakeholders' comments regarding students' personal relationships with science in the WROL are supported by previous research. Where previously students may have not seen themselves as scientists, outreach programmes participation can be when students begin to integrate the idea of 'scientist' as part of their personal identity (Chapman & Feldman, 2017; Millar et al., 2019). Gartland (2015) also argues that STEM ambassadors help this process because of other overlapping identities (such as age) between then mentors and mentees.

4.3.2. Information, advice and guidance on navigating HE

Another potential benefit of the interaction between student and mentor, also suggested by interviewees, includes the information, advice and guidance given on navigating HE. Research has shown how many students from under-resourced backgrounds may not receive information about HE, the application process, careers advice, financial guidance etc. (Bok, 2010; Connor, 2001; Whitty, Hayton, & Tang, 2015). Stakeholders' comments support the previous research:

Some students won't have ever been onto a university site, some of them..., just coming into London and seeing that this is actually what a university is and what a university looks like and seeing the atmosphere around the area,

which is quite important. It means they get the opportunity to speak to students, speak to people, see things that are going on. (T6)

and

this is an excursion to experience what life would be like at university level really, get the feel for campus, get a feel for what life would be like [for students at university] (T9)

Interviewees frequently commented how visiting students learn about these aspects of the university as a result of visiting the WROL. They argued that, because the mentors have recently and successfully completed the process, they could answer students' questions from personal experience:

...they [students] can talk to and ask 'how did you do this' and understand the pressures, may be a little more tangible for students to have those conversations and say 'how did you do this, what did you do, did you always know what you wanted to do?' (AL8)

Teachers also often prompted their students to ask questions while in the WROL:

I think that's something really important to put on the students, really force them to ask mentors questions about their future (T4)

Observation in the WROL (section 6.2.1) did indeed show that students would sometimes ask mentors questions about HE. However, the students' pre-existing knowledge of HE was limited, and this constrained the questions they were able to ask. Only one academic leader suggested that the mentors should lead the discussions on HE:

You start to bring in university life and interaction with the mentors, that is very important and they [mentors] often ask them [students] questions about university, like, where they're going to apply, what subjects they enjoy. (AL9)

There is also evidence from observation in the WROL that the mentors did indeed coach students in navigating the intricacies of HE in the UK (section 6.2.1).

Interviewees also thought that it was helpful for students to receive information from someone similar to themselves, rather than a teacher:

...it's very easy as a teacher to be like 'I've told you this' but..., there's sometimes a bit more weight in hearing it from a peer or from someone else, that makes them go 'oh yeah, actually I will latch onto that a little bit more'. Maybe the conversation between the school and the student can become a little disjointed or a little bit stagnant. (T6)

Again, the interviewees' comments were supported by previous research; Gartland, (2014: 40–41) argued that because mentors occupy an intermediate position between school and HE, they become trusted or 'hot' sources of cultural capital for students. Importantly, Gartland (2015) further argued that *informal* educational contexts help deepen the connection between students and role-models. Educational settings with 'formal attributes' highlight differences between students and adults. In the WROL, stakeholders therefore support the informal connection between students and mentors.

Chapter four summary

In this chapter, I have presented data from interviews with teachers and academic leaders who interact with the WROL as part of the school-university partnership programme. The interviews have helped elucidate and clarify what key stakeholders do (or do not) want from the WROL.

Rather than an extension of school, the WROL is seen by interviewees as an *alternative* educational experience. The interviewees were nearly unanimous in criticising the formal education system's singular focus towards curricular learning and exam success. While qualifications are important, this academic leader summarises how many view the WROL as differing from school:

*Maybe it's a reflection of the school. It [the WROL] is very experiential and pushing the idea that **we're trying to teach a domain rather than teach to a test.** (AL8)*

By visiting the WROL, teachers hoped to challenge the primacy of studying 'science for exams', instead showing students that science is important for exams, but also beyond:

*It's about encouraging or engaging them so that rather than just doing their A levels **it's about continuing their education in science**, ... having science or maths A levels will open up a huge range of science based degree or vocational options, **as well as whatever else and it's about encouraging them into that** (T6)*

Teachers and academic leaders hope that the WROL achieves this, through four key themes:

1. Access to scientific equipment students would not otherwise experience.
2. Time to complete practical activities, which is lacking in school
3. Challenging students' conceptions of 'who' a scientist is by presenting them with a diverse group practicing scientists.
4. Mentors giving practical information, advice and guidance on accessing HE, as they have recently undergone the process themselves.

Interviewees, in the study, hope that these elements of the WROL are those which contribute to the widening participation and social justice mission of the outreach department.

5. Chapter five: Research question two- Does visiting the WROL increase students' levels of science capital?

This chapter presents data to answer research question two and is structured around the science capital questionnaire. As described in chapter three (methods), the questionnaire used in this study comprises of four composite variables from Archer, et al. (2015). Variables chosen from the science capital framework are those most likely to be changed by outreach intervention: 1) future science job affinity (aspiration), 2) valuing science and scientists, 3) utility of science qualifications and 4) self-efficacy in science. Variables, such as 'Parental attitudes and practices', while important dimensions of science capital, were not included as they are unlikely to be affected by the school/WROL partnership intervention.

Each variable is operationalised as several questionnaire items which are aggregated to create a composite variable score, which in turn feeds into the overall science capital score, this is depicted diagrammatically in Figure 3, above.

This study employed a pre-post research design for the questionnaire. Students visiting the WROL completed the modified science capital questionnaire twice. To establish a baseline response, students were given the questionnaire a week in advance of their WROL visit. To assess any immediate changes in science capital students were given the questionnaire immediately at the end of the visit. There was contingency for applying the questionnaire a third time for longitudinal tracking purposes. However, given the lack of change in science capital (results below) between data collection points one and two, it was deemed unlikely that a delayed effect would be observed with a third administration of the questionnaire. The additional data collection was assumed to not yield any meaningful results and therefore not pursued.

As Archer et al. (2015) remind us, quantitative data alone may not encompass the complexity of science capital and the processes that surround it. Group interviews with visiting students were conducted during the WROL trip (section 3.2.1) to add depth to our understanding of the WROL's work, beyond what the questionnaire could reveal. Because the group interviews were only conducted at one point in time (rather than pre-visit and post-visit data collection) the interviews were not designed to directly assess changes in science capital. Instead, group interviews were used on the day of visits to discuss any positive or negative experiences of students. As the group interviews occurred at lunchtime, students had already completed half of their visit and could describe what had happened in their session and whether

it had influenced their view of science. This could later be analysed to explain any potential change in science capital score. Following the critical realist approach taken to this research (section 3.1) the group interviews with students were therefore intended to help elucidate the ‘mechanism’ of any change observed. For example, if a student spoke at length about how much they were enjoying speaking to the mentors, and the questionnaire showed a positive change in ‘Valuing science and scientists’ these two data-points may reasonably be associated. Pertinent extracts from student group interviews are also presented alongside questionnaire analysis below.

This chapter first presents the Principal Component Analysis and Cronbach’s alpha scores, before exploring the data further in four sections reflecting the composite variables. The constituent questionnaire items which form them are analysed within each section. Results of the pre-visit questionnaire are presented to establish the students’ baseline feelings towards each item in the questionnaire; the post-visit results are then compared to ascertain any changes which occurred after visiting the WROL.

5.1. Principal component analysis and reliability check

Archer, et al. (2015) derive their factors for analysis using principal component analysis (PCA) and checked the internal consistency of their factors using Cronbach’s alpha. Considering the novel context of this study it was deemed prudent to repeat the process.

Both the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy and Bartlett’s Test of Sphericity were used to check the appropriateness of PCA. KMO values range between 0 and 1, where a value of 0.6 is commonly considered the minimum accepted value. The KMO measure for the questionnaire data in this study was 0.816 (Appendix X), indicating adequate sampling and suitability for PCA. Bartlett’s Test of Sphericity checks whether a correlation matrix is significantly different from an identity matrix and that factors are related. Given that $p < 0.05$ (Appendix X), this indicates that the correlation matrix is not an identity matrix and that the variables used are related and therefore suitable for PCA. Considering the results of KMO and Bartlett’s Test of Sphericity concurrently, PCA was judged as an appropriate technique for further analysis of the data.

A forced factor PCA, using Varimax rotation with Kaiser normalisation, was run on SPSS. The number of factors was fixed at four, to reflect the four components from the original science capital framework. The expectation was that the questionnaire items would load onto their respective components, as suggested in Figure 3.

However, the Rotated Component Matrix (RCM) (Appendix XI) indicates that three items in this study do not load well onto the constructs in the original framework. Firstly, the

item ‘I would like a job that uses science’ did not load well with the other items in the original component or onto any other construct (no value given) and was subsequently discarded from further analysis. ‘People who are like me work in science’ loaded better with the ‘Self-efficacy in science’ items (0.418) rather than ‘Future science affinity’ (0.381), so was moved. Finally, the item ‘Anyone can become a scientist’ loaded to the ‘Utility of science qualifications’ construct’ (0.573) and was also moved. Figure 5 shows questionnaire constructs resulting from PCA.

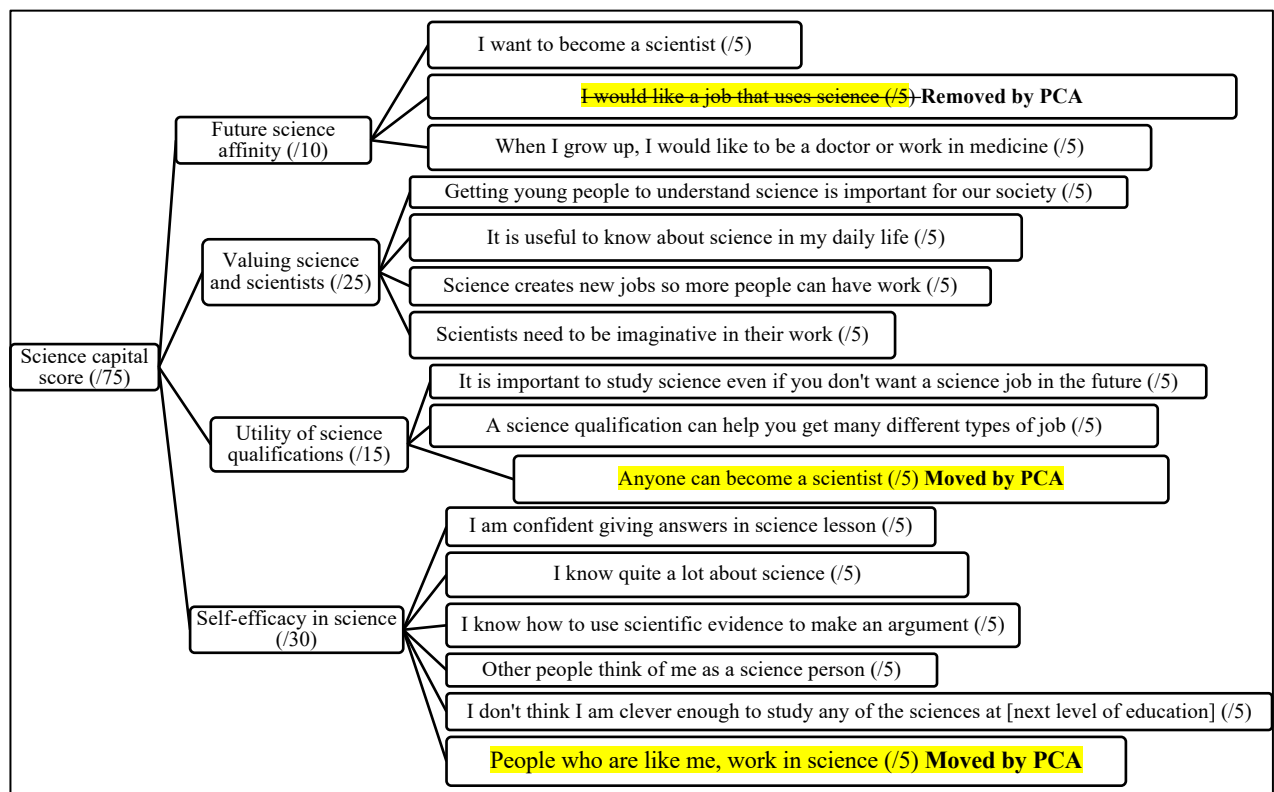


Figure 5: Second iteration of the science capital questionnaire items and components for analysis, as determined by PCA

The internal consistency of each component was then checked using Cronbach’s alpha test. Internal consistency is a measure of reliability, where an alpha value above 0.7 is commonly seen as desirable (although a value too high may not always be desirable and suggest redundancy in items, Tavakol & Dennick, 2011; Taber 2018). As Table 3 shows, the Cronbach’s alpha values for the components ‘Valuing science and scientists’ and ‘Self-efficacy in science’ were considered acceptable (alpha values ~0.8). The ‘Utility of science qualifications’ component had a value of 0.612, suggesting questionable reliability. Nevertheless, the removal of the item added by PCA (‘Anyone can become a scientist’) increased the Cronbach’s alpha value to 0.813. Therefore, ‘Anyone can become a scientist’ was removed from further analysis. The Cronbach’s alpha for ‘Future science affinity’ was also lower than desired (0.566), unfortunately the removal of either remaining item has no

effect on the internal consistency (you cannot have consistency using only one item), it was subsequently decided to continue with the analysis, with the explicit acknowledgment of questionable reliability for this component.

Table 3: Cronbach's alpha values for questionnaire components

Questionnaire component	Cronbach's alpha
Future science affinity	0.566
Valuing science and scientists	0.880
Utility of science qualifications	0.612 (0.813 after removing 'Anyone can become a scientist')
Self-efficacy in science	0.795

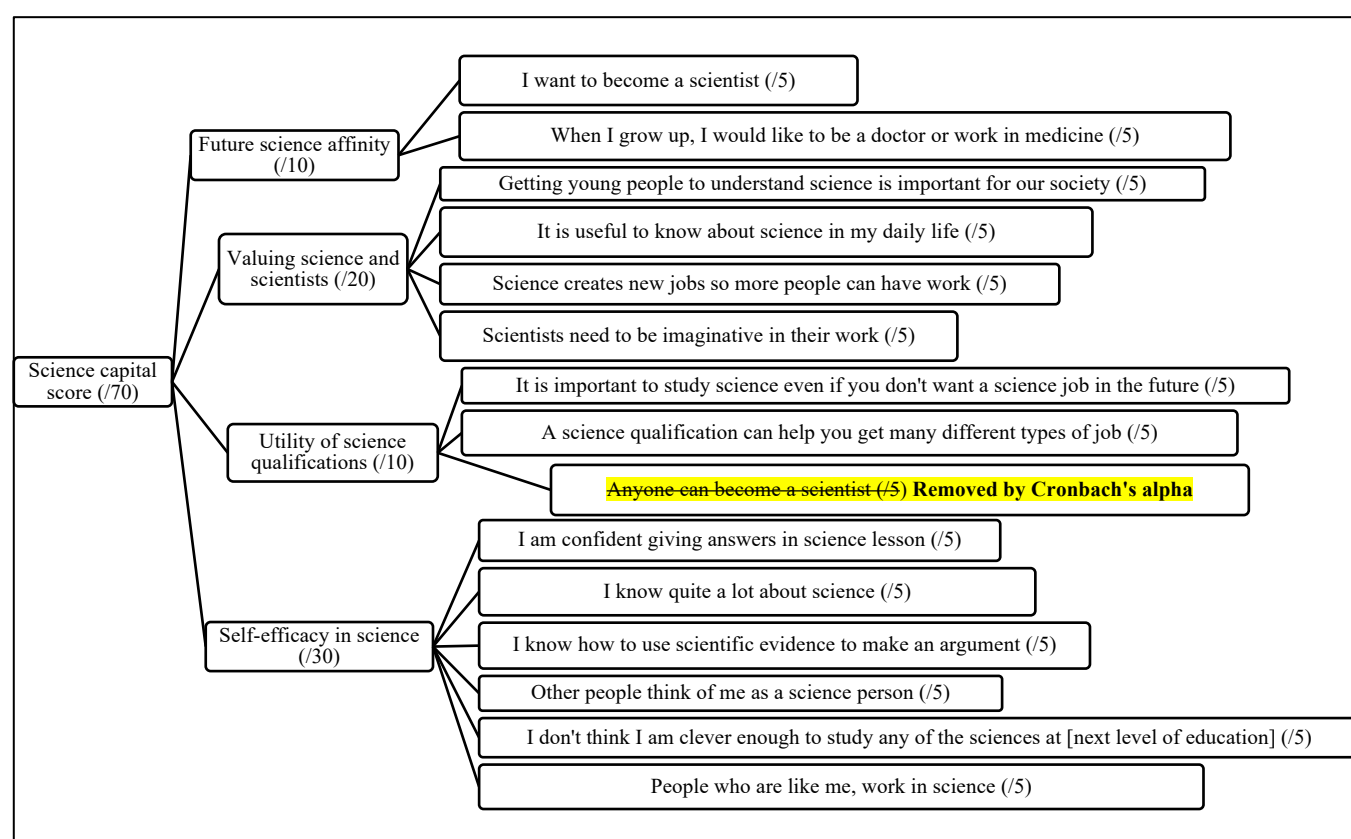


Figure 6: Final iteration of science capital questionnaire items and components for analysis, as determined by PCA and Cronbach's alpha

Although measures of reliability, such as Cronbach's alpha, are primarily applied to single-construct scales (Adams & Wieman, 2011) it does not preclude the use of multi-construct scales to ensure a latent variable is reliably being measured. For this reason, it was deemed prudent to check the overall reliability of the instrument using Cronbach's alpha, which resulted in a value of 0.841, suggesting a good overall reliability in the questionnaire as a survey instrument for measuring the dimensions of science capital identified.

5.2. Changes in science capital?

Out of the maximum possible science capital score of 70, the mean pre-visit score in these students was 50.04. After the visit, the mean science capital score increased slightly to 50.31. The difference in mean science capital score was not statistically significant ($t(261) = 0.151, p = 0.853$).

While the dimensions in the questionnaire all relate to science capital, and have been used to create a single index, theorists emphasise that science capital is a composite measurement of different dimensions and do not claim that science capital is a unitary construct (Moote et al., 2019). It is therefore prudent to also analyse each component separately to see if visiting the WROL has any observable effect on the separate dimensions, when disaggregated from the composite score.

5.2.1. Future science job affinity

Students' career aspirations are an important component of their science capital. However, for many students, even those who have positive views of science, this does not translate into children wanting a career in science (DeWitt & Archer, 2015). Aspirations are determined by a multiplicity of factors, including out-of-school learning experiences (Archer, DeWitt, & Wong, 2014; Laursen, Thiry, & Liston, 2012). As an out-of-school learning experience, it was hypothesized that the WROL may turn students' career aspirations towards science.

The questionnaire measured the extent to which students aspire to a career in science both before and after visiting the WROL. Given the five-point Likert scale (Strongly disagree= 1 to Strongly agree= 5) students were asked to indicate how much they agreed with four propositions, two of which remained in this component following PCA and Cronbach's testing:

- How much do you agree with the following statement? - I want to become a scientist.
- How much do you agree with the following statement? - When I grow up, I would like to be a doctor or work in medicine.

The mean composite score before visiting the WROL was 5.5 (/10), suggesting a very slight positive affinity towards a science career. The mean science affinity score increased marginally to 5.8 after visiting the WROL. However, a paired t test found that the difference between mean pre-visit and post-visit scores were not statistically significant, $t(262) = -1.677, p = 0.095$, indicating that visiting the WROL does not increase students' future science job affinity. The lack of effect was initially surprising considering some of the positive sentiments expressed during the qualitative data collection.

For example, the group interviews allowed one student to express how their aspirations had been positively influenced by visiting the WROL. His comment stood out as a dramatic departure from his previous career aspiration of being a footballer:

It [my career aspirations] changed because, as I said about my perspective, it's like science has been made a lot more fun. (S4)

Indeed, his comment is emblematic of the changes seen in response to the 'I want to become a scientist' questionnaire item (Table 4 and Figure 7). Before visiting the WROL, 25.64% of respondents agreed or strongly agreed that they would like to be scientists. After visiting the WROL, the proportion of those agreeing or strongly agreeing to the proposition had increased by 9.34%. A Wilcoxon signed rank sum test shows that the difference in results for this questionnaire item, pre and post visit, are statistically significant ($Z = -2.293$, $p = 0.022$). This, however, does not explain the lack of significant difference for the overall component.

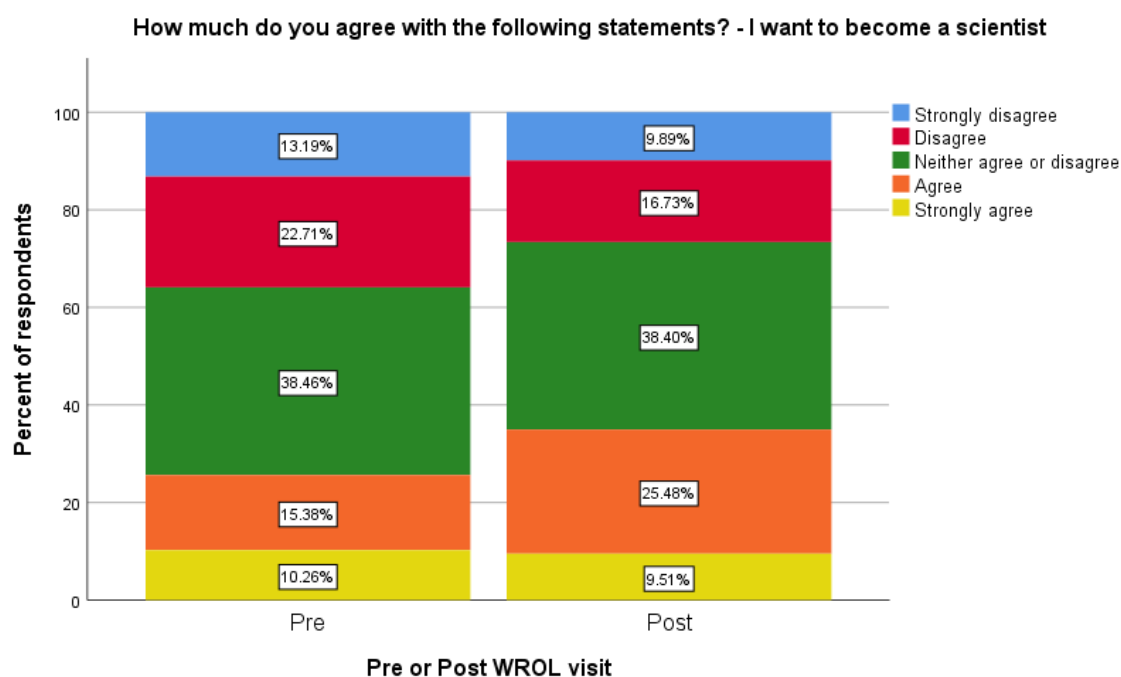


Figure 7: How much do you agree with the following statement? - I want to become a scientist

Looking further into the qualitative data and the other questionnaire item provides some explanation for the lack of significance overall. The student quoted above was the only one in the group interviews who said they had *changed* their career aspirations. More frequently, the students who expressed positive intentions to study science were those who already considered a career in science had their plans strengthened by visiting the WROL:

I am currently in the debate with myself between going down and mechanical science route or going down a humanities/history/politics...Yeah definitely the exposure in the Imperial Labs has persuaded me significantly towards the towards [sic.] the sciences point (S7)

The quote suggests this student was at a juncture and visiting the WROL nudged them towards the science pathway. Another student emphasised how the mentors helped strengthen their pre-existing aspirations towards pursuing computer science:

After speaking to the people in the purple shirts [mentors wear purple shirts], I like kind of want to come here and study computer science because I wanna take like computer science further and do something with computers when I am older, so then after then, [sic.] they have convinced me, 'cos by the sounds of it, I'd quite like it. (S10)

These quotes also support the positive changes observed in the 'When I grow up, I would like to be a doctor or work in medicine' (**Error! Reference source not found.**) item; the proportion of students strongly agreeing or agreeing with the proposition increased after the WROL visit by 5.08%. However, there was also movement in opinion in the other direction, the proportion of students strongly disagreeing also increased by 2.61%, which largely counteracts any net positive change. Overall, the diverging views resulted in no significant difference between pre- and post- visit responses for this questionnaire item (Wilcoxon test: $Z = -0.640$, $p = 0.522$).

Table 4: Future science job affinity questionnaire item results

		Pre		Post		Change	
		Count	%	Count	%	Count difference	% difference
How much do you agree with the following statement? - When I grow up, I would like to be a doctor or work in medicine	Strongly disagree	51	18.68	56	21.29	5	2.61
	Disagree	77	28.21	63	23.95	-14	-4.25
	Neither agree nor disagree	80	29.30	68	25.86	-12	-3.45
	Agree	39	14.29	46	17.49	7	3.20
	Strongly agree	26	9.52	30	11.41	4	1.88
	Total	273	100	263	100.00	-10	0.00
How much do you agree with the following statement? - I want to become a scientist	Strongly disagree	36	13.19	26	9.89	-10	-3.30
	Disagree	62	22.71	44	16.73	-18	-5.98
	Neither agree nor disagree	105	38.46	101	38.40	-4	-0.06
	Agree	42	15.38	67	25.48	25	10.09
	Strongly agree	28	10.26	25	9.51	-3	-0.75
	Total	273	100	263	100.00	-10	0.00

How much do you agree with the following statements? - When I grow up, I would like to be a doctor or work in medicine

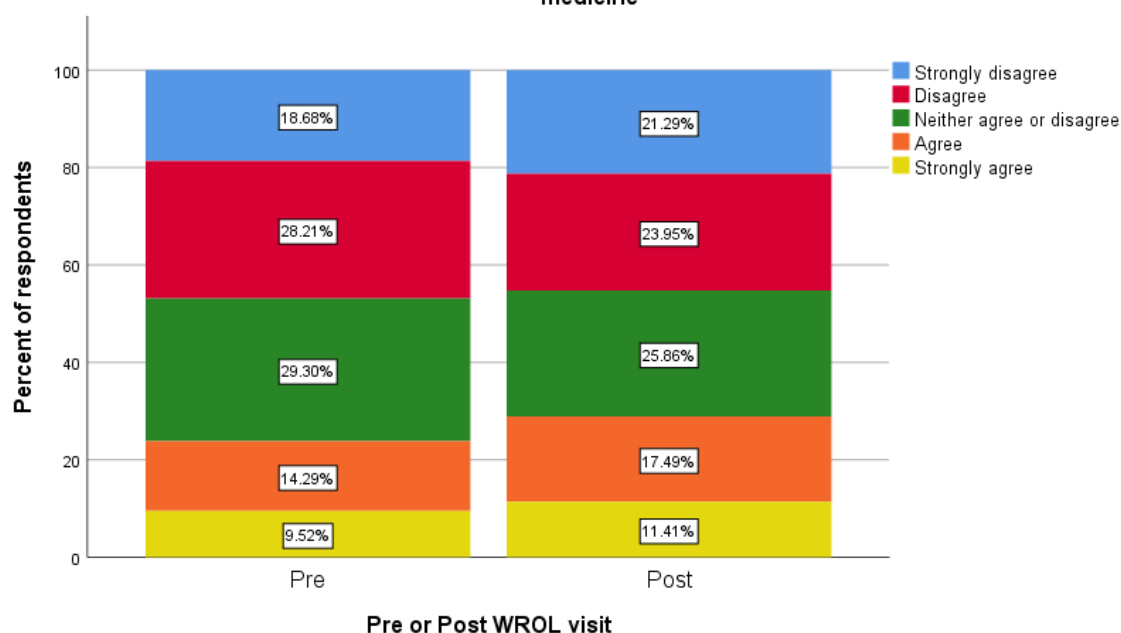


Figure 8: How much do you agree with the following statement? - When I grow up, I would like to be a doctor or work in medicine

The polarisation of opinion here clarifies the lack of overall significance and is further supported by the qualitative data. The students quoted above explains the positive movement as they had their aspirations intensified towards science. However, analysis of the group

interviews also indicates a reciprocal body of students with doubts about a career in science not being influenced:

S15: *I don't know what I want to do*

RZ: *But do you think you could be a scientist?*

S15: *Nope*

RZ: *Why not?*

S15: *Because I'm not very good at science*

This student's response was similar to those of several students who expressed alternate career aspirations (alternatives included: football, law, police officer, and journalism, one student simply wanted to be 'famous'). These students typically said that they rejected a career in science because it was too hard, had too much maths, which linked to the perceived difficulty of science (particularly in physics) or that science was 'too boring'. Visiting the WROL does not appear to have persuaded students with pre-existing perceptions of science as too difficult or too boring. For example, one student declared her prior lack of interest in a career in science:

To be honest, I have always felt like I was destined to go in that direction instead of science (S6)

She went on to say how visiting the WROL reinforced her existing negative views of science and even put her off:

...we came here to do that esters practical and I found the actual practical itself very long and tedious and just got bored quite quick... (S6)

*...one of their teachers [academic leaders] were [sic.] sort of going through chemistry and how things are bonded and to be honest **I was put off kind of as well and because I didn't know what exactly she was saying** (S6)*

The pedagogy used within the WROL and Academic Leaders' presentation skills are discussed further in Chapter 6.

Considering the evidence for this component in its totality, it appears that changes in affinity towards a science career are largely mediated by pre-existing perceptions of science. The significant positive movement observed in the 'I want to become a scientist' item was supported by the group interviews with students already leaning towards science commenting how their views were strengthened. However, students with negative views also had them confirmed, this is evident in the negative movement in the 'When I grow up, I would like to be a doctor or work in medicine' item and negative views in the group interviews. Therefore, the

lack of overall significance for the 'Future science job affinity' component can be explained by a polarisation of opinion, nullifying any net change.

It must be noted these results should be interpreted with caution because of the low Cronbach's alpha score for this component (section 5.1, above).

5.2.2. Valuing science and scientists

Valuing science and scientists is a key variable in determining one's participation with science (Archer, et al., 2015; Sheldrake, Mujtaba, & Reiss, 2017). Evidently if a student values science, and the contribution of scientists to both themselves and wider society, then they are more likely to engage with science. Contrastingly, students unconvinced of the value of science are more likely to become disengaged. How much students valued science and scientists was assessed using four questionnaire items, which all loaded together in PCA and the Cronbach's alpha suggested good internal consistency:

- How much do you agree with the following statement? - It is useful to know about science in my daily life
- How much do you agree with the following statement? - Getting young people to understand science is important for our society
- How much do you agree with the following statement? - Science creates new jobs so more people can have work
- How much do you agree with the following statement? - Scientists need to be imaginative in their work

Before visiting the WROL, the aggregated mean score for the items in this component was 16.11 (out of a possible 20), indicating that the visiting students had a strong pre-existing positive view of science and scientists. This largely supports Jenkins & Nelson's (2005) study which found that students thought science was an important subject.

After visiting the WROL, the mean score for this component rose marginally to 16.22. However, as with the component above, this slight positive change was not statistically significant, $t(262) = -0.335$, $p = 0.738$. Investigating the questionnaire items individually and the qualitative data helps explain the lack of significant observed change.

As Table 5 and Figures 10-13 show, students appeared to value science and scientists, even before visiting the WROL. 81.98% of students either agreed or strongly agreed that getting young people to understand science is important for our society and 81.61% agreed or strongly agreed that it is useful to know about science in daily life. Approximately two-thirds (68.38%) of students also supported the view that science creates new jobs and they largely concurred that scientists need to be imaginative in their work (agree & strongly agree =

72.43%). The group interviews also often showed a strong pre-existing perception of the relevance of science (e.g. “*everything is science*”- S16 and “*in science you learn about reality*”- S18). This strong starting position left little room for improvement from intervention. Indeed, no changes greater than 2% were seen in any response groups for the questionnaire item ‘It is useful to know about science in my daily life’ (Figure 9).

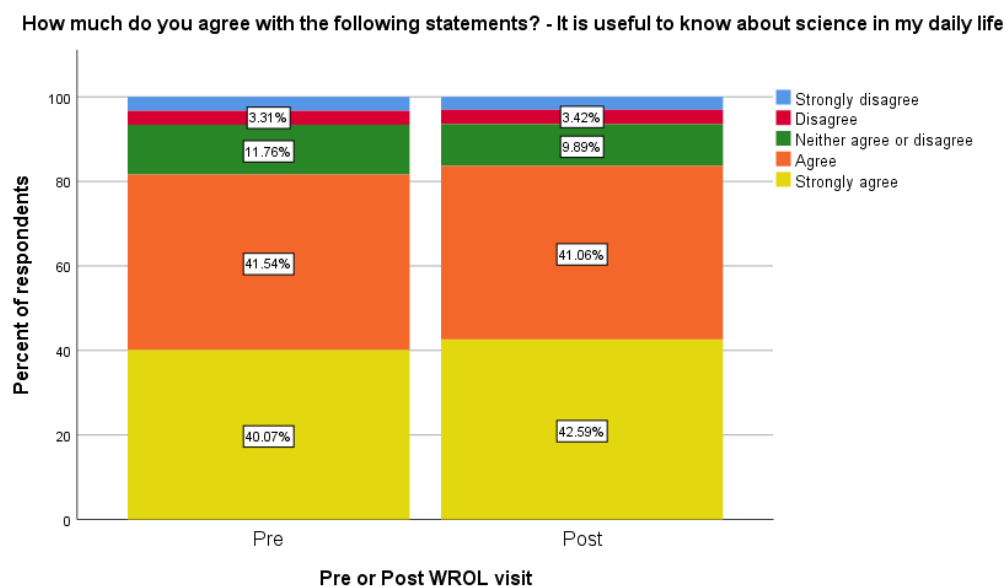


Figure 9: How much do you agree with the following statement? - It is useful to know about science in my daily life

While there was some evidence in the qualitative data shows that WROL science was linked to students’ daily lives, for example:

S17: *Sort of like everything leads to something, for example we’re learning about waves and stuff*

R.Z.: *That’s what you’ve been doing today?*

S17: *Yeah, like I asked about why it was important and they [mentors] said like how there’s radiotherapy and stuff and you need waves for that*

More frequently than not, students would rely on their pre-existing knowledge on the relevance of science. They often referred to the generic skills gained by receiving a science education:

I don't see what we've done here [in the WROL] applies to my everyday life. I mean maybe like the basic skills of like interpreting data or drawing conclusions, those type of skills yes, but I think the actual science itself no.
(S6)

Students also used immediately tangible examples to describe how science is relevant to their everyday lives, instead of applying the topic from their WROL session:

RZ: *Do you see science as relevant to your everyday?*

S16: *Parts of it*

S21: *Some stuff*

RZ: *Which parts?*

S16: *Like some of it is just good basic knowledge to have, like how the body works.*

The application of biology in medicine was common in the discussion on the value of science in society. Surprisingly, this was sometimes contrasted to attitudes about other sub-disciplines which students viewed as less germane:

...you don't need like chemistry as much as you do biology, [RZ: Really!?] like in biology like if anything ever happens to you, if you get a cut and if you study biology in depth then you would know what will happen in your body, but in chemistry it wouldn't be as deep...(S18)

This quote shows, the personal relevance of science was often linked, by students, to tangible models (such as the body). Themes of ‘realness’ and authenticity relating to the practical were also prevalent in discussing the relevance of science in the WROL:

*In school it's much more safety [sic.], so they limit you with what you can do but here's a look better because if you're going to like do something **it's like more realistic more how it would be in the real world.** (S10)*

Practical work in the WROL appears to have added a sense of tangibility for many students. It helped to ground the science into their reality and was also accompanied with a contrasting view of school science as inauthentic:

Sometimes when you do it in school, it doesn't feel that, err, it doesn't really feel that, I don't know how to explain it, but it doesn't feel that proper but here it feels like you're doing it properly and like you know how to you actually genuinely learn how to do it. At school it can be rushed sometimes, it can be stuff like that but here it feels like you're properly doing an experiment. (S1)

The importance of ‘authenticity’ for making science relevant for students has previously been explored (Chapman & Feldman, 2017; Machluf et al., 2017; Tsybulsky, 2019; Ward et al.,

2016). The literature commonly suggests that science, as conceptualised in school, is abstract and difficult for students to link to their own lives. The comments by visiting students in the WROL support Braund & Reiss' (2006) contention that school science can be complemented and contextualised by 'real' out-of-school science learning experiences.

Table 5: Valuing science and scientists questionnaire item results

		Pre or Post				Change	
		Pre		Post		Count	%
		Count	%	Count	%	difference	difference
How much do you agree with the following statement? - Scientists need to be imaginative in their work	Strongly disagree	12	4.41	12	4.56	0	0.15
	Disagree	4	1.47	14	5.32	10	3.85
	Neither agree nor disagree	59	21.69	39	14.83	-20	-6.86
	Agree	102	37.50	122	46.39	20	8.89
	Strongly agree	95	34.93	76	28.90	-19	-6.03
	Total	272	100	263	100.00	-9	0.00
How much do you agree with the following statement? - Science creates new jobs so more people can have work	Strongly disagree	12	4.41	10	3.80	-2	-0.61
	Disagree	10	3.68	8	3.04	-2	-0.63
	Neither agree nor disagree	64	23.53	53	20.15	-11	-3.38
	Agree	109	40.07	113	42.97	4	2.89
	Strongly agree	77	28.31	79	30.04	2	1.73
	Total	272	100	263	100.00	-9	0.00
How much do you agree with the following statement? - It is useful to know about science in my daily life	Strongly disagree	9	3.31	8	3.04	-1	-0.27
	Disagree	9	3.31	9	3.42	0	0.11
	Neither agree nor disagree	32	11.76	26	9.89	-6	-1.88
	Agree	113	41.54	108	41.06	-5	-0.48
	Strongly agree	109	40.07	112	42.59	3	2.51
	Total	272	100	263	100.00	-9	0.00
How much do you agree with the following statement? - Getting young people to understand science is important for our society	Strongly disagree	12	4.41	12	4.56	0	0.15
	Disagree	6	2.21	5	1.90	-1	-0.30
	Neither agree nor disagree	31	11.40	24	9.13	-7	-2.27
	Agree	105	38.60	91	34.60	-14	-4.00
	Strongly agree	118	43.38	131	49.81	13	6.43
	Total	272	100	263	100.00	-9	0.00

The remainder of the questionnaire items in this component showed little change in overall response. Where changes in opinion were observed, these were either negated by

movement in the opposite direction or were not substantial enough to be statistically significant.

For example, the post-visit changes in response to the proposition ‘Science creates new jobs so more people can have work’ were small (Figure 10), the proportion agreeing increased by 2.89% and strongly agreeing by 1.73%. This only represents six students changing their position in the positive (four and two, respectively), and this was mostly counteracted by four other students answering disagree or strongly disagree (two in each category). The net change (two students) does not represent a statistically significant difference between the pre-visit and post-visit results (Wilcoxon test: $Z = -0.666$, $p = 0.505$).

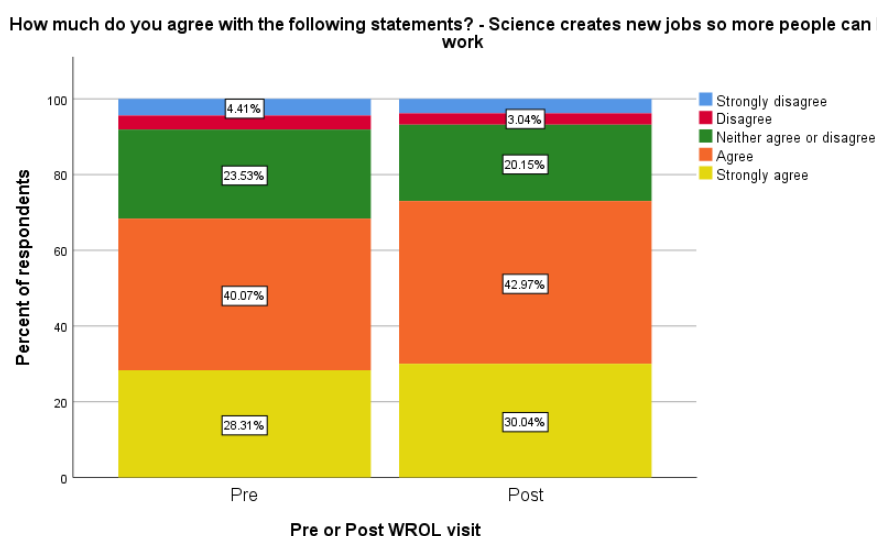


Figure 10: How much do you agree with the following statement? - Science creates new jobs so more people can have work

The proportion of students strongly agreeing that it is important for society that young people understand science increased by 6.43% (Figure 11). This movement indicates a strengthening of opinion, as the proportion of students agreeing reduced by -4%. There was however little movement of those with negative views (+0.15% and -0.3%). Overall, the number and weight of students changing their opinions was not enough to produce a statistically significant change (Wilcoxon test: $Z = -0.830$, $p = 0.406$).

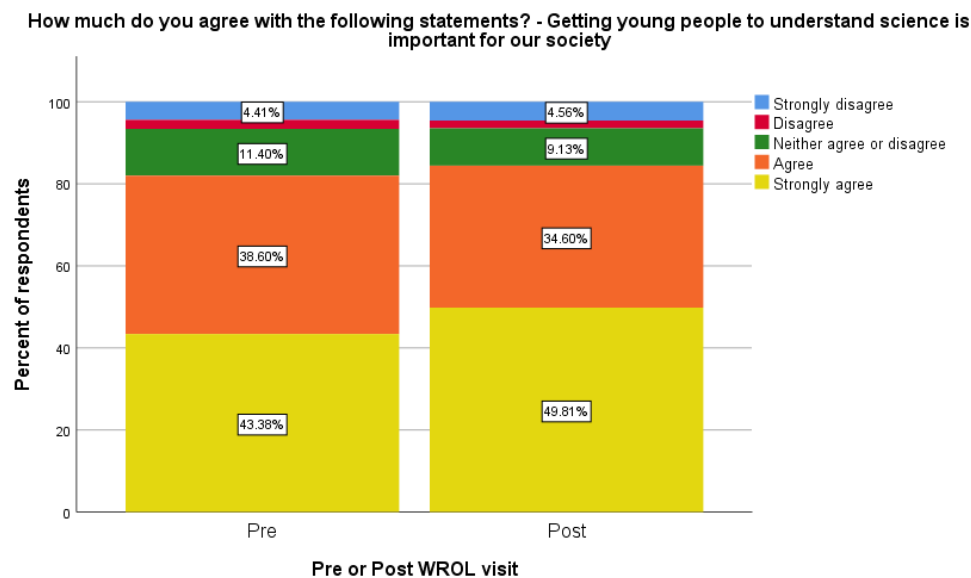


Figure 11: How much do you agree with the following statement? - Getting young people to understand science is important for our society

Some movement was seen in the responses to the proposition ‘Scientists need to be imaginative in their work’; the proportion of those agreeing or strongly agreeing increased by +2.86%, however the proportion of those disagreeing or strongly disagreeing increased by +4.0% (Table 5 and Figure 12). Suggesting a slight overall net movement towards the negative. Yet, the overall difference of opinion was, again, not statistically significant (Wilcoxon test: $Z = -0.996$, $p = 0.319$).

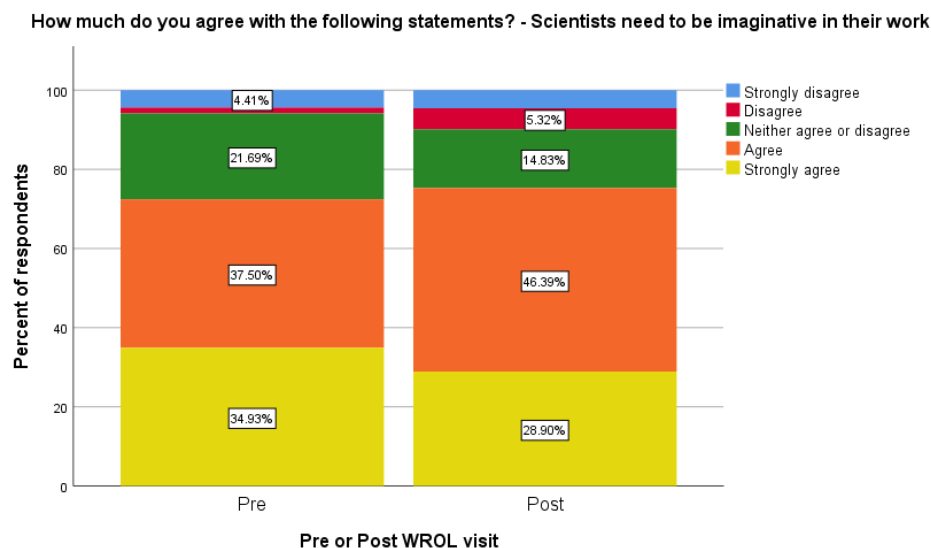


Figure 12: How much do you agree with the following statement? - Scientists need to be imaginative in their work

In the group interviews no students described scientists as imaginative (despite the pre-visit questionnaire suggesting that students broadly agreed that science requires imagination), students would instead describe scientists using stereotypical representations of scientists as

smart/clever etc. The association of science and innate cleverness has previously been found to be a damaging stereotype for students from underrepresented groups, particularly for girls (Archer et al., 2010; Archer, DeWitt, et al., 2013). One student however dissented from the typical descriptors of scientists, while they still suggest that there may be some innate factors that contribute to scientific ability, they also said that a lack of intrinsic scientific talent can be overcome with hard work:

Yeah, like some people are born with the talent and some people work to get a a [sic.] talent. Let's take Cristiano Ronaldo as an example, he wasn't born with a talent because he worked hard to get, because before when he was playing for Manchester United a lot of people called him skinny and he didn't have a lot of power, and then by time he started growing more and more and he worked very hard for it. So, to be a scientist, you don't need to be very smart you just need to work a lot to get to that point.... It's because of that attitude and the mindset. If you have a good attitude and mindset you can achieve anything you want. (S2)

Viewing scientists as hard workers, who need to nurture their talents, this student rejects the commonly held view that scientists are naturally 'smart' or 'geeky'. While no other students expressed opinions like this, this student's perspective is useful to consider as a means challenging stereotypes of scientists in the future. Instead of representing scientists as naturally brilliant, it may improve students' perceptions of scientists if they are portrayed as having worked their way through a process, which is also attainable by the students themselves.

To conclude this component, the evidence shows that visiting the WROL did not change students' valuation of science and scientists overall. Where minor changes were seen in the quantitative data, they were not statistically significant and therefore are likely due to stochasticity rather than any effect of intervention. The pre-visit qualitative data showed how students were already aware of the importance of science in their daily lives and supports previous research which found that students' think that science is important (Archer et al., 2010; Jenkins & Nelson, 2005). This study adds to our current understanding here and suggests that intervention might be better targeted to other components of science capital. This contrasts with Archer, et al. (2015), suggestion 'Valuing science and scientists' may be a prime target for intervention.

While the questionnaire did not reveal any changes in the students' views of the importance of science in daily life, the interviewed students prevailing view on the authenticity

of practical science was meaningful. Students report that the tangible aspect of practical science helped them ground science as a personal experience, when compared to their typical encounters with science as abstract theories in the classroom. This is also supported by previous studies, where practical and authentic outreach science is valued by students (Chapman & Feldman, 2017; Tsybulsky, 2019; Ward et al., 2016)

5.2.3. Utility of science qualifications

Science qualifications are valuable forms of cultural capital, not only as the entry-ticket for employment in the science sector, but also for the exchange value they hold in the wider job market. Evidently, students who believe that science qualifications are only for scientists and do not want to become scientists are likely to become disengaged from science education. Convincing students of the personal utility of science qualifications (whether for science employment or not) is important for encouraging their engagement with science education and potential future participation.

Students' perceived utility of science qualifications, was measured in the science capital questionnaire using two items:

- How much do you agree with the following statement? - It is important to study science even if you don't want a science job in the future.
- How much do you agree with the following statement? - A science qualification can help you get many different types of job.

For this component, before visiting the WROL the mean composite score was 7.3 (out of a possible 10), suggesting that students from the partner school were already largely convinced of the utility of science qualifications even before visiting the WROL. After visiting the WROL, the mean score for this component decreased slightly to 7.1. The change in the mean score was not statistically different, $t(260) = 0.791$, $p = 0.430$. Again, examining the questionnaire items individually and looking at students' comments in the group interviews adds to the depth of analysis.

Before visiting the WROL, students responded to both questionnaire items positively (Table 6). 76.84% of students agreed or strongly agreed that it is important for them to study science even if they did not want a science job (Figure 14) and 84.25% of participants agreed or strongly agreed that science qualifications can help get many jobs (Table 6).

Table 6: Utility of science qualification questionnaire item results

		Pre or Post				Change	
		Pre		Post			
		Count	%	Count	%	Count difference	% difference
How much do you agree with the following statement? - It is important to study science even if you don't want a science job in the future	Strongly disagree	15	5.51	14	5.32	-1	-0.19
	Disagree	15	5.51	13	4.94	-2	-0.57
	Neither agree nor disagree	33	12.13	26	9.89	-7	-2.25
	Agree	124	45.59	126	47.91	2	2.32
	Strongly agree	85	31.25	84	31.94	-1	0.69
	Total	272	100	263	100.00	-9	0.00
How much do you agree with the following statement? - A science qualification can help you get many different types of job	Strongly disagree	14	5.13	11	4.18	-3	-0.95
	Disagree	2	0.73	5	1.90	3	1.17
	Neither agree nor disagree	27	9.89	20	7.60	-7	-2.29
	Agree	111	40.66	130	49.43	19	8.77
	Strongly agree	119	43.59	97	36.88	-22	-6.71
	Total	273	100	263	100.00	-10	0.00

After vising the WROL minimal changes were seen in responses to ‘It is important to study science even if you don't want a science job in the future’, with the largest change being two more students agreeing with the proposition (Table 6). Greater changes can be seen in response to ‘A science qualification can help you get many different types of job’ (Figure 14), with a +8.77% increase in those agreeing with the proposition. This is mostly made from students softening their views from strongly agree (-6.71%). The changes here are source of the reduction in overall component score. Nevertheless, the lack of movement in the first item and the softening of opinion in the second item were not statistically significant, (Wilcoxon test: $Z = -0.340$ and -0.0512 , $p = 0.734$ and 0.609).

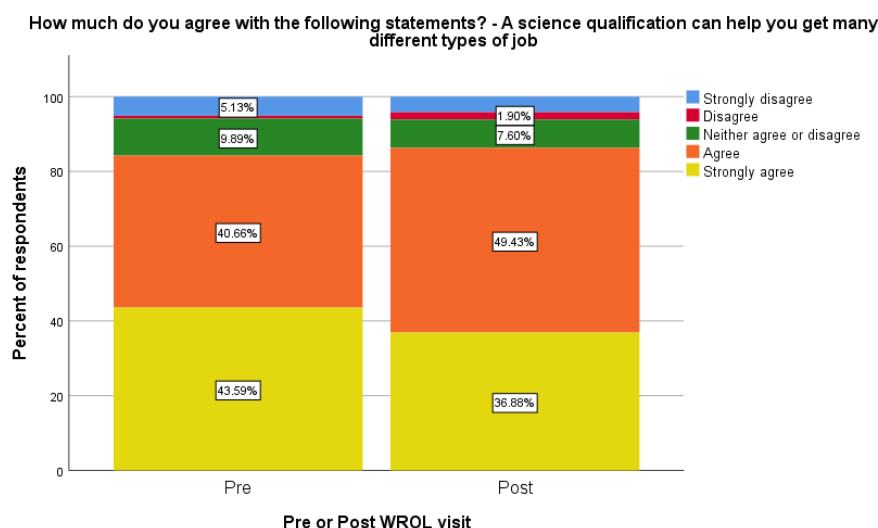


Figure 13: How much do you agree with the following statement? - A science qualification can help you get many different types of job

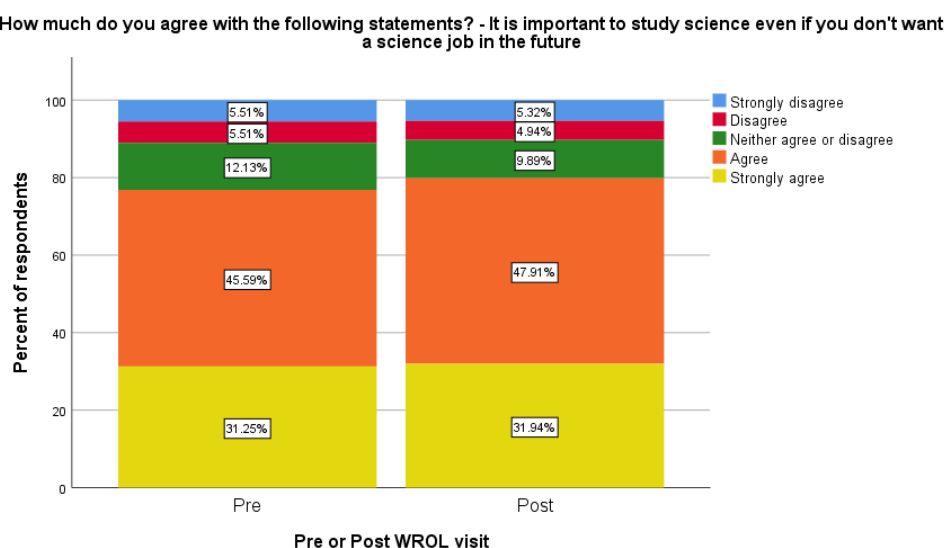


Figure 14: How much do you agree with the following statement? - It is important to study science even if you don't want a science job in the future

The students' pre-existing views on the utility of qualifications were evident during the group interviews. They were abundantly aware of the importance of exams and formal qualifications, and often associated them with the reason for visiting the WROL:

Well obviously, because our GCSEs are in a year and we have test on biology, physics and chemistry (S12)

and

It [the WROL] will give us like basically what was going to end up on the test and just help us understand it more. (S22)

The students' views on the importance of qualifications was well evidenced by a BTEC student who had elected to study applied science post-16 despite not believing they will study science further:

*To be honest I have always felt like I was destined to go in that direction instead of science, **but I chose science first because I was very academic***
(S3)

This student views a BTEC in Applied Science to be an indicator of her academic intellect, and she chose to study this qualification in favour of another qualification which might be more germane to her actual career aspiration.

Although the students showed a general awareness of the importance of qualifications, the interviews also highlighted how they lacked the nuanced knowledge of which qualifications were suitable for which jobs:

Like I don't know the different thing... like for a what courses you have to take what degree do you have to get for certain jobs. (S8)

This student's comments remind us of the cultural capital required to navigate the HE admissions processes and how this is not necessarily provided by school (Moote & Archer, 2018; Reiss & Mujtaba, 2017) or by parents (Menzies, 2013). Bok (2010) compares students applying to HE without the knowledge of HE to performing a play without a script or stage directions. This student also went on to say that the WROL visit helped clarify the pathway to their intended career:

...it [the WROL] has helped me understand certain different things that you need like engineering and stuff, which was helpful (S8)

These interview results further highlight the importance of the qualitative data in supporting the analysis of the questionnaire. Taken alone, the questionnaire results might suggest that students do not need intervention as they already understand the broad importance of qualifications. However, the interviews revealed they only know about this in an abstract sense and do not know how to practicably leverage qualifications.

Alongside their awareness of the importance of qualifications, some students also demonstrated an awareness of the social structures which acted against them succeeding in their science qualifications. One student commented:

*I was watching some kind of show called 'Switched at Birth' and there's this girl who's doing a science test, while she's trying to become a doctor and it was kind of difficult for her because she was an 'A' student and from 'A' student she became a 'C' student. **So that's why it was kind of like doubtful for me to try to become anything involved in science.** (S2)*

The student's views become clear when considering the premise of 'Switched at birth'. The show revolves around two teenagers who discover they were, as the title suggests, switched at birth. The protagonists live in radically different social environments, one in a low-income neighbourhood, the other in a more affluent suburb. The show explores themes of nature vs. nature, identity, privilege, and social injustice. The student appears to suggest that their doubts of their own future involvement in science are due to their socio-economic position, with the implied corollary that if they were born into a more affluent family then their science participation would be more likely. When related to the questionnaire this reveals a nuanced position, where the student believes that one's background determines whether they will get an A grade or a C grade.

Overall, for this component, the results show that visiting the WROL did not change students' perceptions of the utility of science qualifications. Again, the positive starting position of students left very little room for movement, the minority of dissenting students are those most likely to have deeply held views about science qualifications being solely for scientists and were therefore unlikely to be convinced by the WROL experience. The qualitative data however show that visiting the WROL held some benefit to students' deeper understanding in teaching them how to practically use the qualifications (which they already know are important).

5.2.4. Self-efficacy in science

Student self-efficacy (i.e. belief in their own abilities) is significant in understanding students' motivation and resilience in continued science participation. There are several sources of self-efficacy (Byars-Winston et al., 2016), many of which may be present in the WROL, for example performance accomplishments and feedback from mentors (*ibid.*) Self-efficacy in science, before and after the WROL visit, was assessed using six items in the questionnaire, five of which were loaded together originally, and the final item being added after PCA:

- How much do you agree with the following statement? - I am confident giving answers in science lessons
- How much do you agree with the following statement? - I know quite a lot about science

- How much do you agree with the following statement? - I know how to use scientific evidence to make an argument
- How much do you agree with the following statement? - I don't think I am clever enough to study any of the sciences at [next level of education].
- How much do you agree with the following statement? - Other people think of me as a science person
- How much do you agree with the following statement? - People who are like me, work in science.

Before visiting the WROL, the mean score for this component was 16.0 (out of a maximum possible score of 30). The mean post-visit score remained almost constant even after the WROL visit, increasing by just 0.1. The increase in mean score was not statistically significant, $t(263) = -0.088$, $p = 0.930$.

The questionnaire results (Table 7) show that, before attending the WROL, most items were largely answered positively. 62.27% of visiting students considered themselves to know ‘quite a lot’ about science (either agreeing or strongly agreeing). 68.38% of respondents also either agreed or strongly agreed they knew how to use scientific evidence to make an argument. Students also mostly agreed or strongly agreed (65.93%) with the assertion they feel confident in giving answers during science lessons. Finally, 57.56% of students agreed or strongly agreed when asked if they thought they were clever enough to study science at the next stage in their education (GCSE/A level/BTEC/ university).

The group interviews also supported the overall sense that students generally felt confident with their own abilities in science. When asked why they thought they were chosen to visit the WROL, two students suggested this was based on their perceived ability in science: “*Well I guess because we're ... we're good at science*” (S8) and “*I think because... I do quite well and understand the topic well.*” (S10).

Table 7: Self-efficacy in science questionnaire item results

		Pre or Post				Change	
		Pre		Post		Count difference	% difference
		Count	%	Count	%		
How much do you agree with the following statement? - I know how to use scientific evidence to make an argument	Strongly disagree	8	2.94	8	3.04	0	0.10
	Disagree	16	5.88	13	4.94	-3	-0.94
	Neither agree nor disagree	62	22.79	59	22.43	-3	-0.36
	Agree	143	52.57	142	53.99	-1	1.42
	Strongly agree	43	15.81	41	15.59	-2	-0.22
	Total	272	100	263	100.00	-9	0.00
How much do you agree with the following statement? - I know quite a lot about science	Strongly disagree	7	2.56	9	3.42	2	0.86
	Disagree	15	5.49	15	5.70	0	0.21
	Neither agree nor disagree	81	29.67	61	23.19	-20	-6.48
	Agree	132	48.35	135	51.33	3	2.98
	Strongly agree	38	13.92	43	16.35	5	2.43
	Total	273	100.00	263	100.00	-10	0.00
How much do you agree with the following statement? - I am confident giving answers in science lesson	Strongly disagree	6	2.20	9	3.42	3	1.22
	Disagree	17	6.23	21	7.98	4	1.76
	Neither agree nor disagree	70	25.64	57	21.67	-13	-3.97
	Agree	118	43.22	107	40.68	-11	-2.54
	Strongly agree	62	22.71	69	26.24	7	3.53
	Total	273	100.00	263	100.00	-10	0.00
How much do you agree with the following statement? - Other people think of me as a science person	Strongly disagree	28	10.29	18	6.84	-10	-3.45
	Disagree	36	13.24	27	10.27	-9	-2.97
	Neither agree nor disagree	102	37.50	82	31.18	-20	-6.32
	Agree	72	26.47	84	31.94	12	5.47
	Strongly agree	34	12.50	52	19.77	18	7.27
	Total	272	100.00	263	100.00	-9	0.00
How much do you agree with the following statement? - I don't think I am clever enough to study any of the sciences at University	Strongly disagree	80	29.52	66	25.10	-14	-4.43
	Disagree	76	28.04	69	26.24	-7	-1.81
	Neither agree nor disagree	72	26.57	83	31.56	11	4.99
	Agree	23	8.49	28	10.65	5	2.16
	Strongly agree	20	7.38	17	6.46	-3	-0.92
	Total	271	100.00	263	100.00	-8	0.00
How much do you agree with the following	Strongly disagree	13	4.76	16	6.08	3	1.32
	Disagree	33	12.09	35	13.31	2	1.22

statement? - People who are like me, work in science	Neither agree nor disagree	147	53.85	131	49.81	-16	-4.04
	Agree	64	23.44	62	23.57	-2	0.13
	Strongly agree	16	5.86	19	7.22	3	1.36
	Total	273	100.00	263	100.00	-10	0.00

As above, the positive starting position for these items leaves fewer students in the undecided or negative groups to be influenced by the WROL intervention. No changes larger than 1.5% were seen in response to ‘I know how to use scientific evidence to make an argument’ (Table 7) There was a slight positive increase (+2.43%) in students responding strongly agreeing with the proposition ‘I know quite a lot about science’ (Table 7). However, the strength of this change was not significant (Wilcoxon test: $Z = -0.647$, $p = 0.518$). Changes in response to ‘I don't think I am clever enough to study any of the sciences at [next stage of education]’ suggests that students were more uncertain, with an increase of 4.99% selecting ‘Neither agree nor disagree’ (Table 7) again, this does not represent a significant difference (Wilcoxon test: $Z = -1.183$, $p = 0.237$). The proportion of students who did not feel confident in responding in science lessons decreased by 2.98% after visiting the WROL (Table 7) however the results were not statistically significant (Wilcoxon test: $Z = -0.057$, $p = 0.954$).

How much do you agree with the following statements? - I know how to use scientific evidence to make an argument

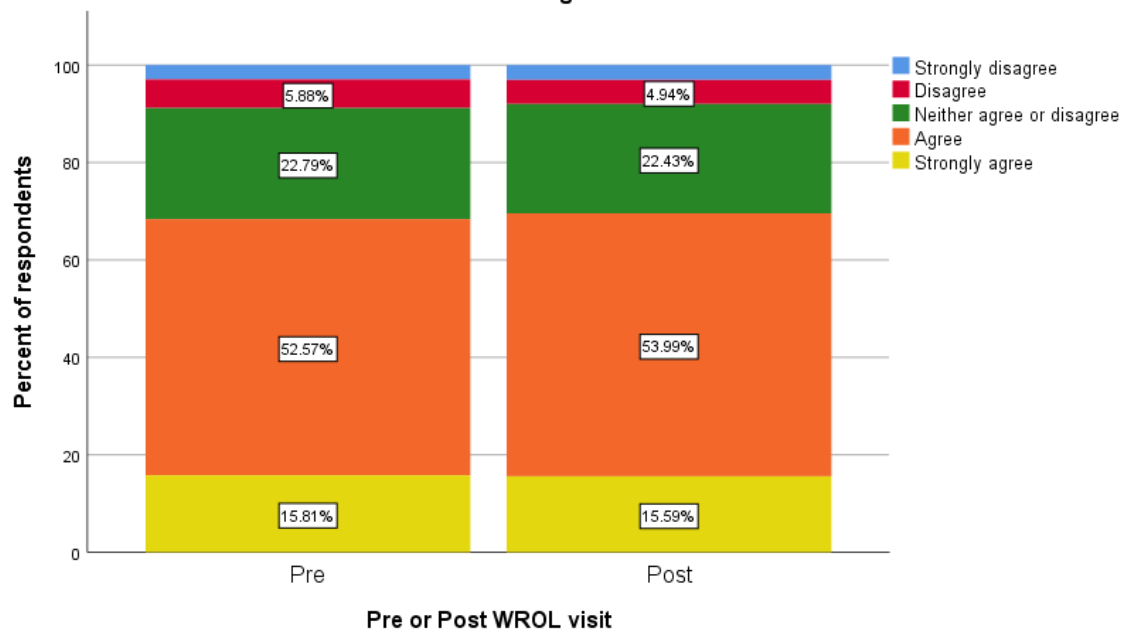


Figure 15: How much do you agree with the following statement? - I know how to use scientific evidence to make an argument

The data for these four questionnaire items indicates that visiting the WROL did not increase students' confidence in answering science questions, use of scientific evidence, self-

concept of scientific knowledge nor did it increase their confidence in studying science in the next educational stage. These findings have links to the observation data in Chapter 6. For example, the field notes describe how students were frequently reluctant to answer questions in the WROL (section 6.2.4) despite the teachers' reassurance that they had already covered the work and knew the content. The WROL presents a potentially intimidating environment for some students, particularly if they come from non-traditional backgrounds. Furthermore, the observation data shows how the session leaders would sometimes present content which was beyond the capabilities of the visiting students (section 6.2.3). These two aspects of the WROL may lead to some students finding the level of science required too difficult for them to contribute positively and may subsequently feel less confident in their own abilities.

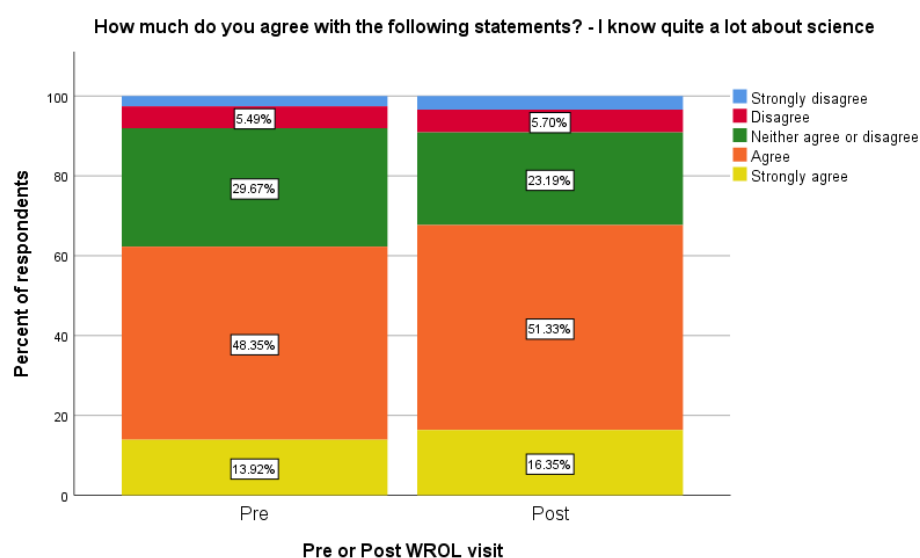


Figure 16: How much do you agree with the following statement? - I know quite a lot about science

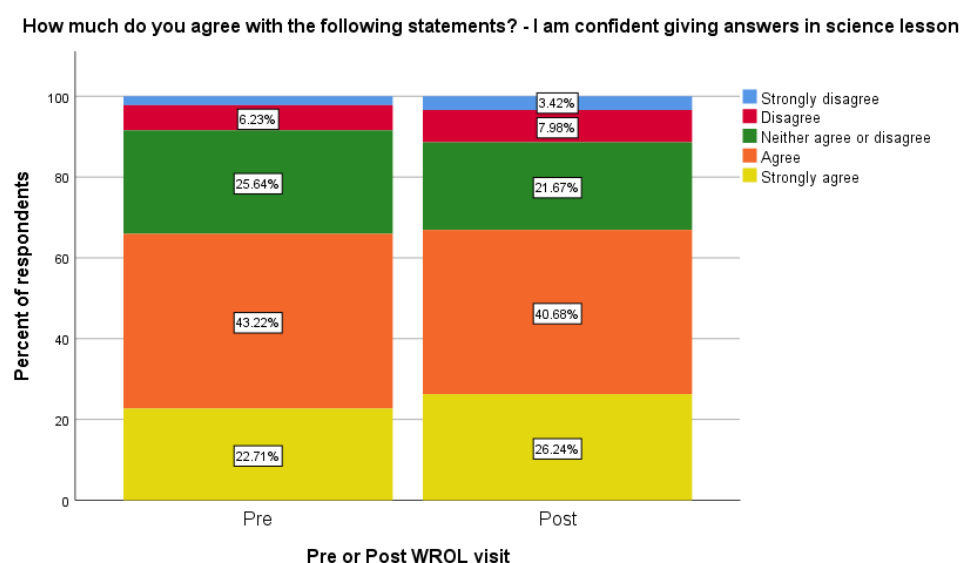


Figure 17: How much do you agree with the following statement? - I am confident giving answers in science lesson

How much do you agree with the following statements? - I don't think I am clever enough to study any of the sciences at University

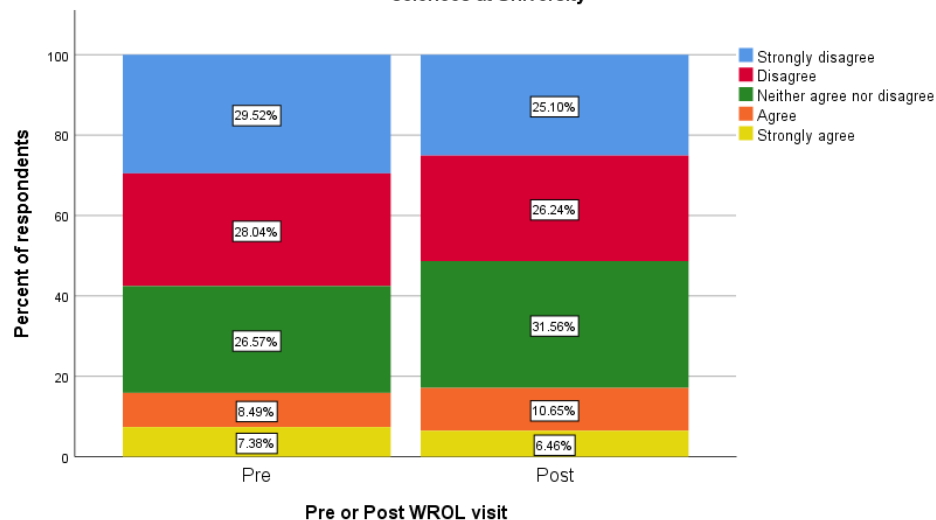


Figure 18: How much do you agree with the following statement? - I don't think I am clever enough to study any of the sciences at University

The two remaining questionnaire items stand out as having subdued pre-visit responses. Just 38.97% of respondents agreed or strongly agreed that other people saw them as a ‘science person’ and only 29.3% of visiting students agreed or strongly agreed that ‘People who are like me, work in science’. This is interesting because the previous questions relate to how students view their own scientific competency, but these questions ask how students think *other people* view their scientific competency and how their self-efficacy relates to the wider scientific community. The muted pre-visit scores for these two items suggests areas ripe for intervention.

Indeed, the proportion of students strongly agreeing with the ‘People who are like me, work in science’ item (Table 7) increased by 1.36 %, however this is mostly negated by the 1.32% increase in students strongly disagreeing. The overall difference between groups is not significant (Wilcoxon test: $Z = -0.028$, $p = 0.978$). However, a large change in response was seen in the ‘Other people think of me as a science person’ item after visiting the WROL (Table 7) with +12.74% more students agreeing or strongly agreeing that other people see them as a scientist. A Wilcoxon signed rank test showed that this change was statistically significant ($Z = -2.919$, $p = 0.004$).

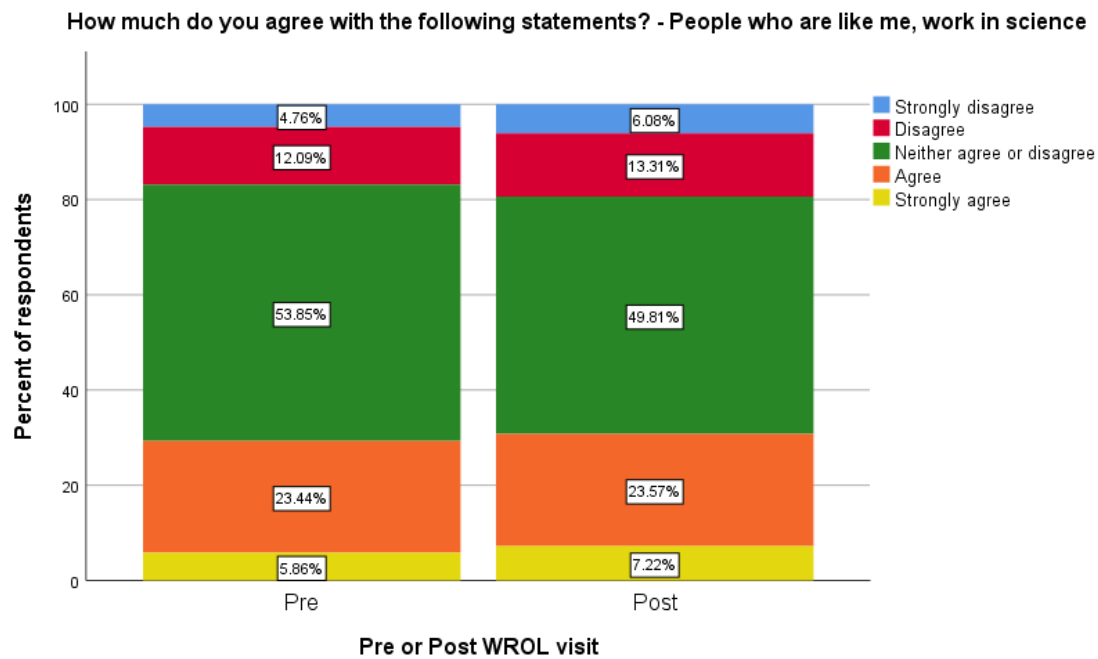


Figure 19: How much do you agree with the following statement? - People who are like me work in science

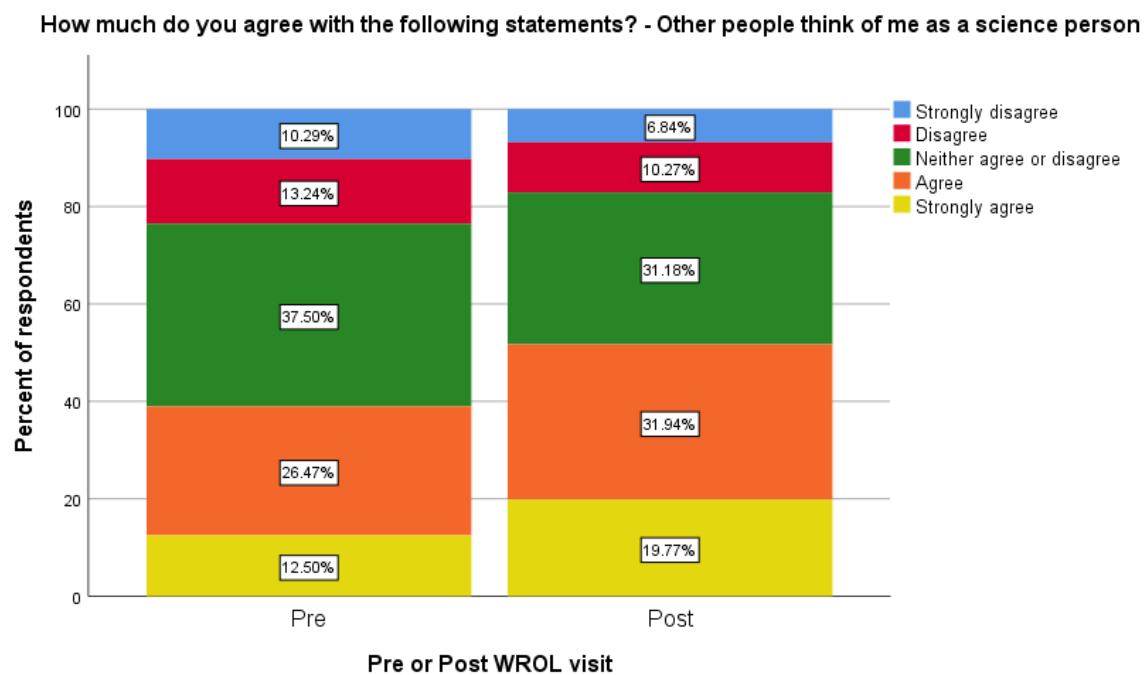


Figure 20: How much do you agree with the following statement? - Other people think of me as a science person

Despite the lack of statistical significance in response to ‘People, who are like me, work in science’ proposition, the group interviews add further insight into students views regarding these two questions together. During interviews many of the students commented how the mentors had a positive effect. Having undergraduates in the WROL helped visiting students to see people like themselves studying science at a higher level:

...you think people [university students] would be super serious and have like super mature behaviours, but realistically they are not much more different than us and if you think about it it's just a couple years difference, it's not like a hundred years difference... I feel like yeah, it's it's [sic.] great to have them [mentors] because you have someone to like kind of relate to. You're in your studies and they're in their studies as well, so you both have kind of like an idea of what each other is doing. (S7)

Several other students supported the importance of mentors in highlighting the parallels between the two groups. One student forged a connection between the course they are studying with the mentor's and sessions leader's own qualifications:

Yeah I've talked to the undergraduates students a bit, but it was interesting 'cos obviously the lead lecturer [session leader] did the same thing [referring to International Baccalaureate qualification] that we're currently doing, a few years ago. But the one who is currently doing her undergraduate did it, less than a year ago, which kind of gives more of an insight into our generation and it's more relatable, but both are quite relatable, both of them being so young. (S7)

The value of students' identifying with the mentors and their use of them as a source of information was further made apparent:

We were talking to them [mentors], if we needed help [in the practical] and we are asking them why they decided to come here and what made them choose science and they were telling us a bit more about life here... and then we're talking about like what they had to do to come here and how they enjoy it and how much it costs and that stuff. (S10)

This student also went on to say this was the first time they had talked to anyone about university as a potential option. The research literature emphasises how poorly science career education is resourced in school (Moote & Archer, 2018; Reiss & Mujtaba, 2017) and that students from disadvantaged backgrounds will often not have the experience or knowledge in their own social networks to receive advice (Menzies, 2013). This also links back to the student in section 5.2.3 who said they didn't know which qualifications applied to which university courses.

These findings here suggest two key benefits are associated with the presence of mentors, which may support students' self-perception as scientists. First, students may identify with the mentors because of their socio-demographic characteristics (even if the only overlapping characteristic is age) and, secondly, that the mentors are a source of information, advice, and guidance for students to learn how to access HE. These findings support Clare Gartland's (2014: 30) statement that STEM ambassadors are seen by students as 'hot' sources of information (compared to 'cold' official sources, for example teachers or university websites, which students consider less relatable).

It is also worth noting that in the group interviews some students talked about their self-efficacy, not in science alone, but confidence in an HE context:

Yeah, I was very nervous, but now I feel more confident with a university setting because we've been here a couple of times, getting used to it.... because before coming to Imperial I had considered doing a science degree and then after experiencing an actual university lab with all the equipment, technology it has, it has given me the chance to see was actually like and made me, so when I do start my university degree I wouldn't be as nervous, or I wouldn't be as not confident. (S6)

This student suggests that the increased confidence in HE has correspondingly strengthened their self-assurance if/when they start their science degree. This again highlights the importance of the group interviews in allowing students to voice opinions not captured by questionnaire.

Overall, the evidence in this component suggests that students' self-efficacy in science is largely unaffected by visiting the WROL. Nevertheless, the statistically significant change in 'Other people think of me as a science person' questionnaire item and the group interviews provide some indication that visiting the WROL helps students feel that people do indeed view them as scientists. This improvement is important to consider in the context of the other questionnaire items. The pre-visit results of the other items showed that, despite seeing themselves as scientific, they thought that other people do not see them as scientific. This locates the issue not within themselves, but in the way that other people perceive them. It appears the WROL helps convince visiting students that other people do indeed see them as scientific because the mentor's perceptions of them aligns with views of themselves.

Chapter five summary

In this chapter I have presented quantitative data which suggests that visiting the WROL has little effect on students' levels of science capital. Although statistically significant changes

were observed in two questionnaire items, 'I want to become a scientist' and 'Other people think of me as a science person', when aggregated with the other questionnaire items into composite variables, the effect was annulled. Overall, the quantitative data show no statistically significant difference in the components of science capital measured before and after visiting the WROL.

The lack of significant change is largely attributed to the starting position of the visiting students. Many students had pre-existing aspirations for careers in science, demonstrated high self-efficacy, they already valued science and scientists and knew the utility of science qualifications. The pre-existing conditions left little scope for positive change. This student quote summarises the lack of observed changes:

Well, I liked science to start with and I still like at the end so it might not have necessarily changed my view that much (S8)

It is hypothesised that the initial high scores are in part due to the partner school's culture and ongoing WROL/school relationship, which acts to instil the importance of science and qualifications as well as giving students high aspirations and self-efficacy from Year 7. Indeed, although the science capital framework helps identify important dimensions of one's relationship with science, students from a socio-economically deprived area in London are not automatically lacking in each. Previous research has shown how students, even from historically underrepresented backgrounds have high aspirations for themselves, (Harrison & Waller, 2018) and already value science and scientists (Archer et al., 2013; Jenkins & Nelson, 2005). This suggests that targeting efforts towards specific dimensions of science capital is prudent. The results from this study suggest two items in particular: 'People like me work in science', with the majority (53.85%) of students responding with 'Neither agree nor disagree' and 'Other people think of me as a science person', with 63.97% of students disagreeing or strongly disagreeing. This suggests that this is an area which should be the focus of future outreach efforts.

Although the high starting-point may explain the lack of significant changes of many of the questionnaire items. Some consideration must also be given to the questionnaire items where positive changes were matched by negative movement, annulling any statistical effect. For example, in the questionnaire item 'When I grow up, I would like to be a doctor or work in medicine'. The polarisation in views was interpreted as students with positive pre-existing views having their preconceptions verified and vice versa, those with negative preconceptions have their opinions confirmed. While the WROL cannot convince all visiting students, it is

important to consider when the WROL may act to reinforce negative conceptions of science. The qualitative data in this chapter suggests that a ‘business as usual’ approach is not effective to disrupt any pre-existing negative views of science. For example, the students who perceived school science as ‘hard’ because of the maths content did not have their views disrupted by visiting the WROL. This has implications for the pedagogies used in the WROL, perhaps the session with that student might be improved with a lesser focus on maths, or with further scaffolding to support maths development. The pedagogy of the WROL is further explored in section 6.2.4 and suggestions are made in section 7.2.

The data collected in this chapter also highlight the value of employing a mixed-methods approach to research. While the quantitative element was invaluable, the group interviews raised several supplemental points which not captured in the science capital survey instrument. For example, the students’ views on the importance of mentors and authentic science experiences were a particularly dominant themes within the interviews which help deepen the analysis of the questionnaire data.

The next chapter addresses question three: ‘What are the features and pedagogical practices of the WROL?’, which provides further insight into possibly why no statistically significant changes in science capital, nor the constituent components, were observed.

6. Chapter six: Research question three- What are the features and pedagogical practices of the WROL?

This chapter presents the data gathered during observation in the WROL, to help answer research question three, concerning pedagogy in the WROL.

The fieldwork was initially guided by Millar's (2009) Practical Activity Analysis Inventory (PAAI). After analysis of the interview data (Chapter 4), the focus of observation was changed—it became important to widen attention to other practices in the WROL, which relate to other forms of science capital. This chapter describes results from both observation frameworks.

6.1. Initial observation using the PAAI

The PAAI framework firstly examines the broad 'general objectives' of practical activities. Most frequently, practical activities in the WROL were focussed on developing scientific skills and skills-based outcomes (49% of sessions observed), rather than conceptual learning or learning 'how science works'. The activities commonly (46%) aimed to teach students how to 'use a piece of equipment or follow a practical procedure that **they have not previously met**' (as opposed to reinforcing existing skills). As the aim of the WROL is to allow students to complete practical work not provided in school, these data are unsurprising. This outcome is supported by the comments made by teachers during interviews (section 4.2), where the value of conceptual learning was seen as less important than other outcomes.

The PAAI further revealed that practical activities in the WROL are largely 'closed' in their design. The classic Schwab-Herron scale (Henige, 2011) describes how open or closed laboratory activities can be. An 'open' activity is one which gives students lots of choice; with an open problem, different 'ways and means' to resolve the problem and allows them to 'discover' undisclosed answers. An 'open' approach most closely reflects a true scientific investigation. Conversely, a 'closed' activity gives students a shorter leash; students are given the question, told how to proceed and even given the answer before data collection. Observation using the PAAI showed that most activities in the WROL were closed in design. 68% of sessions at the WROL gave students a question to investigate and detailed instructions on how to proceed. 24% of sessions gave students a question to answer but left *some* choice of how to do so up to them. Only 7% of sessions allowed students a free choice in how to answer a given question and no session gave students the opportunity to develop their investigative skills. Despite this, there were still instances where critical thinking was required from students

within the practical. For example, on 5/2/19 an experimental protocol offered students conflicting information and the following exchange occurred:

Student: *When the protocol says 10 seconds and 30 seconds, which is it?*

Academic leader: *Good question, your choice. If it goes wrong, you can blame me and then try again!*

In another example, during an astrophysics session (21/11/19), students were given some autonomy in following the protocol. Field notes describe how students were given power supplies, signal generators and oscilloscopes. They were then given a briefing on how to use them safely, but subsequently were given the freedom to “*try to set it up yourself*”. Students then had the opportunity to experiment with different frequencies, waveform types and the voltage (amplitude) before being a set task.

The majority (73%) of practical activities observed in the WROL were organised with students collecting data and attempting to interpret this information using theories that had been provided by the academic leaders. Most practicals that were observed at the WROL were ‘confirmatory’ practicals (Gatsby Foundation, 2017), where the outcome is known from the outset and the data collected are used to corroborate established theory, thus validating the academic leaders’ presentation. A minority of practicals (15%) allowed students to derive their own theories (typically based on prior knowledge from lessons in school).

Observation with the PAAI showed that it was possible to complete practicals in the WROL with little pre-existing scientific knowledge. Presentations before practical activities usually involved concepts, theories, or models relevant to the practical activity (61% of sessions) or the equipment and procedures used (51%). Academic leaders also made explicit links to previous schoolwork in 49% of sessions. However, these theories and concepts were not fully linked to the practical activity themselves. This was typified by a didactic presentation to start the session, followed by practical activity which was implicitly connected. For instance, it was quite possible to complete the ‘Newspaper bridge building’ activity, without understanding structural mechanics. The scientific ideas from the presentations were therefore deemed to be ‘unimportant’ or ‘not very important’ in the practical work in 63% observed sessions. Practical activities that do not require much scientific knowledge have been termed ‘cookbook’ practicals (Boz & Boz, 2005), where students performatively follow a procedure, collect data and present superficial findings with little regard for the underlying theories. Indeed, 73% of sessions in the WROL had students following standard operating procedures, yet only half required students to actually decide if a given theory applied to the data collected.

This suggests that the domain of ideas and the domain of observables are disconnected (Millar, 2009) and hence may contribute to some teachers' statements that learning of curricular knowledge may have been better in school (section 4.2).

The activities themselves were presented to students by a variety of means. Most sessions involved the academic leader explaining the practical orally (90%). Activities not explained orally by the academic leader were usually carousel activities, where students would sequentially visit 'activity stations' around the WROL and mentors explained there instead. Visually projected instructions were also presented in 81% of sessions and written worksheets (worksheets are further discussed below in section 6.2.4) were provided in 85% of sessions. Giving students information in various ways may support their practical activities but reflects the 'closed' nature of the activities (above).

Class discussion *following* the session rarely completed the educational story; only 35.9% of sessions concluded with a conversation about the practical activity. Academic leaders frequently ran out of time to sum-up the practical work and 51% of sessions had no discussion at the end to draw the concepts of the day together. This represents several missed opportunities to strengthen the links between practical work with theoretical science in the WROL.

In summary, the PAAI provided a descriptive snapshot of how practical activities were being used in the WROL. The data above show that the activities were mostly designed to achieve skills-based outcomes, specifically to allow students to learn how to use kit which they had previously not encountered. This is, however, at the expense of conceptual learning. The data show that procedural practical work was the focus, leaving little room for true experimentation or theoretical discussions.

6.2. Observation using the novel science capital framework

Following the observation using the PAAI and analysis of the interviews with teachers, it was determined that a novel approach to capture a broader range of data was desirable. The science capital observation schedule was developed. Thematic analysis (section 3.2.8) revealed four key themes in the WROL:

- Teaching students about how to access science at HE
- The use of science media and cultural references
- The use of language (both scientific and non-scientific)
- The use of traditional school pedagogies

Exemplar vignettes and recorded conversations from the fieldnotes are presented below to show how each of these practices either built science capital in students or presented opportunity to improve the pedagogy in the WROL.

6.2.1. Teaching students how to access science in HE institutions

A criticism of the existing school provision is that students are not taught adequately how science qualifications are transferable in the labour market (Archer et al., 2015). Teachers and academic leaders in Chapter four: **Research question one- What are the desired outcomes of the Wohl Reach Out lab?** described how they wanted students to interact with practising scientists and use the experience to gain knowledge about entry to HE. Students and mentors were frequently observed discussing this and was a key theme when practices observed in the WROL were analysed. Data indicate that visiting the WROL helped students learn how to enter courses in science at university and beyond.

The formalised application and admissions processes for HE have been found to be burdensome to students. Gorard et al. (2006) suggest students find the process both dull and bureaucratic. Visits to the WROL allowed students to discuss the system for application with mentors, the very people who had recently navigated this process successfully themselves. This type of conversation is typified by the following brief interaction overheard during a Year 7 session on 20/5/19:

Student: *“Wait, so how hard is it to get into this school? [referring to the Imperial College London]”*

Mentor: *“It has changed a bit since I started, but we have something called ‘entry requirements’ which are the grades you need to get in and they depend on your subject. A lot of the time you don’t pick super specific subjects, I chose chemistry and then I did lots of different types of chemistry and then specialised in my third year, so you start with a general course and then go on to specialise. Every different university will have different types of physics courses, every university will have different chemistry courses.”*

The mentor here is explaining some of the ‘basics’ of the university application to the young student, who likely has little to no knowledge of HE. Fundamental information about higher education was also experienced in the following interaction about the role of this post-graduate student:

Student: *“So are you staff or student at the university?”*

Mentor: *"Kind of both, I'm doing research as a student, but I get paid because I am doing my PhD"* (13/6/19)

While much of this information may seem self-evident to those embedded within the everyday practices of HE, mentors encouraged students to think explicitly about university specific details. Observation frequently noted how students had unpretentious misconceptions about HE; for example, they frequently misused basic university-specific terminology. Students used what they saw as school-based equivalences: *'lecturer'* became *'teacher'*, *'lecture'* became *'lesson'*, *'university'* became *'college'* or *'school'* and students sometimes asked about *'homework'* instead of *'coursework'*. While these terms are somewhat interchangeable, using them at university would potentially 'out' students as not being familiar with the specific terminology. When students used these terms, academic leaders and mentors would often explain to visiting students how HE differed.

While teaching younger students HE-specific terminology was useful, the older visiting students received guidance on navigating the difficulties inherent in the university application system. Navigating the university admissions process can be difficult for most students, but it is far more burdensome for students from underrepresented backgrounds. In addition to requiring knowledge of a subject to be studied and the advantages of having social connections, research has highlighted the importance of 'knowing the ropes' (Whitty et al., 2015). Considered another way, the 'navigational capacity' of an individual is determined by their previous experiences and stock of cultural capital (Bok, 2010). Students from families without knowledge of HE are less likely to be able to explain to their offspring how they could navigate the application process, Bok (2010) compares it to performing a play without a dress-rehearsal or script. Observation showed that mentors frequently provided sixth-form students with guidance on the logistics of the university application process, or indeed a 'script' to follow. For example, conversations about choosing a suitable university and a possible course (which may not be happening in students' homes). On 21/11/18 mentors were observed giving a list of various criteria which could help make a decision between HE providers: close to home/far away, campus/city, university rankings, one mentor even contributed to the discussion by describing how some university comparison websites publish the gender ratio. During the 5/11/18 session one mentor used her own experiences to reassure uncertain students on how difficult it can be to choose a university to apply to. She stated that when choosing a university in London the choice is almost subjective and that she personally decided based on tube station architecture. Mentors in the WROL further helped students with information regarding which courses were available at which institutions:

Mentor: *"I don't think Imperial does offer a history BSc."*

Student: *"Is there any Russel Groups [sic.] that do history?"*

Mentor: *"I know that lots of universities that do history, I know Cambridge does history, I'd check each of their websites, or UCAS"* (13/6/19)

One mentor explained the difference between medicine and a course for paramedics (30/4/19). Another mentor gave more detail of why they chose their own course: *"I chose my degree to be as broad as possible because I wasn't sure what I want I want to do in the future"* (28/3/19). These conversations help visiting students explore options and rationalise the choices made by current undergraduate students.

Tuition fees, student finance and the debt burden of university remain a consistent concern for students from less advantaged backgrounds (Connor, 2001). Market research conducted by Imperial College London, has highlighted concerns that potential applicants have about finance, tuition fees, travel-costs and living expenses. The lure/pressure of earning a wage straight from sixth-form can be more attractive than accruing debt (regardless of possible earning potential in the longer term) (YouthSight, 2019). Conversations observed in the WROL support the market research findings. Many visiting students remarked that they were concerned about financing their future studies. However, mentors were also frequently seen to teach students about financial support available. Because the mentors themselves were in receipt of various sources of income to sustain their studies they became a source of information by students. During the session on 5/11/18 students were observed discussing student loans and part-time jobs with the mentors:

Student: *"It's [tuition fees] so much money though"*

Mentor: *"To be honest, it's not that bad. London is expensive, but there's the loan and things which means you can live"*

Student: *"So I could just take the money and not go to uni?"*

Mentor: *"[Laughing] No, you do need to be a student, it's a **student** loan. Although most of my mates have got jobs to help."*

This interaction highlights how mentors in the WROL can reassure students about the possibility of attending university, regardless of their socio-economic status. The mentor also went on to explain the long-term financial benefit of attending university, which went to

reassure the concerns of students about tuition fee debt. The WROL appears to be the first opportunity for many of these students to have a discussion about student finance, student loans and bursaries in a frank manner. The mentors, as undergraduates, have personal insight into challenges and solutions which students' teachers, tutors or careers advisors may not have experienced themselves.

Mentors were also able to give further guidance to students on university admissions interviews. Previous research has shown that interviews are a barrier to HE, which disproportionately affects students from underrepresented backgrounds (Burke & McManus, 2009; Cleland & Palma, 2018). The gatekeeping practices of admissions tutors makes the interview an intimidating prospect. On 21/11/18 a student was observed asking a mentor: “...for the interview, I apparently need to bring a bit of work, what should I bring?”. The mentor was unable to recall bringing schoolwork to their own interview and suggested that perhaps this was only applicable for arts subjects where a portfolio would be required. Another example was observed 14/2/19, with a mentor describing personal experiences of the interview process, to gain a place at Imperial to study medicine: “*I remember my interview; it wasn't so bad. There was [sic.] no trick questions, but they made you think. I just made sure I read my BMAT¹⁸ and CV before, loads of prep. [sic.]*” Although the interview process is more involved than portrayed by the mentor, saying it “wasn't too bad” lowers the pressure for the prospective students.

Later, the mentor discussed some of the legends surrounding the notorious Oxbridge interview process with students. The visiting student explained they'd heard a rumour that admissions tutors asked deliberately perplexing and obscure questions, for example: “*If you were to be a biscuit, what type of biscuit would you be and why?*”. Whether or not admissions tutors actually ask these questions is relatively immaterial, the folklore around the interview process was evidently a concern for the student in question. While discussion of these fabled questions might perpetuate the perception that HEIs are difficult to access, the mentor reassured the students by exposing the ‘*secrets*’ to answering these otherwise inconceivable gatekeeping practices. The mentor explained that the questions had no right or wrong answers, but instead were designed to be explored through discussion, show applicant idea development, problem-solving skills and demonstrate original thought. The conversation seemed to reassure the students—they began sharing tricky interview questions they had heard and attempted to work through them together. This is another example of where the WROL gives students the

¹⁸ BMAT is the BioMedical Admissions Test which students intending to study medicine must take.

opportunity to explore and demystify the HE access and admissions process in a non-threatening environment.

Overall, observation showed that the WROL helps students gain some of the knowledge required to navigate the HE admissions process which they may not otherwise gain at home or at school. Considering the proximity of shared lived experiences between students and mentors (compared to the distance between the experiences of teachers and students) it appears that having the mentors deliver this advice is beneficial (Gartland, 2015).

However, these conversations required two things; students needed to know what questions to ask and they needed time to ask their questions. At the beginning of WROL sessions, the academic leaders would frequently prompt students to ask mentors about HE, but often students didn't know where to start their enquires. Field notes from 16/5/19 record a mentor asking: "*Have you got any questions about Imperial, or university?*"— none of the students asked any questions. Furthermore, no time was formally allocated for these conversations. Most time was devoted to science theory or the procedures involved in the practical activity. Conversation only turned to HE entry during the lulls in teaching or during lunch. It is suggested that relying on students to come up with questions is not the best strategy. Instead, mentors should be encouraged to prompt students when they can, but students need more support in what questions to ask. Suggestions to achieve this are presented in section 7.2.

6.2.2. Using science media and cultural references in the WROL

Science media is a key dimension of Archer, et al.'s (2015) science capital framework. Media references portraying aspects of science were frequently noted during observation in the WROL. For example, during a presentation on space exploration (11/6/19) the academic leader presented a video of the Tesla car which served as the dummy payload during the Falcon Heavy¹⁹ rocket's maiden test flight. On the car's dashboard the phrase "*DON'T PANIC*" can be seen, a reference to the words at the front of the electronic guidebook in "*The Hitchhiker's Guide to the Galaxy*". "*The Hitchhiker's Guide to the Galaxy*" is well-known in the scientific community, but also found success in popular culture. Yet, students in the WROL had evidently not read it, nor listened to the radio adaptation, nor watched the televised versions. When the academic leader asked: "*Does anyone know where 'DON'T PANIC' comes from?*", no students responded. Surprised, the sessions leader said, "*If you want to be a scientist, you **have to** read*

¹⁹ The Falcon Heavy is SpaceX's reusable heavy-lift launch vehicle which is intended to eventually carry human commercial passengers into space beyond low Earth orbit. The launch itself was a culturally noteworthy scientific event, with the live-stream garnering over 2.3 million concurrent viewers on YouTube.

The Hitchhiker's Guide to the Galaxy". Without the experience of reading the book and knowing the wider cultural significance this was unappreciated by students, suggesting that simple exposure to science media is not enough. Indeed, Archer, et al. (2015) use the phrase 'science media **consumption**' (emphasis added), suggesting a higher degree of active engagement is required for science media to be internalised as students' own cultural capital.

The use of cultural references that students did not understand continued in this session. During the launch of the Falcon Heavy, two David Bowie songs were also played on loop: "*Space Oddity*" and "*Life on Mars?*". Again, looking for recognition of this 'nod' to the intersection of science and popular culture the academic leader asked: "*Does anyone recognise the music?*". Again, the students were unaware of the song titles referencing space and the academic leader exclaimed exasperatedly that they really *should* know these. When the songs were explained, the students were, again, nonplussed. This isn't to suggest that David Bowie's music, science and the students' lives *couldn't* be connected. However, this academic leader failed to create a meaningful case for students.

Academic leaders also sometimes struggled to engage with media references when presented by students. For example, field notes from 30/4/19 describe how the student asking their mentor: "*What type of radiation was Spiderman²⁰ bitten by?*". It is then noted in the fieldnotes how the mentor pauses, but then moves the conversation on without acknowledging the question. This represents the academic leader missing an opportunity to engage the student in a conversation around popular depictions of science and science-fiction in which the student was evidently interested. The leader later discussed satellite dishes and referenced the giant satellite dish seen in the 1995 Bond film *Goldeneye* (the film's climax was shot at the Arecibo Observatory in Puerto Rico). The students in the group had never seen *Goldeneye*. Here we see two examples of discordant cultural references. Both *Spiderman* and *Goldeneye* are being used to try and engage science, but the academic leaders' and students' dissimilar backgrounds evidently present a challenge in finding relevant media.

Students were occasionally observed successfully using their own forms of media to engage with the WROL topic. For example, students taking photos of each other during the Forensic Science session (29/3/19). Although the photos were ostensibly for their portfolio of evidence, required for their Applied Science BTEC qualification, they were enthusiastic to share their pictures on social media. Another example was seen during the dissection of

²⁰ Spiderman is a fictional superhero, originally created in the 60s, who featured in several popular films around 2016-19, portrayed by actor Tom Holland.

cuttlefish (5/11/18). One student noted how the cephalopods reminded them of the aliens in the film *Independence Day*. The mentor supervising that group was surprised that such an old film was known by the comparatively young students. Conversation then revealed that the student had actually seen the 2016 sequel, *Independence Day: Resurgence*. The mentor's frame of reference for the original 1996 films overlapped with the student's more recent frame of reference. Further examples include: when observing the diffusion of food colouring (10/6/19) one student remarked how it reminded them of the introduction to *Sherlock* (2010-17 TV series) where blood drips into another liquid. Similarly, *The Martian* (2015), starring Matt Damon as an astronaut stranded on Mars was raised by a student and resulted in much conversation (20/5/19). These examples demonstrate that media references *can* connect students to science when these associations are student-led.

More often than not, media references worked better when presented by students. However, some examples indicate that media reference *can* work when chosen by academic leaders. Academic leaders sometimes leveraged students' existing cultural capital to make links with science. For example, the Mars Rover was described as taking a 'selfie' of itself on the Martian landscape (31/1/19), which resulted in a positive reaction from students. Indeed, 'selfies' have previously been identified as an opportunity through which students from underrepresented backgrounds have engaged with science in informal settings (Dawson et al., 2019). The 31/1/19 session on Astronomy was noted as the only session in which computer games were used by an academic leader. To make a connection between the students' lives and science *Kerbal Space Programme*²¹ was referenced. It was clear from the students' reactions that some (but not all) had played the game. The link between scientific modelling of orbits by astronomers and the game meant that the gaming students had a supplementary association between the scientific field and their free time. Although this was only a brief moment in the WROL, previously computer games have been noted to engage students, particularly in science education (Dezuanni, O'Mara, & Beavis, 2015; Egert & Phelps, 2011; Ellison & Evans, 2016). They have also been used as a tool for students from BAME backgrounds to engage with issues concerning social justice and narratives about their own culture (Ellison, 2017).

Overall, these examples show that academic leaders should be careful when choosing media references. Observation data suggest that discordant references can cause students to

²¹ *Kerbal Space Program* (KSP), is a computer game which allows players to simulate modular rocket building, the physics engine has been particularly praised for its orbital mechanics, which permits real-life orbital manoeuvres such as Hohmann transfer orbits and bi-elliptic transfer orbits.

disengage. Student-led references helped forge connections between students' everyday media consumption and science. Media references made by academic leaders occasionally worked when they align with students' existing cultural capital. Finding the common ground by refining academic leaders' media references could provide an opportunity for better connecting students to science (recommendation made in section 7.2).

6.2.3. Use of language in the WROL

Language can be understood as cultural capital which is an indicator of the level of inclusion or exclusion in a social group (Bourdieu, 1991). It is self-evident that being able to converse scientifically is a pre-requisite requirement for science participation, and therefore language forms an integral part of a science identity (Claussen & Osborne, 2013). Archer et al.'s (2015) first dimension of science capital is '*Scientific Literacy*' and '*Talking to others about science*' is a further dimension in their framework. The academic leaders' and students' use of language in the WROL was a significant theme within the observation data. Below, the data are split into two strands, firstly the academic leaders' use of scientific language and the extent to which students were also able to engage with it. Secondly, the students' attempts to use their own lexicon in the WROL and how this was received.

6.2.3.1. Use of scientific language in the WROL

The scientific language used by academic leaders in the WROL was often beyond the comprehension of the visiting students. While the scientific community relies on functionally efficient and precise language, this is achieved through formal 'rules' which can seem 'dull and alienating', in contrast to everyday experiences (Lemke, 1990: 133-134). The use of inaccessible language was exemplified in the WROL on 28/1/19. During the academic leaders' presentation on biotechnology students were presented with highly technical information about CaMV 35s terminator genes, with little about the concepts or terminology required by students to help them understand. During their explanation, the academic leader realised their presentation was not conveying the concepts well. Students had stopped listening and the leader decided to skip the information on the slide altogether. This is an example of where the information in the lecture presentations was not seen as important for the subsequent practical activity. Field notes from the 25/3/19 session gives further evidence of how students were being bombarded with scientific language: "*they [the academic leader] uses lots of 'forces' terminology (new motion, body, vector, statics and dynamics, equilibrium, member etc.), are students following?... Lots of assumed prior knowledge*". While these terms are not beyond the comprehension of most Year 8 students, the academic leader used them without checking their previous knowledge or defining the key-terms. Tomkins and Tunnicliffe (2001) have shown

that students undertaking scientific work without adequate previous knowledge have a limited potential for learning and this may even introduce misconceptions.

The assumption that students had the pre-requisite language to follow WROL presentations often left them behind. For example, (17/5/19) after several minutes into an explanation of waves and after the mentor had repeatedly used a key-term, one confused student interrupted: “*what do you mean by vibration?*”. This fundamental explanation had been skipped and the student could not make the connection between an oceanic wave and the vibration in sound waves that the mentor was describing. During a demonstration of the wave-tank, the mentor gave this definition of transverse waves to students: “*You need to know that; ‘Transverse waves: where oscillation is perpendicular to the direction of propagation’. This is a really good exam answer so you should probably write that down*”. The students then asked the mentor to repeat their answer several times so they could write the definition verbatim. While the mentor’s statement is correct, the manner in which this information was presented is unlikely to be remembered by students, as there is little cognition involved in dictation. Ultimately this focus on the formal definition of language, rather than deeper understanding of concepts, is unlikely to encourage further scientific practice. The exam-focus is also contradictory to the desires expressed by interviewees in section 4.2. Furthermore, observation also showed that students often did not keep worksheets (explored further in section 6.2.4 below).

The academic leaders’ use of scientific jargon was particularly apparent during the primary school sessions. When giving instructions on building spectroscopes (19/6/19) the academic leader said to the primary-school students: “*The diffraction grating will go here* [indicates to diagram on board]”, unfortunately the students were not told what a diffraction grating is. The students subsequently became stuck when it came to this part of the spectroscope construction. The mentors eventually guided their groups in terms their students could understand; they clarified that the academic leader was referring to “*the little bits of see-through plastic*”—a more relatable explanation for a nine-year old. This example is indicative of the assumptions made by academic leaders about the level of language and knowledge required by their audience to progress with the practical work.

Several instances were observed in the WROL where students initially appeared to be engaging with scientific language, however, upon probing by mentors the students revealed a superficial understanding of the scientific concepts. For example, when completing calculations as a group, students were asked how to calculate the speed of sound the students

were able to regurgitate the formula: ‘speed=distance/time’ but struggled to apply it. The following exchange occurred:

Student: “*Divide it?*”

Mentor: “*No*”

Student: “*Multiply it?*”

Another student (interrupting): “*Do the mean?*”

The conversation then collapsed into students suggesting vaguely scientific words and phrases, even “*enzyme*” was suggested. Airey and Linder (2009) present the concept of ‘discourse imitation’ “*to characterize discursive fluency without a corresponding experience of the associated facets of a disciplinary way of knowing.*” The students’ use of science ‘soundbites’ and key terms often masked a shallow level of understanding of science for the mentors and academic leaders. This was often observed in practical activities, where students (when asked) could share the title of the procedure given at the beginning of session but would often struggle to explain *why* they were doing it or how it worked in scientific terms.

The use of scientific language typically failed when the academic leaders were covering new concepts and the associated terminology was unfamiliar to students. In contrast, sessions where visiting students had already covered the pre-requisite scientific theory in school and therefore had the technical language requirements, were much more successful. For example, during the ecology session on 10/6/19 students were expected to fill in a glossary table of key terms (producer, consumer, autotroph, biome etc.) which students had covered in the preceding lesson in school. While not the most exciting task, students used their prior knowledge and worked collaboratively to reach consensus definitions, finishing the task relatively quickly and largely correctly. This ‘quick win’ resulted in students congratulating each other, as well as being confident in using the key terms correctly in the remainder of the session.

Overall, the use of scientific language in the WROL reflects the findings of Claussen and Osborne (2013) who suggest that, as a form of discourse, the academic language associated with science acts as a barrier to participation for students from non-scientific backgrounds. The use of certain terminology, which *could* be understood by students, was not clearly explained by the academic leaders and served to exclude them from fully engaging conceptually with the topics, as well as inter-personally within the scientific field. A simple remedy here would be to take the time within sessions to check prior understanding of key terminology and where gaps exist, to carefully define the language for students, so it can become part of their vocabulary.

6.2.3.2. *Use of students' lexicon in the WROL*

In the WROL, students from the partner school were regularly observed using language and diction, which would widely be regarded as 'not scientific' and directly contrasted with the formal tone normally associated with HE. Below, exemplar instances are presented where students tried to use their own linguistic resources, with limited success.

An example of a student trying to use their own use their own lexicon in the WROL occurred during the DNA workshop on 28/1/19. The academic leader begun the session by asking about the group's understanding of molecular biology laboratory techniques and asked what the thermocycler might be used for during polymerase chain reaction (PCR)²² practical, one student enthusiastically responded: "*It makes **bare** DNA fam!*". The student chose to answer a question in a manner which actively resists the dominant discourses of science (Brown, 2004). This colloquial response deserves some 'translation'; where '*bare*' actually means the opposite of its traditional meaning, the student is using it to say, '*a lot of*'. '*Fam*' is an abbreviation of 'family' and is used to refer to people that are extremely close; as if a family member. This answer is, in general terms, scientifically sound—the student showed an understanding of PCR that it produces a lot of DNA. The students' response was also combined with a term of familiarity where the student identities the academic leader as a someone that they can relate to.

Initially, the interaction was noted as an example of a student managing to use their language within the scientific field, their diction was accepted and therefore legitimised. Alone, this interaction could be seen as an example of inclusive practice in the WROL. However, the students' attempt at engaging with the session was rebuffed by the academic leader's response: "*Can we say that in a more scientific way? Like you would in an exam?*". The academic leader's request to 'formalise' the student's answer dismissed the student's personal mode of discourse as 'incorrect' and reinforced the primacy of learning science solely for formal qualifications, rather than learning science for personal relevance or enjoyment. The student was able to re-phrase their response in an institutionally acceptable manner, but they were evidently cowed afterwards and reluctant to answer further questions. By dismissing the students' personal cultural resources and reinforcing the dominance of established discourses, the academic leader excluded the student from participation (although not physically). This interchange is also supported by Brown (2006), who found that students were able to absorb

²² Polymerase chain reaction (or PCR) is a widely used lab technique used to make copies of DNA. PCR is a technique which is widely recognised as an indispensable technique for biology students to master.

the epistemic elements of science (the answer showed a correct understanding of the concept), but find it more difficult to engage with discursive practices.

It must be noted that students using non-scientific language were not always rebuffed in such an overt manner but excluded more passively. During a presentation on the chemical concept of the mole, one student was heard calling out excitedly: “*He’s my boy, Avogadro*²³!” (14/2/19) (Here ‘*my boy*’ is used as slang term to express a close male friendship). Despite the hubbub around the room and opportunity to share the students’ excitement the academic leader appeared unsure of how to react to the students’ language and continued with their presentation without acknowledging the students’ enthusiasm for Avogadro. In another session, after having the ripple tank demonstration by the mentor, a student exclaimed “*That is 200 IQ!*” and looked to his peers for approval, the small group of students chuckled as the mentor was left perplexed, “*I have no idea what you’re talking about*” and moved the session on rapidly without enquiring further what the student meant. ‘200 IQ’ is a reference to an online gaming meme, where a player’s intelligence is referenced hyperbolically (sometimes satirically) after an impressive move or play. The student here was attempting to compliment the mentor and convey they were impressed by the ripple-tank demo. The use of their esoteric colloquialism briefly allowed the student to bring their ‘non-science’ life into the WROL. However, by rapidly moving the session on the student’s reference was ultimately rejected.

These two instances are indicative of several occurrences where students attempted to challenge the ‘normal’ (and hegemonic) discourses of the scientific community. Ultimately, the power dynamic always returned to favour traditional science discourse when the academic leaders moved the conversation on, often without acknowledgment or even rebuff. Ignoring students when they are not using formal language reinforces the idea that they are not part of the scientific community. These examples (and those from other studies e.g. Godec, 2017) show how the expectation of ‘talking scientifically’ and silencing of non-scientific language contribute to the exclusion of students from non-traditional backgrounds. These vignettes can also be considered as an instance of ‘symbolic violence’ (Bourdieu & Passeron, 1977; Claussen & Osborne, 2013) in the WROL.

Overall, the academic leaders in the WROL rely heavily on the assumption that the scientific language they used is shared commonly with visiting students. However, this is not the case and subsequently the students’ exclusion from science discourse was apparent. Simply

²³ Amedeo Avogadro was a scientist who is best known for “Avogadro’s constant”, the number of atoms found in one mole of a substance: $6.02214076 \times 10^{23}$.

being surrounded by scientific terminology was not sufficient for students to learn its meaning and then use it correctly. The academic leaders use of technical vocabulary cannot not be passively absorbed into students' everyday lexicon, instead it should be taught explicitly. Recommendations on this are made in section 7.2.1.

6.2.4. Use of traditional school pedagogies in the WROL

Observation in the WROL revealed that pedagogical practices from traditional 'school culture' were prevalent. Although it is difficult to define precisely what is meant by school culture, Carlone's (2004) conceptualisation of the 'prototypical science education' describes the normative and taken-for-granted practices which commonly occur in science classrooms. Elements of 'prototypical science education' were commonly noted in the field notes. Results show several parallels between sessions in the WROL and practices which may be seen as 'typical' or mainstream in science lessons.

Questioning is an integral pedagogical tool and forms an essential part of the educational dialogue in any teaching environment, the WROL is no different. Questioning allows the person leading the session to gauge students' pre-existing knowledge, assess progress and check understanding. However, during the observation in the WROL it became apparent that high pressure questioning techniques used by the academic leaders would make students uncomfortable, contrary to the inclusive atmosphere which would build positive dispositions towards science.

Numerous instances of closed questioning were noted, and academic leaders would often ask questions to the whole group and only one student would have the opportunity to answer. The questions also mostly relied on yes/no answers or factual recall. For example, during the session observed 11/6/19 on space rockets, the academic leader started their session promptly by asking: "*Does anyone know what methane is?*". While this question may have been designed to elicit students' understanding of fuels and begin a discussion, field notes describe how the question was asked without warning, students looked at each other uncertainly and the question remained un-answered. The academic leaders continued and asked about the parent concept: "*Do you know what hydrocarbons are?*", again, there was no response from the class. The academic leader was evidently expecting the students to have at least some prior knowledge of these concepts and was surprised by the lack of response, they subsequently had to improvise an explanation for these concepts and rushed through some hydrocarbon theory on the board.

Later in the session, perhaps in an attempt to get any response from quiet class, the academic leader posed an easy conceptual question: "*How do you make a gas from a liquid?*".

This question required students to recall basic factual information from their earlier scientific education— by Year 10 students should know about raising the temperature of a liquid and evaporation. However, the students were now aware that the academic leader would progress with the session, regardless of anyone answering questions. As a result, there was little incentive for students to volunteer and ‘risk’ the emotional cost of answering incorrectly in front of their peers (no matter how easy the question). Subsequently, this question also went unanswered, apparently perplexing the academic leader— they declared exasperatedly how they could not understand why students could not answer such a simple question about evaporation. In fact, upon my later questioning during the practical element of the session it was clear that students knew about methane, hydrocarbons and evaporation. They could have answered the academic leaders’ questions easily, but the questions were not framed in a way which students felt confident enough to participate.

In part, the problem with this academic leaders’ questioning approach is asking the whole group and then relying on an individual student having enough confidence to propose an answer. From the perspective of the children, they have just entered a novel educational environment, some of them may view formal educational establishment as places where they do not feel welcome, especially if not congruent with their own family backgrounds (Archer et al. 2016; Dawson, 2014). They have just been introduced to the session leader, who was frequently described as an academic expert and the students are having their knowledge tested by this person, alongside their peers. Although questioning is a standard practiced in school, it is not an emotionally neutral exercise for the students. Questioning in the WROL was often seen to be intimidating and students were evidently uncomfortable with the class-wide approach; pupils were shifting in their seats or taking great efforts to avoid eye-contact with the academic leader. This whole-class approach also meant that most sessions were dominated by a small handful of confident students. Academic leaders tended to rely on a few enthusiastic students to prevent awkward silences, occasionally academic leaders would recognise this and say: “*how about someone else?*”, but often would return to the reliable contributor.

The problematic questioning was further exemplified during one of the earliest sessions observed, where the post-grad student running the session led with: “*OK guys, have you done PCR before?*”. Again, this question only allows students a yes/no answer. The question is open to (mis)interpretation as to what ‘doing PCR’ actually means; is the academic leader asking whether the students have previously covered the theoretical concepts in school, or is the academic leader asking whether the students have physically carried out the procedure? The

students, again, did not respond and sat in awkward silence. Unlike the previous example, instead of marching on through the session this academic leader upped the ante: “*If no one volunteers, I’ll have to pick someone to answer!*”. Most of the students looked even more uncomfortable, with furtive glances at each other to see if anyone will succumb to the social pressure to answer, again avoiding eye-contact with the academic leader lest they were chosen to answer. One adventurous student eventually volunteered that they “*have done some of it at school*”. The academic leader then proceeded through their powerpoint presentation, covering theoretical concepts and the students also went on to complete the practical in the afternoon as well. It is unclear as to the purpose of the initial question, if the information gleaned from the student showed a great understanding of the topic, would the leader have skipped the presentation? If students had previously completed the practical, would they have skipped the practical activity? Regardless, the question served little purpose to the session and students were evidently uncomfortable.

It might be tempting to conceptualise the interactions above as the students not engaging with the session. However, this disregards the *reasons* for students’ reluctance to answer questions in the WROL. The widening participation literature talks extensively about how students from underrepresented backgrounds do not feel as if they ‘fit in’ science institutions (Dawson, 2019). Students from these backgrounds with different cultural capital have previously been found to be reluctant to contribute in class (even after educational intervention aimed at making science more ‘open’) (Archer, et al., 2018). As it currently stands, questioning in the WROL does not create an environment in which students with low science capital feel relaxed and this is unlikely to create a positive sense of belonging.

Although the evidence above suggests that the questioning within the WROL which makes science less inviting and excludes students from participation, it can be readily amended using simple pedagogical techniques to be more inclusive. Suggestions are presented in section 7.2.1.1.

Another element of prototypical science education observed in the WROL was the abundant use of worksheets. The PAAI observation (above) found that 85.4% of session had students use worksheets as the students’ record of their practical work. Some ‘carousel sessions’ with several ‘stations’ for students to visit, had as many as five different worksheets for students to collect at each table (e.g. session on 30/4/19). Worksheets are ubiquitous in the UK education system. They have also been found to support learning within the informal learning contexts (Nyamupangedengu & Lelliott, 2012). However, despite the potential benefit

and common use across the science education sector, observation the WROL showed that worksheets were not always conducive to learning.

For example, the worksheet used on 25/3/19 asked students to ‘fill the gaps’ in incomplete Newton’s laws. This activity assumed that students already knew Newton’s laws, as no information was given on the worksheet, nor were Newton’s laws presented in the presentation at the beginning of the session. Therefore, if students didn’t already know the answer this task was essentially impossible. Indeed, one student was overheard as describing the sheet: “*Ugh, this is long*” (where ‘long’ is used in a pejorative sense, to describe effortful task, which is not considered worth the effort). This task could be used as a revision activity but was not particularly beneficial without any theoretical priming beforehand.

As such, the sheets were often left abandoned by students, strewn across the lab benches at the end of the sessions in the WROL. Sometimes efforts were made by the teachers or mentors to reunite the worksheet with the associated student and cries of “*Who’s worksheet is this?*” often followed students out into the corridor while they collected their bags. This suggests that students view the worksheets have a single-use purpose and, beyond the context of the WROL, the information will not be useful.

Nyamupangedengu and Lelliott (2012) suggest that worksheets can be used in post-visit learning to extend the students experiences beyond the immediate session. Indeed, when this idea was suggested during the interviews (27/3/18) the academic leaders said: “[It] *Depends on the teacher...several times the teachers have said 'make sure they take these worksheets, because we will build on them in class' and that I think is really amazing and great, I wish it happened every time.*” However, they then conceded: “*But to be honest, I think mostly these worksheets guide them through the session*” another academic leader was equally pessimistic: “*I don't think they'll go back for reference, I don't think they'll go back and read them*” (10/4/18), so even if taken away from the WROL, their further use is questionable. This suggests that the worksheets are most useful in procedurally helping students through the practical work and somewhere to jot down practical results, rather than for learning theory.

Despite academic leaders’ use of prototypical classroom practices, there were occasional instances of academic leaders trying to move students away from making comparisons between the WROL and school. On 5/2/19 the academic leader begun the session with a precis: “*I want to have a chilled-out day, not too stressful. If you want to ask anything, just ask. No need to put your hands up and say 'Miss'. You’ll make feel dead old!*”. Similarly, on 7/5/18: “*The whole point of today isn’t just to learn the content that you need to know for the exams, but we want you to engage with science and work independently*”. These comments

try to distance the WROL from school, yet conflict somewhat with the practices actually used by the academic leaders (above). The academic leaders' attempt to shift students' perceptions of the WROL, away from 'school science' is well intentioned and recognises that students' experiences of science in school may not always be positive.

The attempt to differentiate the WROL from school science and school norms did however have some unintended consequences. In moving away from school norms, students sometimes pushed the boundaries of behaviour. While there were no observed instances of overt and deliberately malicious misbehaviour, some low-level disruption, not expected by their teachers, was observed. For example, this was apparent on 8/5/19 when the academic leader asked for the attention of the class students continued with their practical work and the academic leader asked several more times before their normal class teacher interjected: "*Come on guys, I don't want to have to shout to have to get your attention, you wouldn't be like this in my class, don't be like this here*". This shows how students' behaviour changed as a result of being in the new WROL setting and may be a response to the 'not-school' atmosphere.

Although there is a large body of literature which shows how common school practices contribute to the exclusion of students from unrepresented backgrounds (section 2.1.2), this example highlights how certain school practices have legitimate basis e.g. not talking while the session leader is trying to give information. The WROL therefore represents a strange 'hybrid space'. The academic leaders often suggested that the WROL *isn't* school, yet many of practices within the WROL are comparable to school.

Overall, observation showed that the pedagogy in the WROL is heavily influenced by the academic leaders' own experiences of education. This finding is supported by previous research, Bruce et al., (1997) similarly found that university students leading outreach activities, as amateur educators, typically replicate the didactic, textbook-based or lecture approaches they experienced. The use of classroom practices in the WROL therefore requires further consideration. While the educational literature suggests that many classroom practices result in inequitable outcomes, when the academic leaders attempted to move away from 'school', the behaviour of students worsened. Reconsideration of exclusionary school practices is important; however, retention of legitimate logistical practices is also required.

Chapter six summary

This chapter has described events of over 300 observed hours in the WROL. Indicative incidents and exemplar interactions which exemplify the key themes have been presented.

The use of science media was frequently observed in the WROL. Although science media is considered an important dimension of science capital (Archer, et al., 2015), and

frequently used in the WROL, the media used often did not allow students to internalise it as their own capital. Instead, science media frequently served to highlight instances where students were not *au fait* with science culture. Occasionally, students' and academic leaders' cultural references were aligned, and students' cultural resources were recognised. When this occurred, it was seen as an inclusive practice in the WROL.

Similarly, the use of scientific language in the WROL, while considered as an important form of science capital, it was frequently used in a way which could not be internalised by visiting students. The use of overly complex scientific language without adequate explanation served to exclude students who did not have the required pre-existing knowledge. Unfortunately, observation also showed that students' own linguistic cultural capital is often rejected from the WROL.

Observation also showed that the pedagogical practices used in the WROL were largely informed by traditional school culture. The evidence highlighted how academic leaders in the WROL engage in, what Carlone (2004) describes as, 'prototypical science education' and reproduce their own classroom experiences (Bruce et al., 1997). This was manifested in the WROL in several ways: use of high stakes questioning, use of didactic presentation and worksheets. Because common pedagogical practices are those which already act to marginalise students, it is suggested that 'more of the same' is not desirable. Academic leaders sometimes attempted to distance the WROL from comparisons to school, but the extent to which this was achieved is questioned.

Finally, evidence was presented that showed how mentors in the WROL help demystify the tacit aspects of HE for students. Students were given advice on how to choose which university and which courses to apply to, information regarding finance and guidance on admissions interviews. This information was seen as particularly valuable coming from the undergraduate mentors. The closeness of overlapping identities between the students and the mentors allowed a more informal transfer of information, akin to the trusted 'hot sources' of information found in previous research (Gartland, 2015). Overall, conversations on HE arose 'organically', during the lulls of practicals rather than as a concerted effort. It was noted that students were often prompted to ask questions about the admissions process, this approach assumes that students know what to ask about.

Overall, the WROL represents an intersection between the school, the scientific community, HE and students' own lives. Each of these social fields brings certain norms and practices, some of which helped align students with science, others replicated exclusionary practices which distance student from science or HE.

7. Chapter Seven: Conclusions, recommendations and limitations

This thesis began by describing how current patterns of participation in science are inequitable and this concern was a key issue for in developing this study. During the work, the formal education sector was explored as a potential source of this inequality and informal science education proposed as a solution to widen participation. The school-university partnership based in the WROL has been described as one such initiative to encourage participation and was evaluated during this project. This study borrowed from Bourdieu's and Archer's theorisation about cultural and science capital. A mixed-methods case-study approach was used to address three questions:

- What are the desired outcomes of the WROL?
- Does visiting the WROL increase students' science capital?
- What are the features and pedagogical practices in the WROL?

Data were presented in chapters four, five and six. The key findings from each study are now summarised before being drawn together to provide a holistic picture of the school-university programme. On the basis of these findings, recommendations to improve the practices within the WROL are made with a view to improve its mission of making science more attractive to all school students, irrespective of their background. The limitations of this project are also explored and discussed. Possible areas for future research are also considered.

7.1. Key findings and contribution of this study

7.1.1. Question One: What are the desired outcomes of the WROL?

The first question focussed on the perspectives of two key groups of those who participate in the WROL. These are the teachers who visit with their students and also the academic leaders who run the sessions. The success of school-university partnerships relies on shared goals (Kim et al., 2013) and this question was designed to determine the extent to which views of the two groups were aligned.

Results found that teachers and the academic leaders were broadly united in their opinion of the purpose of WROL and how it may achieve its goals. The interviews indicated that both groups were critical of the provision of science in schools and this encouraged their belief in the value of the WROL. Both groups wanted students to use scientific apparatus to which they would not have access at school. As well as specialised equipment, interviewees wanted students to use everyday science objects, such as lab coats. Such items were seen as important by participants in helping students to form a material connection to science (cf. 'identity artefact mentioned by Calabrese-Barton et al., 2013). The amount of time available

for science practicals in the lab was also regarded as a benefit by both academic leaders and teachers.

Both the teachers and academic leaders rejected outcomes which simply improved knowledge of facts in the curriculum. This was grounded in a criticism of the focus of school science towards formal examinations. Most interviewees expected extra-curricular understanding instead. Teachers were more unanimous in asserting that the WROL should not emulate school science. Most academic leaders agreed with the teachers, but some academic leaders wanted to deliver syllabus content to try and improve exam attainment.

Finally, both groups thought a key advantage of the WROL was that it encouraged students to interact with practicing scientists. Interviewees hoped this would challenge science stereotypes and mentors would provide students with information and guidance on procedures for entry to a university course.

7.1.2. Question Two: Does visiting the WROL increase students' science capital?

This question was designed to identify changes in the attitudes and perception of students following their visit to the WROL. Using a modified version of Archer's Science Capital questionnaire, students were asked sixteen questions before and after their visits to the WROL. These questions were collated into four composite variables and reflected dimensions of science capital most likely to be changed by their visit.

No significant changes were seen in the levels of science capital after laboratory visits. Nor were there significant differences in composite variable scores before and after attendance in the WROL. This lack of change was attributed to two issues. Firstly, the high starting position of the responses of the students. Many students had pre-existing aspirations for careers in science, high self-efficacy, already valued science and understood the value of science qualifications. Their pre-existing levels of science capital left little scope for positive change. Where positive changes in response were seen, any statistical effect was annulled by a negative change elsewhere. This was interpreted as the WROL reinforcing pre-existing views. So, when students showed a pre-existing positive attitude, their views were strengthened. Unfortunately, the converse was also true, the negative views that students exhibited about science were also reinforced.

Only when individual questions were analysed were some significant changes seen. Students' responses to both: 'I want to become a scientist' and 'Other people think of me as a science person' showed a statistically significant increase as a result of visiting the WROL.

The quantitative data in this chapter were further supported by focus groups with students. Data from the focus groups broadly aligned with the questionnaire results. Students' pre-existing views (positive or negative) were either reinforced or unchanged by the visit, rather than a uniform positive movement.

7.1.3. Question Three: What are the features and pedagogical practices of the WROL?

The final question was designed to explore the inner workings of the WROL to learn how science capital might be increased to encourage widened participation in science. The question was addressed by observation in the WROL and data revealed common features of sessions delivered by academic leaders.

The fieldnotes were critically analysed and showed how student-mentor interactions often resulted in students learning directly about the higher education application process, life at university and what a career in science might involve. Data also revealed that media references were used to variable effect in the WROL. When students' cultural references were recognised, this was seen as inclusive practice. However, when discordant media references were presented by academic leaders, or students' cultural references were ignored, this served to highlight how students were not already part of the scientific community. Furthermore, science language used in the WROL was often incongruent with the students' own language. Observation also revealed that 'traditional school science' was a significant influence on the practices used in the WROL, for example, academic leaders aligning their sessions with curricular knowledge, using hands-up questioning and worksheets. Academic leaders would refer to their own earlier educational experiences and often replicate them in the WROL. Again, the replication of school science appeared to reinforce, rather than challenge students' views about science.

7.1.4. Tension between formal/informal learning and the dominance of qualifications as science capital

This study highlighted a tension between formal and informal learning in the WROL and in science education more broadly. It has also re-affirmed that the dominant cultural capital, most valued in science, are formal/institutionalised qualifications.

Data gathered in this project add to the existing evidence that raises concerns about formal science education. Interviews with both teachers and academic leaders (Chapter 4) support the prevailing criticism of formal education established in the literature (sections 1.2.1 and 2.1.2). The academic criticism and the views of the interviewees offer a rationale for less formal programmes such as the school-university partnership in the WROL. This study

clarified the expectations of the stakeholders that the WROL will do things differently to schools. Indeed, the views of teachers followed the logic of Archer, et al. (2018), who suggest that the application of science capital theory may offer “...*ideas for how things might be ‘done differently’ in the ongoing struggle for a more socially just education system*”.

Nevertheless, despite the expectations that things would be ‘done differently’ in the WROL, the influence of formal school science was still evident in the pedagogy of academic leaders (section 6.2.4). Observation showed that ‘school science’ and a focus on traditional pedagogies influenced by exam-focus influenced the choices made in the WROL.

The findings between these two sets of data are contradictory. Why would the academic leaders persist in replicating their school experiences in the WROL after the teachers (and many of the academic leaders) had criticised many elements of school science in the interviews? Herein lies a tension in the WROL and wider science education community. Formal education provides students with the knowledge needed for examination and qualifications. These qualifications can be seen as institutional cultural capital (Bourdieu, 1986). There is little doubt of the value of qualifications as capital in the science sector; without institutionally recognised qualifications they are unlikely to be accepted in the scientific community (no matter what other science capital a student accumulates). Therefore, incorporating formal elements of schooling in the WROL is reasonable. As Brown (2006) argues, it “*would be nearly impossible*” (quoted in Claussen & Osborne 2013) to achieve social mobility without any exposure to the dominant forms of capital; in this case, formal qualifications.

The persistence of the practices from school science in the WROL may also go some way to explain the lack of significant results in the science capital questionnaire (Chapter 5). The science capital questionnaire is not designed to capture students’ understanding of formal curricular content. Instead, the measurement of science capital is largely related to students’ emotional connection or personal relationship to science.

Zipin's (2005) work (as described in section 2.1) helps explain the apparent contradiction between the interviewees’ desires and the academic leaders’ actual practises. Zipin (2005) puts forward two possible approaches to social justice in education: *redistribution* of dominant forms of capital (e.g. formal qualifications) or *recognition* of non-dominant capital (e.g. students’ non-curricular interests). Redistributing valuable capital can provide students with the resources to thrive. However, this approach reinforces the dominance of certain capitals over others and non-dominant capitals are devalued. Zipin’s alternate approach, *recognition*, reevaluates the importance of non-dominant capital and disrupts the power of the

dominant capital. However, again there is a problem: this approach denies students' access to the existing dominant capital which might otherwise improve their life prospects.

The two impulses (redistribution and recognition) are contradictory and therefore present a paradox: both are required but each is liable to criticism. This current study suggests that the impulse to redistribute dominant forms of science capital overshadows the recognition of students' existing science capital in the WROL. Observation showed how the academic leaders rarely called on the students' lifeworld or existing knowledge to help them forge connections with science. Indeed, instances were observed where students' existing stock of capital was rejected as 'not scientific'. The view that 'doing science' and 'doing school' are strongly associated is well-established (Varelas, Kane, & Wylie, 2011). By focussing on the dominant forms of science capital in the WROL, this idea is reinforced.

Claussen & Osborne (2013) ask a pertinent question: "*Whether the dominant cultural capital has an intrinsic justification... or whether it is simply a product of a sociohistorical context... is a long- standing matter of debate*". Archer et al.'s (2015) concluding remarks are also relevant here: "*is science capital a 'good' or 'bad' thing? Many sociologists regard capital as negative and problematic, in that it is integral to the reproduction of inequalities. Yet many educationalists may see it as a hopeful concept, in that it offers the promise of changing social inequalities.*" This debate continues. As it stands, the WROL occupies a difficult educational position. Should it challenge the current focus on science qualifications and try to bring value to the students' existing science capital? Or should it accept the argument for the overriding value (and 'natural' justification) of formal science qualifications and give students 'more school' to ensure they absorb the pervading science capital, regardless of the other important dimensions?

7.1.5. Reconciling formal & informal learning: The WROL as a hybrid/third space?

Throughout this thesis and other works (e.g. Braund & Reiss, 2006) the divide between formal/informal education is often presented as a binary. This is a false dichotomy. Evidently, the WROL isn't simply 'more school'. Even with the presence of elements of formal school, there are also elements of the WROL which are radically different (some of them are discussed in chapter 6). Lin & Schunn (2016) present the idea of 'semi-formal' science experiences, which enrich school curriculum but also build new skills and enrich students' interest in the subject. They go on to argue that:

“...adult providers of these kinds of programmes may be less well prepared in instruction than are science teachers, and they may choose to organise the programmes to be too similar to formal science classes” (p. 2555)

This study suggests that this is what has happened in the WROL. The difficulty in educating ‘differently’ means that academic leaders largely revert to the ‘default’ mode of education and the balance lies in favour of replicating formal teaching methods.

To improve the outcomes of the WROL, hybridity (or third space) theory (Bhabha, 1994) may provide some resolution. Hybridity theory recognises that spaces can be the sites of competing discourses, tensions and powers. As such, the WROL is neither a truly formal nor informal educational establishment, it occupies a hybrid ‘third space’. By explicitly addressing the differences between formal and informal learning and rebalancing them in the WROL, the desires expressed by interviewees in Chapter 4 may be realised. Barton, Tan, & Rivet (2008) say that:

“...a third space that has elements of both. This third space is described as a hybrid space because it brings together the different knowledges, discourses, and relationships one encounters in ways that collapse oppositional binaries...” (p. 73)

Similarly, Handscomb, Gu, & Varley's (2014) suggestions for school-university partnerships speak to the idea of hybridity:

“Partnerships are a third space distinct from the culture of the partnering organisations. This “hybrid” space not only draws on the knowledge and discourses of two distinct communities but also facilitates them.” (p. 5)

Although, Handscomb, Gu, & Varley are discussing the difference between school and university, the principle of balance remains, neither partner’s culture should dominate.

If the WROL can come to represent a third space better, balancing the formal/informal, school/home, school/university, scientific/non-scientific then it may reconcile Zipin’s redistribution/recognition impasse where:

“On the one hand we need to redistribute these codes of elite cultural embodiment...on the other hand such redistribution efforts need to scaffold from curriculum that, first and foremost, recognises, valorises and makes use of knowledge from learners’ home and community life worlds (2009)

On the basis of the findings of this study and discussion above, recommendations are now made to improve the outcomes of the WROL, as well as implications for the wider sector

7.2. Implications and recommendations

The various findings of the research present several implications. Firstly, this study has direct applications for the WROL and the pedagogical practices within. Beyond this immediate relevance, this study also has repercussions for the wider sector, which could inform practice and thinking in both formal and informal science education settings.

7.2.1. Academic leader pedagogic training

The findings suggest several modifications to the pedagogy used in the WROL, to help move to a hybrid approach and to rebalance the ‘redistribution/recognition’ approaches and improve outcomes. It is suggested that academic leader training should be used to challenge some of the commonplace educational practices that may actually serve to exclude students from science. Instead, practices which recognise the students’ existing capital (dominant or not) should be encouraged.

7.2.1.1. Improving questioning in the WROL

The first recommendation is to ‘soften’ academic leaders’ approach to questioning. Observation in the WROL showed that academic leaders tend to use questioning methods which create an environment where students feel uncomfortable (section 6.2.4). For example, academic leaders asking the overly-broad question ‘what do you know about topic X....?’ and cold-calling on students, without allowing them any time to consider their answer.

Questioning in the WROL can be easily improved by training academic leaders in simple techniques. For example, instead of asking for volunteers to share with the class immediately, students could discuss collaboratively with their table to write down what they know about the topic, before sharing their ideas with the wider group. This method allows students to try out ideas within a small group, lowering the embarrassment of being incorrect. It also allows students with less to contribute, to learn from their peers and to have time to prepare mentally for speaking publicly.

Additionally, techniques such ‘think, pair, share’ (Kaddoura, 2013) can be used to give students time to develop their answers. When students are posed a question, they are given time to ‘think’ independently, then prompted to discuss their ideas with the person next to them (in a ‘pair’), and then finally ‘share’(ing) with the whole class. This simple technique lowers the social pressure of answering a question; students are allowed to collaborate, in pooling their ideas they are actively thinking about the concepts and are more likely to be prepared to answer in front of everyone.

7.2.1.2. *Making the language in the WROL more accessible for students*

Secondly, the use of scientific language in the WROL was seen as an obstacle to student engagement. In section 6.2.3, several examples were presented where academic leaders used overly technical scientific and academic language. The implicit use of specialist science terminology meant students could not follow the session. These observations were additionally supported by teachers who thought that content was being pitched too highly for their students (section 4.3). Furthermore, students' own language was sometimes dismissed by academic leaders or mentors, even when students demonstrated understanding of scientific concepts or showed enthusiasm towards science (section 6.2.3.2). This could lead to students feeling less welcome, but can readily be remedied in the WROL.

One approach to making the language in the WROL more accessible could be to ask academic leaders to moderate or avoid using advanced terminology. This approach however may deprive students the opportunity to learn important scientific language. Learning how to use scientific language is an integral part of engaging with science. Indeed, scientific literacy is the first dimension of science capital (Archer, et al., 2015). Therefore, it is suggested that academic leaders should not shy away from scientific language, but rather than assuming students understand, they should instead be selective and explicit in defining key terminology from the outset. Greater dialogue, before sessions, with the class teachers would help in this endeavour. Where terms, previously not covered, are required for students to engage in the session, academic leaders should be sure to make careful and explicit definitions. This would allow students to engage with the language of science and the science itself in the WROL in the future.

Furthermore, academic leaders should be mindful that students may express themselves using non-standard English or language which is traditionally considered 'not scientific'. When this does occur, academic leaders should take care to not over 'police' students' language. While it might be appropriate for schools to 'correct' language for formal examination, the findings highlight the strength of the WROL in not being considered a school. Allowing students some leeway in their diction helps soften the barriers to engaging with science on their own terms, rather than feeling as an outsider because of their language.

Reflections here are reminiscent of the dilemma presented by Delpit (1988) and Zipin (2005). Removing all scientific terminology and allowing students to use their own language may help students feel welcome in a scientific setting, this however denies them full access to the language required to fully engage with the community in future. It is therefore necessary to teach them the language of science, this however reinforces the primacy of a language which

can be alienating (Lemke, 1990). A compromise is therefore required, children must be carefully taught scientific language in the WROL and also allowed to use their own language to express their scientific understanding. As it currently stands, the balance between the two requirements currently leans towards the former— formal science language in the WROL dominates. Overall, the recommendation is to ‘soften’ the language, make sure specific terminology is taught explicitly and ‘non-scientific’ language is not so heavily controlled.

7.2.1.3. *Using appropriate media and congruent cultural references*

Another theme to emerge during observation was the use of media references in the WROL (e.g., TV and film). As discussed in section 6.2.2 the cultural references used by academic leaders were often incongruent with visitors’ own cultural backgrounds. Additionally, when the students used their own cultural references, academic leaders unaware of the allusion would pass over the students’ remarks. Therefore, despite the hopes of the interviewed stakeholders in this study (chapter 4) the connection between mentors and students was sometimes dissonant.

It is recommended that the cultural references used in the WROL in future are more closely aligned with the students’ backgrounds, to help them feel more in-tune with the culture of science. Academic leaders should carefully consider the media they use in sessions. They should ask: *Is it a cultural reference that students are likely to understand? If yes, will the students value it, understand its relevance and will it help them make connections to science? If no, can it be explained in a meaningful manner in the sessions so that students can understand why it is relevant to them and valuable for scientists and them as individuals?* Ensuring that students and the WROL have a common frame of reference may go some way to help students feel like they belong in the scientific community.

That is not to say that all references to culture need to be completely tailored to the latest trends, recent movie releases or popular music which may be relevant to children. To attempt to stay completely up-to-date may create a cultural ‘arms race’, where academic leaders struggle to keep up with students’ ever-changing interests, which become rapidly outdated. Indeed, students may value certain media, precisely because they aren’t officially recognised by formal institutions (i.e. the WROL or Imperial). As soon as adults appropriate elements of youth culture, they cease to be enjoyable for teenagers or children and therefore lose their value. Academic leaders clumsily referencing cultural capital valued by students risks patronising them.

It is therefore safest to use media that has broad appeal, which has both cultural relevance to the students and also links to science. The discussion observed in the WROL

regarding *'The Martian'* is a good example. *'The Martian'* is a science-fiction, age-appropriate, popular film, released three years prior to the visit. This meant that many of the visiting students had seen it and could discuss the science and themes on an equal level with the mentors and academic leader. One may argue that *'The Hitchhikers Guide to the Galaxy'* also has universal themes (evidenced by its enduring legacy), however, in the context of the WROL and students from the partner school, a radio-play (from 1978) and book (1979) has limited relevance to students' lives, unless explicitly made clear.

It is further recommended that students are given opportunities to connect science with media, rather than the academic leaders deciding on their behalf which media references are relevant. Evidence from chapter 6 showed that, given the opportunity, students were quite capable of making links between their own culture and science. When students make these connections, they need to be encouraged, recognised and validated by the academic leaders. Even if the cultural reference is 'foreign' to the academic leader, part of encouraging the students into the culture of science means allowing them to bring their own interests into the fold.

7.2.1.4. Use of worksheets in the WROL

Further thought should be given to the use of the worksheets in the WROL. As they are currently constructed, the worksheets often rely on 'fill-the-blanks' activities which are impossible to complete without pre-existing knowledge (section 6.2.4) Observation highlighted how the worksheets were often not completed and left abandoned at the end of WROL sessions.

Worksheets are ubiquitous in education, but this does not automatically make them effective for learning or meaningful for students. Ransom & Manning (2013) suggests that educators ask themselves two questions before photocopying worksheets: "*Do they truly support learning? Are there alternatives I can use that better enrich the students' experience?*". Because this project has recognised the WROL's forte in practical science, it might be tempting to suggest that worksheets are abandoned in favour of more practical activities. However, reading and writing about science is an important and often overlooked element of science education (Osborne, 2015; Pearson, Moje, & Greenleaf, 2010) and worksheets can still be used to support learning in out-of-school contexts (Nyamupangedengu & Lelliott, 2012).

To improve the use of worksheets in the WROL explicit consideration must be given to the purpose of each worksheet and whether the task achieves this. For example, the worksheet discussed in section 6.2.4 nominally helped students learn about Newton's laws by asking them to 'fill-the-blanks'. This task may help in memorisation of stock phrases but did

little to meaningfully engage the students with these important concepts. The worksheet task can be improved so students learn about Newton's laws more meaningfully. For example Atasoy & Ergin (2017) found that embedding conceptual cartoons helped students engage in learning about Newton's laws and this improved learning outcomes. Conceptual cartoons that reflect the practical activity may help here. Beyond the Newton's laws worksheet, most WROL activities have an associated worksheet which should be critically reviewed.

7.2.2. Use observation for academic leader feedback and development

Alongside the academic leader training, it is suggested that a scheme of observation and feedback is used to improve the pedagogy in the WROL.

The current training for academic leader roles in the WROL currently requires novice leaders to observe experienced leaders, before moving to co-leading with the experienced leader, then leading sessions alone. During the interviews, some academic leaders expressed regret that, after training, they were largely unaware of what other academic leaders were doing in their sessions. This gap provides an opportunity for further training and improvement in the WROL.

Peer-observation is a well-established means of training and developing educators (Dillon et al., 2020; Joyce & Hassenfeldt, 2020). It is suggested that a programme of academic leader peer-observation would be beneficial to the culture and pedagogy of the WROL. Peer-observation would allow academic leaders to watch each other, collaborate, share pedagogical practices that they thought were effective, critique ideas and give feedback on each other's sessions.

While the suggestion to implement peer-observation is intended to allow the sharing of good practice amongst the academic leaders, this is not guaranteed. This study has highlighted elements of 'prototypical' science education (Chapter 6) used in the WROL. It has also previously been shown that incorrect, yet popular, educational theories are common in novice educators (Menz, Spinath, & Seifried, 2020), indeed, 'learning styles'²⁴ were mentioned several times during the interviews with academic leaders. With peer-observation there is a risk that educational misconceptions will be repeated and promoted. Although the training suggested above may help address some misconceptions about education it is suggested that observation and feedback is also undertaken by someone with some formal educational training.

²⁴ There is a vast body of literature which criticizes 'Learning styles' as an educational theory (e.g. Menz, Spinath, & Seifried, 2020 and reference within), yet it is popular and persists even within education.

This recommendation is also suggested with caution. Any observation in the WROL must be framed as formative; it must be made clear that the intention of feedback is to help academic leaders develop their pedagogy, rather than a summative assessment of their teaching ability. If feedback is overly negative or punitive, it is possible that academic leaders may be reluctant to sign up for future leading opportunities. There is a fine balance to be struck between formalising the role of academic leader, to improve the pedagogy, but also maintaining the informality to maintain the good-will of volunteers.

7.2.3. More ‘take-away’ science artefacts from the WROL

Both the interviews with academic leaders and teachers showed how they wanted students to access objectified science capital (section 4.1.1) and observation showed that the WROL achieved this by engaging with science artefacts. Although the rare or expensive science equipment accomplished the stakeholders’ aims, more mundane science objects (e.g. labcoats) were also seen to engage students in everyday science practices. Furthermore, the science objects which students created themselves (e.g. cardboard spectrosopes or rockets) were evidently valued by the students. The cost or rarity of the science objects appeared unimportant to the students, much of the value was symbolic, ownership or access was enough to forge an emotional connection.

An additional benefit is also predicted with science objects that students can take home from the WROL. Students that were most keen to take their science objects home were motivated by sharing their science object and their WROL experiences with their families. The importance of young people discussing science at home is already well established (Alexander et al., 2012; Archer et al., 2012; VanMeter-Adams et al., 2014), yet parents with low cultural capital might be unlikely or unable to discuss science at home with their children.

There are few existing WP programmes which help parents/guardians in having conversations about science with their children. Most existing WP work focusses interventions towards students in school or informal settings, rather than attempting to encourage science in the home. This subsequently represents a neglected area in science outreach. It is suggested that take-home artefacts may help in this area. It is therefore recommended that academic leaders are encouraged to plan sessions where students make science artefacts. Take-away items from the WROL may introduce science into homes where science might not be a typical topic of conversation. Of course, practical activities with a ‘take-home’ element may increase the cost of consumables within the WROL, but as discussed these can often be relatively inexpensive. The proposed benefit of take-home science objects is assumed, so this also

presents an area of further study; it would be useful to follow-up with students to see if such objects did indeed facilitate science conversations in their homes.

7.2.4. Giving students enough knowledge to ask questions on accessing and navigating university

Section 6.2.1 describes how the mentors in the WROL gave students advice on navigating the HE application process. However, these conversations often relied on enquiring students to ask question during lulls in the practical activities. Although mentors may ask “*Have you got any questions about Imperial or university?*”, observation showed that this was too open, and students could not think of questions to ask.

For this reason, it is suggested that students are given some pre-work before visiting the WROL. Students should be given some pre-written questions to ask the mentors and academic leaders. In their session introductions, academic leaders often highlighted that the mentors were a source of knowledge and that students may want to ask them questions. They did not suggest *what* questions to ask. This part of WROL sessions is a good opportunity to suggest some questions that students could ask: “What is your favourite part of university? How did you apply for Imperial? What is the most surprising thing about university you’ve found? What is one piece of advice you would give your sixth-form self? etc. These conversation prompts would allow students to think about HE and what might be important and help them begin their own discussions with the mentors. The conversation prompts retain some elements of the ‘organic’ conversations, without relying too heavily on just presenting information to students didactically.

7.2.5. Is the WROL targeting the right students with this partnership?

The results of the science capital questionnaire (section 5.2) showed no major changes between the pre-visit and post-visit responses. The lack of significant change was largely attributed to the starting position of students’ views on science; many students had pre-existing aspirations for careers in science, high self-efficacy, they already valued science and scientists and knew the utility of science qualifications— these pre-existing views left little scope for positive change.

This unfortunately raises the question whether the students who come to the WROL are the correct target for intervention. To preserve the anonymity of students in this study, the school that is partnered with the WROL has been anonymised. However, nominally these students come from a socio-economically deprived area in London, which might initially suggest that students would have low levels of science capital. However, results in this study show these students have high levels of science capital (in the dimensions measured) and these

students may be more likely to participate in science than originally expected. Further work may be required to analyse the student population of the school to ensure they are indeed unlikely to participate in science.

There were two questionnaire items which were answered less positively, indicating gaps in science capital which the WROL can bolster: ‘People like me work in science’ and ‘Other people think of me as a science person’.

To address the first item; this study has highlighted the importance of students seeing people ‘like themselves’ in science; data from the interviews and observation have shown that mentors’ identities overlapping with students’ is necessary. However, there was scant evidence that identities were explicitly addressed in the WROL, instead there was a reliance on implicit recognition by the students. It is suggested that rather than avoiding the topic (as suggested by one academic leader) any commonalities between student and mentor identity are highlighted in the WROL.

The second questionnaire item (‘Other people think of me as a science person’) was one of only two items that showed WROL increasing students’ science capital. This item doesn’t relate directly to the students’ self-perception, instead it reflects how they think others view them. Mentors and academic leaders gave positive affirmations during WROL sessions to the competencies of the students’ as scientists, challenging the students’ initial belief that others don’t think of them as scientists. This positive result is encouraging and provides evidence to support the assertions of the importance of mentors made by the academic leaders and teachers.

7.2.6. Wider implications for the science education sector

This research supports previous critiques of formal science (explored in section 1.2.1) and has implications to improve school science. The existing view that science in classrooms is overly focussed on exams, lacks relevance to students’ lives and practical science is at risk of marginalisation is borne out empirically in this study. The interviewed teachers and academic leaders in this study reinforce the existing perception of school science being singularly focussed toward exam success (Nott & Wellington, 1999; Hodson, 1992). While the importance of formal qualification is acknowledged as a key form of science capital, the weight of interview comments suggests the sector might re-consider the time, attention, effort and status given to such a restricted set of outcomes. It is suggested that a greater value is given to both 1) other subjects and 2) ‘other’ science qualifications. Achieving ‘parity of esteem’ between different qualifications and subjects is by no means an easy feat. For example, attempts to measure and normalise the relative value of different qualifications through UCAS

Tariff points system have struggled to affect change; achieving three Distinction *s in the Applied Science BTEC National Extended Diploma would nominally merit the same 168 UCAS points as three A*s at A level, yet some universities will only accept the more highly regarded A level qualifications. Indeed, schools should consider broadening which students are studying these qualifications and universities should consider broadening their acceptance criteria to alternative or vocational qualifications. By challenging the hegemony of narrow formal qualifications, other forms of science capital may become more highly regarded, what ‘counts’ as science would be expanded, and more students would be able to participate.

Another concern raised by participants in this study is the threat to practical science in classrooms. It is recommended that efforts are made to protect or strengthen the provision of practical science in formal settings. The benefits of practical science have been well explored in the existing literature (section 1.2.1) and are supported by comments in the interviews here (section 4.1). However, it appears that the prioritisation of exam content threatens the time available and quality of practical science education. Furthermore, the physical infrastructure and equipment available to schools falls short of what teachers want. Indeed, despite the widely accepted importance of practical science, the provision in school has been of concern, in policy and previous studies (section 1.2.1). While this study recommends *more* practical science in schools, it must be good quality practical science, not just ‘cookbook’ (Boz & Boz, 2005) or ‘confirmatory’ practicals (Gatsby Foundation, 2017).

Similarly, consideration should also be given to the formal science curriculum. Part of the teachers’ rationale for visiting the WROL is the authenticity it brings to students’ experiences, which contrasts with their conceptualisations of classroom science. The science curriculum taught in the classroom should be made more authentic by grounding content in children’s lived experiences. To this end, wider application of the science capital teaching approach (Godec, King & Archer, 2017) in classrooms would be useful.

Another implication of this study, for the formal science sector, is the consideration of science career advice. The students visiting the WROL were given advice on both science careers and on accessing university (section 6.2.1). However, previous research has described career advice in the UK as ‘patchy’ (Moote & Archer, 2018). Formal education providers should consider opportunities like visiting universities and engaging with employers to give their students access to this information.

Finally, the formal sector should consider the language through which science is communicated. Evidently some standardisation and technical language is to be expected and has legitimacy within the sector, however, this study has reinforced the views of Claussen &

Osborne (2013), who consider the language of science as ‘symbolic violence’. The findings presented in section 6.2.3 show how scientific language can be inaccessible to students not familiarised with it. Furthermore, students’ own language was considered unscientific. If the language of science were to be ‘softened’, this might allow more students to engage with it as an academic subject.

Overall, the implication of this study for the formal science sector, if it is to become more equitable, can be summarised as: 1) challenge the narrow focus on exams/qualifications, 2) increase provision of authentic practical science experiences, 3) improve the authenticity of the curriculum, 4) create further opportunities for career advice and information on accessing university for students and 5) consider the acceptable discourse used in science. These recommendations are made with the explicit acknowledgment that many of the issues raised in formal science education are deeply systemic. The dominant forms of science capital and practices which perpetuate their value are not readily altered. To challenge the hegemony of, for example, science qualifications, and not negatively impact the life chances of students will require public change, rather than altering individual’s qualifications.

This research also has implications for *other* science outreach providers and informal science settings.

Firstly, this study highlights the importance of carefully considering pedagogy when undertaking informal science outreach. Section 6.2.4 of this thesis describes how easily science outreach can revert to ‘the norm’ and replicate classroom practices. ‘Classroom science’ is perhaps the most common form of science education and Varelas, Kane, & Wylie (2011) remind us that ‘doing science’ and ‘doing school’ have become closely aligned. However, some consideration should be given to whether this is desirable as the default approach. Section 1.2.1 of this thesis outlines several shortcomings of formal science education, particularly with regard to practices which result in inequitable outcomes for students from underrepresented backgrounds. ‘More of the same’ and replication of inequitable practices is unlikely to address these issues. A considered approach to a different type of pedagogy is required. It is acknowledged, that some science outreach *does* deliberately focus on supporting students’ formal academic studies. In these programmes it may be suitable to apply more ‘traditional’ pedagogies, and these efforts are not to be discouraged (especially considering the importance of academic qualifications).

This study also reinforces the need for stakeholders and science outreach providers to be aligned on desired outcomes. Although most science outreach efforts are grounded in a general social justice mission, given the myriad of potential outcomes from science outreach

initiatives, it is recommended that goals are intentionally set. While most of the participants in this study were in agreement as to the aims of the WROL (sections 4.1 to 4.3), there were some dissenting views. Aligning views in other outreach programmes could be a collaborative exercise at the outset, where the community around the outreach project develops their ‘Theory of Change’ (Sullivan & Stewart, 2006) model to define the context, inputs, activities, outputs, intermediary and desired long-term outcomes. It is also suggested that outreach projects periodically revisit their goals, desired outcomes or ‘theories of change’ models to avoid ‘mission drift’.

Other outreach providers should also give careful consideration to who the beneficiaries of their programmes are. This study has shown that students from the WROL partner school had high pre-visit responses to several dimensions from the science capital questionnaire (section 5.2), which raised some questions about intervention targeting (section 7.2.5). While it may not be practicable to assess each students’ background prior to each visit, strategic guiding principles could help organisations prioritise their work. For example, working intentionally with state schools that serve a higher proportion of pupil premium students may be more beneficial than working with students that have the privilege associated with private schools or other ‘low-hanging fruit’. While broad socio-demographic metrics may be a ‘blunt’ means of considering eligibility, identifying students most deserving of additional support may help address social inequalities in an intentional and purposeful manner.

7.3. Limitations of the study

Despite precautions taken during planning (chapter 3), limitations affect all research projects. Limitations are typically categorised in two: the methodological and the theoretical.

7.3.1. Methodological limitations

This study utilised a mixed methods single case research (MMSCR) approach, with the rationale for this being described in chapter 3. MMSCR borrows from both the quantitative and qualitative paradigms, bringing together the benefits of both. Unfortunately, this approach also brings associated criticisms from both paradigms.

7.3.1.1. Observation limitations

The criticism typically levelled against observation is its susceptibility to observer bias (Simpson & Tuson, 2003: 18). Either because of ethnographic ‘blind-spots’ or because of deliberate selective observation. Although not perfect, to lessen potential bias, observation schedules were used to pre-determine which events were ‘*significant events*’ (Simpson & Tuson, 2003: 25) or ‘*critical incidents*’ (Cohen, Manion, & Morrison, 2011: 464).

Observation in research is a demanding activity and data may still have been missed. Although a schedule was used to guide and focus observation, constant and rigorous observation is impossible over extended periods of time. Observer fatigue or attention deficit (Cohen, Manion, & Morrison, 2011: 473) may have meant that examples of significant events in the WROL were sometimes overlooked. However, the extensive observation across many sessions means that data saturation is likely to have been reached. The purpose of observation wasn't to collate anecdotes, but to determine common occurrences (or 'demi-regularities', Fletcher, 2016). Even if an instance was missed, if the event was occurring frequently enough then it is likely other instances would have been noted in other sessions. Because thematic analysis was used to determine common themes across several sessions, individual data-points were of little consequence.

Finally, demand characteristics or so-called '*Hawthorne effects*' may have had an effect on the data collected during observation (Cohen, Manion, & Morrison, 2011: 473). The very presence of an observer may influence the system under investigation. For example, an academic leader may have put extra effort into their delivery, or a student may have been more reluctant to contribute to a session if many adults were present. Although covert observation techniques were considered in the planning of this study (chapter 3), for ethical and logistical reasons it was considered that overt observation was still preferable.

7.3.1.2. Interview limitations

Despite efforts to build rapport (Henn et al., 2006: 163) to elicit frank and open discussion (section 3.2.1) some students were reluctant to give extended answers during interviews. Encouraging these students to expand their comments was sometimes difficult. Interviews with students were also limited to 20 mins; this was an intentional limitation so they would not miss too much of their lunch (an important element of the day, which allowed them to interact with the mentors in a more informal setting). Some interviews were cut short because it was time for the session to restart in the WROL. This was particularly frustrating if the interviewees were providing comprehensive answers. Nevertheless, participating in research should not negatively affect the students, so interviews were drawn to a close when required.

Conversely, adult participants were much easier to build rapport with. However, it is possible that 'over-rapport' limited the data collected (O'Reilly, 2012). During this study, meaningful relationships were developed with several of the academic leaders and teachers. Over-rapport risks the objectivity of interactions. Much like demand characteristics (above) it is possible that interviewees gave responses that they thought were desirable for the interviewer, rather than what they thought was correct.

7.3.1.3. *Questionnaire limitations*

One of the limitations of questionnaires is the accuracy of responses. Adolescents have previously been found to respond inaccurately for two reasons: due to carelessness or confusion, secondly, deliberate false response by ‘jokesters’ (Fan et al., 2006). Again, consideration was given at the planning stages to account for these responses. For example, certain statistical techniques exist to ‘trim’ the most extreme answers (Robinson-Cimpian, 2014). However, this approach may still remove respondents with legitimate views. Overall, it was decided that keeping potentially spurious answers was less damaging than deleting genuine fringe opinions.

The science capital questionnaire used in this study was deliberately limited to the dimensions which would reasonably be affected by WROL intervention. By omitting the constructs which were unlikely to change (e.g. parental qualifications) the science capital scores in this study are not comparable to previous studies which used the same survey instrument. Archer, et al. (2015) already caution that their instrument may not capture the complexity of a construct as multifarious science capital, so the questionnaire used in this study certainly misses aspects of science capital that may be important.

7.3.2. *Theoretical limitations*

Although this study has utilised Bourdieu’s concepts it is not overtly ‘Bourdieuian’. For example, this thesis has followed the example of Lareau (2011) in being informed by Bourdieu’s theories, but not using his language. A strict sociologist or Bourdieu adherent might see this as a limitation of this particular study.

Although nuance is attractive and often demanded, it is not necessarily a virtue of good sociological theory (Healy, 2017). Much like Charles Darwin’s theories form the foundations of a modern geneticist’s work, it is unlikely they will extensively reference ‘*On the Origin of Species*’ or ‘*They Voyage of the Beagle*’. Similarly, while Bourdieu’s theories have become ubiquitous in educational research (Reay, 2004) the academic field has moved on significantly since their initial conception. It is suggested that contemporary educational researchers must be mindful of his work, but it is not necessary to get entrenched in the minutiae.

One particular criticism of Bourdieu’s theory, that this study tries to overcome, is the lack of practical redress. Watkins (2018) describes Bourdieu’s work as leaving “*little room for capacitation*”. Bourdieu’s criticism of education is absolute, his declaration that “*All pedagogic action is symbolic violence insofar as it is the imposition of a cultural arbitrary by an arbitrary power*” (Bourdieu & Passeron, 1977) means that *anything* an educator does is liable to

criticism. As such, this theoretical cul-de-sac is disheartening to anyone seeking to practicably improve education.

However, contemporary theorists have attempted to move on from the impasse presented by Bourdieu. For example, Archer, et al.'s work is "*underpinned and driven by a commitment to equality*", intended to have transformative and practical application (2015), this study follows their example. However, this does require some departure from Bourdieu's fundamental 'standard model', for which this study may be liable to criticism. Reay (2004) argues that Bourdieu's concepts are rarely made to "*work in the context of the data and the research*". It is hoped that, by using case-study approach to apply theory intentionally, rather than liberally, this research goes against this trend. The practical recommendations (above) are *directly* applicable to the work of the WROL. Because of this, it is hoped that distance from Bourdieu's original work and pure theory are justified.

7.4. Possible future directions of study

As with any study, this research has not resulted in omniscient understanding, it has raised several further avenues of interest and presents numerous opportunities for future research.

7.4.1. Other programmes in the WROL

While there were several benefits to focussing on the school-university partnership programme in detail (section 3.2) the WROL hosts many other programmes. The same justifications for evaluating the school-university partnership programme apply to the other programmes and each is deserving of in-depth academic research.

The remaining WROL programmes evidently share some features with the school-university partnership programme; they are focussed on practical science, students have access to equipment, sessions are facilitated by both academic leaders and mentors with the ultimate aim of widening participation. There are also several very important differences which are of particular research interest. Where do the other WROL programmes fall on the formal/informal science education spectrum? Which elements or practises of school-science are used, which are not used? Do these programmes increase students' science capital more than the school-university partnership? If so, which practises are most significant in achieving these increases?

As an initial exploration, key programmes are briefly described here. The 'STEM Potential' programme is a long-term cohort programme for students in Years 10-13. Students are engaged for an extended period, during the time they are studying for their GCSE and A level courses. The programmes comprise of a series of lectures, workshops and a (non-residential) summer-school. Students on the programme will periodically visit the WROL for

masterclasses in the evenings, weekends or school holidays. Sessions are sometimes unrelated to the curriculum, but around exam time revision sessions tailored to improve exam success are added to the agenda.

The extended nature of STEM potential programme, on a concentrated group of students is of interest. By the end of STEM potential, students are frequently on first-name terms with academic leaders or other outreach staff. This is contrasted with the school-university partnership which manages to engage a large number of students over an extended period of time (most students from the partner school will visit the WROL several times during their time at the school), yet the visits are often a year apart, so there is little opportunity for extended relationship building. The concerted focus on a smaller group of students in STEM potential may yield better science capital results (but for fewer students).

The shorter-term but intensive summer school programmes may also provide further insights into potential valuable programme elements. Like ‘STEM potential’, the summer school cohorts are much smaller than the school-university partnership and provide a more intensive intervention. Different strands of the summer schools appear to have varying levels of formal learning which provides the basis for comparative study. For example, the Year 12 residential summer school website states: “*The content ... is similar to what our undergraduate students cover in their first year*” (Imperial College London, 2019c). Alignment with first year undergraduate content suggests formal learning may be a significant programme feature. Whereas the ‘Y11 STEM Challenge’ summer school advertises that it:

“...aims to provide participants with the opportunity to work in small teams to solve current world problems. Focused on how different STEM subjects interlink, participants will use their knowledge of different subjects to creatively develop solutions...” (Imperial College London, 2019b)

The interdisciplinary approach to teaching science contrasts with a modular curriculum commonly found in school science. The differences between two summer programmes and between other programmes are worth further exploration.

‘Pathways to Medicine’ is another programme hosted in the WROL that may provide further elements of interest. This programme is particularly focussed on guiding interested Year 12 students into careers in medicine. The programme aims to achieve this through:

- *taster sessions in different areas of medicine*
- *informative talks by admissions tutors, academics and practicing clinicians*

- *opportunities to meet and interact with Imperial medical students (including eMentoring)*
- *professional insight and university experience days (Imperial College London, 2021)*

The defined outcome of guiding students into medical degrees appears to narrow the focus of the programme. Teaching students how to navigate the university application system is reminiscent of the findings in section 6.2.1 where mentors were observed teaching students how to apply to university. Teaching students this was seen as an effective element of the school-university programme, so if this were the singular focus of ‘Pathways to Medicine’ then positive outcomes are predicted.

Overall, design of educational interventions requires decisions on which elements to include. The WROL provides a rich resource for research, with each programme having slightly different configurations of these elements. It is recommended that further comparative research is undertaken to determine the relative effects of changing these variables.

7.4.2. Other outreach spaces

Although the WROL was one of the first dedicated science outreach spaces in a UK university, due to the WP agenda (section 1.3) several HEIs are now developing or using similar models as part of their Access and Participation Plans.

During this research project, several outreach practitioners from other HEIs visited the WROL, interested in establishing their own dedicated lab space for outreach. They commented how most outreach practitioners in HEIs have to ‘*beg, borrow or steal*’ lab time for outreach purposes. Having the WROL, as a reserved space, was evidently a feature that members in the sector were interested in emulating.

Furthermore, several research organisations (charity and corporate) are also undertaking public engagement and outreach work. With several establishing their own outreach labs as part of their wider social responsibility policies. To name a few: Bayer have established their UK ‘*Baylab*’ in 2017, the Crick Institute have ‘*Crick’s Weston Discovery Lab*’, Vertex Pharmaceuticals have three ‘*Learning Labs*’ internationally and L’Oréal have partnered with the Royal Institute founding their ‘*Young Scientist Centre*’.

The establishment of other dedicated science outreach spaces, both in universities and in corporate organisations, provides further opportunity for research. As above, with the different WROL programmes, each of these spaces will make choices as to the elements included in their educational interventions, each modification may result in different outcomes.

To begin this research, a rigorous (inter)national benchmarking review is required to establish a better understanding of the landscape. Although this current project has generated an informal network of practitioners in different HEIs or other organisations, this has been *ad hoc* and some of the connections resulted from chance encounters at meetings or conferences, rather than a concerted academic approach.

7.4.3. Other age groups and socio-demographic characteristics

Although observation in this study included the four days which the partner school ‘donates’ to local primary schools, students and teachers from these schools were not interviewed. This provides another opportunity for exploration.

The importance of early experiences in science are increasingly being recognised (Archer et al., 2010; Murray & Reiss, 2005). Primary schools are subject to the same shortcomings (Wellcome Trust, 2017a) identified by the secondary school teachers in this project (chapter four). However, much of the WROL’s efforts focus on students’ key transition points; i.e. from secondary school to sixth form, or sixth form to university. By the time students are making choices about their ‘next steps’ their views on science may already be entrenched and an intervention may require a greater impact to convince them that science is for them.

Therefore, it may be beneficial to target interventions earlier and primary school students visiting the WROL represent an area that deserves further investigation. More broadly, the assessment of science capital in younger children has already begun. The original longitudinal ASPIRES tracking study (Archer, et al., 2013) began with students aged 11-18 and continues to follow these students into their 20s in ASPIRES 3. However, Padwick, Dele-Ajayi, Davenport, & Strachan (2016) have started investigating science capital in younger students. By simplifying the language and representing the Likert scales pictorially (using smiley faces) they have adapted Archer et al.’s (2015) science capital questionnaire to make it suitable for 7-11 students. This new survey tool might be further adapted for primary students visiting the WROL.

Although the original science capital questionnaire asks socio-demographic questions, these questions were removed in this study at the request of the ethics committee, ICREC (section 3.3), the rationale being that this was sensitive data. Without this data, the present study could not disaggregate the students of various backgrounds from the study population and examine whether the WROL interventions had differential effect on students from these groups. However, understanding the racial and classes dimension of science participation remains of interest and concern to the sector. If means to gather socio-demographic data are

developed which may pass ethics review, then this would add further insight to our understanding of science outreach activities in the WROL.

7.4.4. Long term tracking of outcomes

One of the difficulties in evaluating widening participation programmes is that if participation is widened, this often occurs some time after intervention. The long-term nature of these ultimate outcomes can make it difficult to attribute causality; it is possible that other factors may have determined participation, extraneous to the original intervention or study parameters. In using science capital as an immediate measure after intervention, any changes could be directly attributed to the WROL. This is somewhat similar to the ‘small-steps’ approach advocated by Harrison & Waller (2017) to overcome the issue of causal attribution.

Nevertheless, this approach does rely on the assumption that science capital is indeed predictive of future participation. This assumption warrants further exploration through longitudinal tracking.

Longitudinal studies have previously been used to assess the effectiveness of outreach programmes (e.g. Banerjee, 2016; Gibson & Chase, 2002; Markowitz, 2004). Longitudinal tracking of WROL participants could also be used, in conjunction with the immediate measures, to further evaluate the school-university partnership and other WROL programmes. This ‘belts and braces’ approach would provide evidence to align any immediate changes in science capital to long-term behaviours.

Coda

The WROL’s *raison d’être* is to make science more equitable. This thesis ends with explicit recognition that the pursuit of social justice is difficult. Many people and initiatives have tried to make the science sector more equitable. They are fighting deeply entrenched inequalities that permeate society. A great deal of academic literature has been produced exploring the reasons and proposing solutions for these inequalities. Yet, the sector has remained obstinately stratified and this research has served to highlight, again, how challenging the WROL’s mission is. It is hoped that this thesis provides some insight into the complexity of widening participation and that the recommendations help move the WROL closer to achieving its ultimate aim. However, the WROL forms just a small part of the science ecosystem; there is still much to research and many changes to be made to the wider sector to achieve equality in the scientific community.

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Appendices

Appendix I: Academic leader interview schedule

WROL Staff interview protocol- (questions are indicative and not necessarily to be asked in order)

Introduction

Welcome, introduce myself & research briefly

Present information sheet & consent form

Reiterate right to withdraw and not answer any questions

Stress that this is not an evaluation of performance and there are no incorrect answers

Ask participants to say their name and age.

Descriptive factors

1. What is your main role at Imperial College London
 - a. What is your research area?
 - i. Has this been used in any sessions?
2. What was your experience of science at school?
 - a. How has this informed the development and approach to sessions?
3. How does the WROL compare to your experiences of school science?
4. Ethnicity?

WROL experience questions

5. How long have you worked for the WROL?
6. How many sessions do you think you have completed with students?
 - a. What positive learning experiences have there been?
 - b. How have you developed your teaching practice over time?
 - c. In your own words, could you describe your approach to teaching?
7. What is the primary purpose of the WROL?
8. What motivates students?
9. How do you think students learn best?
10. How have you used practical science in your sessions?
11. What is the primary focus of your sessions? What do students gain from visiting the WROL?
12. What works well in the WROL?
13. What doesn't work well in the WROL?
14. How does the WROL compare to your experiences at school?

Session design questions

15. What are the topics you have taught in the WROL?
 - a. What is the primary focus (develop conceptual understanding/lab skills/ scientific method?)
 - b. How was this decided? (Links to curriculum)
 - c. Have you thought about the language you will be using the present the ideas? (Keywords/ definitions?)
 - d. Have you made any links to your own work at the university?
 16. What do the students typically 'do' in your sessions?
 17. How important are practical elements to the session?
 - a. What does the practical add to the experience?
 - b. How are ~~practicals~~ structured (open ended investigation/ set experiment to follow?)
 18. Typically, do the students work individually or in groups?
 - a. Why? What value does it add to the session?
 19. Is there a discussion element to the session?
 - a. Why? What value does it add to the session?
 - b. What opportunity do students have an to explain what they have done/learnt at the end of sessions?
 20. What is the role of the mentors be during sessions?
 21. How do you present the information (presentation/worksheet/verbally?)
 22. Do you assess the students in any way?
 - a. What do you be assess (understanding/skills?)
 - b. How do you assess this?
-
23. What records are students expected to make of the sessions? How will they be used?
 24. Are your sessions accessible to students of different socio-demographic backgrounds?
 - a. Have you given consideration for student's cultures/gender/class?
 25. What links to the real world do you use to support student learning?

Thank interviewee for taking part in the interview.

Check participant is happy with what they said during the interview.

Appendix II: Student interview schedule

Student semi-structured interview protocol- (all questions are indicative and not necessarily to be asked in order)¶

Introduction¶

Welcome, introduce yourself & research.¶

Present information sheet & consent form¶

Reiterate right to withdraw and not answer any questions¶

Stress that this is not a test and there are no incorrect answers¶

Views on science¶

1. →What, in your view, is 'science'?¶
2. →What's the point in learning about science?¶
3. →What are your general thoughts when you think about 'science'? (areas of science, interesting/boring/scientists, like/dislikes)¶
4. →What kinds of people do/like science? Who would you think is a 'science person'? (Are you?)¶
5. →What sort of person do you imagine to be a scientist? (clever, hardworking, imaginative, geeky don't lead)¶
6. →Do you want a science career? (What do you want to do in the future?)¶
7. →Do you think it is important to know about science? Why/why not?¶
8. →What do you think about the language scientists use?¶

School science¶

9. →What do you think about science at school?¶
10. →Do you like science lessons?¶
 - a. → Follow up positive views¶
 - b. → Follow up negative views¶
11. →What generally happens in science lessons¶
 - a. → How often do you do ~~practicals~~ practicals?¶
 1. →What do you think of practicals?¶
 1. → Follow up positive views¶
 2. → Follow up negative views¶
12. →How does science compare to other subjects?¶
13. →What do you find most interesting in science lessons?¶
14. →What do you think of your teachers? (likes/dislikes)¶
15. →To what extent is science you learn at school useful in your everyday life?¶

WROL Science¶

16. →Have you been to the WROL before?¶
 - a. → If yes: what can you remember about your previous visit?¶
17. →Why do you think your teachers bring you the WROL?¶
18. →How would you describe your experiences of the WROL so far?¶
 - a. → How does it compare to school?¶
19. →What practical work have you been doing?¶
 - a. → What are the underlying scientific concepts?¶
 - b. → How does this relate to the work you do at school?¶
20. →What do you think about the topic being taught?¶
21. →What do you think about how it is being taught?¶
 - a. → Have the concepts/instructions been clear?¶
22. →How relevant is the topic been to your life?¶
 - a. → Have any useful applications been mentioned?¶

Science at home and outside the classroom ¶

23. →What kind of other activities do you usually do with your families, e.g., during the summer, at weekends?¶
24. →What kinds of science-related activities do you do outside school? (zoo, museum, doing experiments?)¶
25. →Who do you talk to about science? (help with science homework; parents, friends, siblings)¶
 - a. → How often?¶
26. →Do you know what your parents think about science? Do they think it is important? Do they encourage you to do science?¶
27. →Does anyone in your family work in science/science-related job?¶
28. →What kind of expectations do your parents have of you? What would they like you to be in the future? Why? Does anyone you know do this job?¶
29. →Do your parents expect the same from your brothers or sisters?¶

Thank students for taking part in the interview.¶

Check again that students are happy with what they have said in the recording.¶

Appendix III: Teacher interview schedule

Visiting teacher semi-structured interview protocol (all questions are indicative and not necessarily to be asked in order)

Introduction

Welcome, introduce myself & research briefly

Present information sheet & consent form

Reiterate right to withdraw and not answer any questions

Stress that they will be anonymised and they can be candid with regard to their school or the WROL

Ask participants to say their name.

Teacher background & experience

- 1) How long have you been teaching?
- 2) Do you have a specialism (biology/chemistry/physics/other?)
- 3) How would you describe your approach to teaching? Do you have a particular style or approach?

School science

- 4) What are your thoughts about how science is taught in the UK?
 - a) Is there anything you would change about the way science is taught in the UK?
- 5) What are your thoughts about how science is taught in your school?
 - a) Is there anything you would change about the way science is taught in your school?
- 6) What are your thoughts about practical science?
- 7) What are your thoughts about the science in the national curriculum?

WROL science

- 8) Have you been to the WROL before with your students?
 - If yes:
 - a) What can you remember about your previous visit?
 - b) Were there any positive changes to your students when you returned to school?
 - c) Were there any negative changes to your students when you returned to school?
- 9) What, in your view, is the purpose of visiting the WROL with your students today?
- 10) What do you think works well in the WROL?
- 11) What do you think doesn't work well in the WROL?
- 12) How are students selected to come on this fieldtrip?
- 13) Do you think there are any weaknesses in the WROL experience? What could be done better to improve the students' time in the WROL?
- 14) How would you describe today's session? How has it been designed? What are the students doing?
- 15) What do you hope the students will take away from today's experience?
- 16) Does visiting the WROL relate to the curriculum you are teaching in school?
 - a) How are the topics for the WROL trip chosen? Were you consulted in the decision?
How much contact have you had with the WROL in planning this trip?

Thank teacher for taking part in the interview.

Check again that teacher is happy with what they have said in the recording.

Appendix IV: Science capital questionnaire exemplar

Y7 Post-visit science capital survey

Start of Block: Default Question Block

Information

We hope you had a good day in the WROL and would like to ask you some follow up questions.

Thank you for completing the Pre-visit questionnaire, this one should be quicker!

This is not a test, so please don't worry about getting anything 'wrong' or skipping questions you don't want to answer. You do not have to participate in this study and there is no consequence of not taking part. If you do take part, but change your mind, please let me know within one month of completing this survey and all data relating to you will be deleted. Your participation will be completely anonymous.

Future science affinity
How much do you agree with the following statements?

	Strongly disagree (1)	Disagree (2)	Neither agree nor disagree (3)	Agree (4)	Strongly agree (5)
I would like a job that uses science (1)	☐	☐	☐	☐	☐
People who are like me, work in science (2)	☐	☐	☐	☐	☐
When I grow up, I would like to be a doctor or work in medicine (3)	☐	☐	☐	☐	☐
I want to become a scientist (4)	☐	☐	☐	☐	☐

Utility of science qualifications

How much do you agree with the following statements?

	Strongly disagree (1)	Disagree (2)	Neither agree nor disagree (3)	Agree (4)	Strongly agree (5)
It is important to study science even if you don't want a science job in the future (1)	☐	☐	☐	☐	☐
A science qualification can help you get many different types of job (2)	☐	☐	☐	☐	☐

Page Break

Self-efficacy

How much do you agree with the following statements?

	Strongly disagree (1)	Disagree (2)	Neither agree nor disagree (3)	Agree (4)	Strongly agree (5)
Other people think of me as a science person (1)	☐	☐	☐	☐	☐
I know how to use scientific evidence to make an argument (2)	☐	☐	☐	☐	☐
I know quite a lot about science (3)	☐	☐	☐	☐	☐
I am confident giving answers in science lesson (4)	☐	☐	☐	☐	☐
I don't think I am clever enough to study any of the sciences at GCSE (5)	☐	☐	☐	☐	☐

Page Break

Valuing science & scientists

How much do you agree with the following statements?

	Strongly disagree (1)	Disagree (2)	Neither agree nor disagree (3)	Agree (4)	Strongly agree (5)
Scientists need to be imaginative in their work (1)	☐	☐	☐	☐	☐
Science creates new jobs so more people can have work (2)	☐	☐	☐	☐	☐
It is useful to know about science in my daily life (3)	☐	☐	☐	☐	☐
Getting young people to understand science is important for our society (4)	☐	☐	☐	☐	☐
Anyone can become a scientist (5)	☐	☐	☐	☐	☐

Page Break

Thank you for completing this survey, we hope you found some of it interesting.

Please press the 'next' button to complete the survey.

End of Block: Default Question Block

Appendix V: Science capital observation framework exemplar

Date: 20th May 2019

Session topic: Y7 Space science

	Dimension	Evidence
Cultural science capital	Scientific literacy	
	Delivering content from the curriculum	How do rockets work- brief presentation on Newton's laws at the beginning of session. AL Very briefly covers the laws verbally, no engagement with students in theory. <i>Lots of forces terminology (new motion, body, vector, statics and dynamics, equilibrium,). Prior knowledge required to engage with some of the topics. Are students following? Do they need to for practical task (not really)</i> Linkage between the theory (Newton's laws) and practical activity (rocket building) not made explicit. Theory evidently not focus of session. Some information on the planets presented- focus on Mars exploration- (topical w/ recent news regarding Space X?) Some maths content- students using time of flight and incline (height) to calculate rocket speed. This is not linked to Newton's laws but does allow data collection and numeracy practice. <i>(Bit arts and crafts? Low expectations to actually do/learn much science. Cf. criticism of 'fun' interventions as not enough to ensure participation.)</i>
	Developing skills from the curriculum	None explicitly
	Showing the nature of science/ How science works	Problem solving required in rocket building activity, mentors giving little instruction but asks guiding questions and hints.: AL: "Think about which way you want to turn your paper, you can choose, but one way will definitely fly better than another" S: miss can we add a parachute? M: sure, but how will you make sure it opens at the right time? S: [describes various solutions, which would likely not work] M: [generally supportive, but leading student to better design] Highlighting the importance of data collection for later analysis: AL: "Don't forget to write down your rocket flight time"
	Non-curricular science literacy	Staged rocket launches explained during presentation SpaceX recovery of boosters- linked to economics of space exploration

		Using an inclinometer to show how to measure how high each rocket goes. (AL: “using trigonometry, which is really fun and cool” – being sarcastic?)
	Scientific-Related Dispositions/ Preferences	
	Show the applicability of science in everyday life and ‘broadening what counts’	AL: “You can also decorate your rocket, think about which bits of your rocket are going to be seen” Product design highlighted as part of science to s.s with arts being incorporated into the activity.
	Building positive attitudes towards science	One student is answering all questions- AL is relying on this one student because no other students are willing to respond. (Called on at least 4 times now, only 1 other student has spoken) End of mars section of presentation is completed with a quick recall quiz: “are days shorter or longer on mars?” “why is mars red?” -Not sure of the purpose of this questioning other than to check that students were listening 2 mins ago- easy recall and verbatim answer if students were paying attention to information presented (questioning not used to develop deeper understanding of topic here) AL: “Why do we care about any of that [rocket theory]? Because you are going to be making your own rocket!”- Attempt to create positive link between science theory to the practical in the WROL, but s.s can easily ignore/not follow the theory to create a rocket. Students allowed to decorate their rockets, with no guidance as to what to add- gives s.s some ownership and autonomy over their activity rather than being ‘hand-held’ throughout Students allowed to work in groups of their friends to create their rockets- highlighted by mentor as the importance of collaboration in science S.s sharing out roles within their groups- 1 on cylinder duty, another making fins. One student wants to make a re-entry parachute. AL: You can’t have an internal parachute, because the cone needs to be attached otherwise the rocket wont launch. You can try an external parachute,

		it might not work properly, given the time we have today, but I don't want to curb your creativity -Evidence for student being allowed to fail- science isn't all about being 'right' Rocket launch in park is evidently very exciting, students are keen to launch their rocket and see how they perform. The pressure mechanism of the launch device adds to the tension! Returning to lab to do calculations- anticlimactic after excitement of launches? AL: "What did anybody notice about the rockets?" (no response- students are given opportunity to give open answer, but none respond- too high stakes with such a broad question)
	Giving students the opportunity to embody/ imitate scientific dispositions	Student's pre-existing knowledge being valued- "does anyone know what rocket this is?" S:"Apollo 6?", AL: "yeah, it is one of the apollo mission launches, well done" (unsure if actually #6, but irrelevant)
	Knowledge About the Transferability of Science in the Labour Market And science education more widely	
	Showing what scientific jobs there are	Limited evidence M: "This is like you're going to be launch control"- Mentor links s.s to scientific role they may have seen in film
	Showing how to get scientific jobs (knowledge about the extrinsic value and transferability of science qualifications)	S: how strict are the teachers? M: not really, we're given a lot of independence: S: oh, thank goodness M: we don't really have teachers, the lecturers let us get on with our work outside of lectures. S: that sounds great, -Evidence for student learning about How university works, ideas he has previously not considered like the lecturer/student dynamic. Mentor supports this developing understanding in a gentle manner. S: So what are lectures?

		M: is depends on what you're actually studying, but we had one-hour lectures on a topic, some students had four-hour lectures. -Evidence for student learning about HE from Mentor (not sure sharing that some lecture are four hours will encourage s.s however) S: Wait, so how hard is it to get into this school [university] M: It has changed a bit since I started, we have something called 'entry requirements' which are the grades you need to get in and they depend on your subject. A lot of the time you don't pick super specific subjects, I chose chemistry and then I did lots of different types of chemistry and then specialised in my third year, so you start with a general course and then go on to specialise. Every different university will have different types of physics courses, every university will have different chemistry courses. -evidence of students learning how to access university, which forms of institutional capital are required for entry. Learning this in year 7 means that students know the rules of entry early enough to make informed GCSE and A level decisions. S: How long do you spend at university? AL: Well I spent three years on BSc [no explanation of what BSc is]
	Showing how science can be relevant to non-scientific jobs	Limited evidence (The design element perhaps tangentially, but not linked explicitly)
Science-Related Behaviours and Practices	Consumption of Science-Related Media	
	Highlighting new science media for students and valuing existing media-consumption as scientific	Video of Apollo mission launch- very brief. Video of spaceX re-entry During rocket construction activity: S: "has anyone seen 'the Martian'?" M goes on to link popular depictions of science to real life science research (whilst also acknowledging the movie isn't 100% scientifically accurate). S.s then have a good, extended conversation about the Martian- evidently lots of them have seen it
	Participation in Out-of-School Science Learning Contexts	
	Signposting other out-of-school	No evidence

	science learning opportunities	
Science-Related Social Capital	Family science skills, knowledge and qualifications	
	Linking existing familial knowledge/practices (funds of knowledge) to science.	No evidence
	Knowing people in science-related roles	
	Mentor and academic leader introduction and interaction	Very brief- mentor introductions limited to name and subject S.S meet 8 different scientist- academic leader and 7 Mentors, 3 women, all white. S: Where are you from? M: [country of origin, redacted to anonymise] S: Oh my friend is from there, I'm from Romania. -Evidence for identities overlapping, different races and backgrounds being valued as participants
	Talking to Others About Science in everyday life	
	Encouraging students to talk about science in all contexts	Members of public in park looking on to rocket launch- AL engaging some in conversation about what's happening. Although not s.s talking to them (for the best), AL showing that science can be of interest to others (not just science teachers or scientists) as well. Mentor at end of session encouraging s.s to take their rockets home, s.s keen to share with their siblings (even though they lack the launch apparatus)- gives opportunity for s.s to talk to their families about what they've done in the WROL today. (also saves on tidying in the WROL!)

Appendix VI: Exemplar consent form

Imperial College
London

Sheffield
Hallam
University

Informed Consent Form for Children

Title of Project: Assessing the effectiveness of external providers of STEM education-
A case study of the Wohl Reach Out Lab.

Principal Investigator: Professor Robert Winston



Please initial each
box if you agree
with the statement

1. I confirm that I have read and understood the information sheet
2. I have been allowed to ask any questions and they have been answered fully
3. I understand that my participation is voluntary
4. I understand that I am free to withdraw my participation (within one month), without giving any reason
5. I understand that the interview will be audio recorded digitally and notes will be taken during the session
6. I agree to take part in the study

☐☐☐☐☐☐

☐

Name of student

Signature

Date

Student's date of birth

Name of Person taking consent
(if different from Principal Investigator)

Signature

Date

Student consent form v2 18/01/2018

Appendix VII: Exemplar study information sheet



Dear Student,

I would like to invite you to take part in a research project with Imperial College London and Sheffield Hallam University, into the ways that children learn science at the Wohl Reach Out Lab. The aim of the study is to better understand science education and how we can make it even better for future visitors!

Taking part in this study is easy and there are no expected negative effects!

The study will involve a researcher interviewing you and will ask you questions about your experiences of the practical sessions at the WROL, as well as some questions on science in general. The interview should take no longer than 30 mins, the audio will be recorded digitally, and notes will be taken at the same time.

This is not a test, so don't worry about answering any questions incorrectly, or saying you don't want to answer anything if you don't want to.

Your participation will be completely anonymous.

All data collected as part of this study will be kept securely and treated in accordance with Imperial College's data protection policy and the Data Protection Act 1998.

You **do not** have to participate in this study and there is no consequence of not taking part.

If you do take part and you later change your mind, you have the right to withdraw your participation and do not have to give any reason. Any data about you will be deleted. If you wish to withdraw, please do this *within* one month of your interview/ observation.

You will be asked to complete a consent form if you decide to take part in the study.

If you have any questions about the research, please ask now, or contact me at:
r.zivtins17@imperial.ac.uk

Roberts Zivtins



If you would like to be kept up-to-date with the outcome of this research, please provide your email address below. Your email address will be kept private.

Email address:

Appendix VIII: Ethical approval



Imperial College Research Ethics Committee
Level 2, Medical School Building,
St Marys Campus
London
W2 1PG
Tel: +44 (0)207 594 9484

researchethicscommittee@imperial.ac.uk

Robert Winston
205, 2nd Floor
Skempton Building
South Kensington Campus
Imperial College London

9th August 2018

Dear Professor Winston

Study Title: Assessing the effectiveness of external providers of STEM education- A case study of the Wohl Reach Out Lab.

ICREC reference: 17IC4316

The above study was reviewed by the Imperial College Research Ethics Committee on 09/01/18.

Following the review of your documents, the Joint Research Compliance Office would like to grant full approval of the study by Chairs Action.

Documents

The documents reviewed were:

- ICREC application form
- Protocol (v5 8/5/18)
- WROL Staff information sheet (v2 18/1/18)
- WROL Staff consent form (v2 18/1/18)
- Parent information sheet (v2 18/1/18)
- Parent Consent Form (v2 18/1/18)
- Student information sheet (v2 18/1/18)
- Student consent form (v2 18/1/18)
- Head Teacher consent
- Science Capitol Questionnaire
- Student semi structured interview schedule (v1 19/01/18)
- WROL Staff semi structured interview schedule (v3 15/2/18)
- R01 – Reach Out lab faculty risk assessment (2/10/17)

Yours sincerely,

Michael Dixon,
Chair, Imperial College Ethics Committee

Imperial College of Science, Technology and Medicine

Appendix IX: Interview data analysis- coding framework for teacher and academic leader interviews

Literature derived themes	Code (# references)	Thematic clustering	Thematic overlap	Sub-theme
WROL Outreach feature/pedagogy	Academic leader planning (3)	Practical in the WROL	Experiences of practical science	Science equipment (contrast School & WROL)
	AfL (3)	School/ curriculum overlap		
	Constructivism (2)	Science artifacts		Practical logistics (time in school vs. time in WROL)
	Discussion (11)	Criticism of school science		
	PBL (3)	National/school Curriculum		
	Group work (12)	Practical in school		
	Mentor (56)	Authentic experience		
	Practical in the WROL (68)	Science skills		
	Real-life link (21)	Scientific related dispositions, preferences and values		
	Building on Existing knowledge (1)	Broadening what counts		
	Outreach improvements (26)	Interest		
		Exams		
	Rules (2)		Non-curricular science experiences	(cf. formal focus on curriculum)
	School/ curriculum overlap (23)	Real-life link		
	Science artifacts (26)	National/school Curriculum (-ve)		
	Subject matter (9)	Exams		
	Targeting of initiative (15)	Criticism of school science		
	Extra-curricular (36)	Authentic experience		
		Career advice (navigating the field)		
Formal science education	Criticism of school science (80)	Participation in out-of-school science learning		
	National/school Curriculum (12)	Subject matter		
	Practical in school (68)	Extra-curricular		
	Exams (12)			
		Mentors		Challenging science stereotypes

Identity	Gender (6)
	Race (2)
	Class (2)
Outreach outcomes	Affective or emotional (12)
	Authentic experience (25)
	Cognitive or curricular (12)
	Career advice (navigating the field) (51)
	Science skills (6)
	Interest (12)
	Unintended or side benefit (2)
Science capital dimension	Consumption of science related media (7)
	Knowing someone who works in science (34)
	Parental science qualifications (2)
	Participation in out-of-school science learning (29)
	Science literacy (9)
	Scientific related dispositions, preferences and values (7)
	Symbolic knowledge about the transferability of science (9)
	Talking to others about science (13)
Science capital teaching approach	Broadening what counts (16)
	Personalising and localising (7)
	Eliciting, valuing and linking (9)
	Building the science capital dimensions (coded above as each dimension)

	Interacting with real scientists and university students	IAG from mentors- (navigating the field)
Real-life link		
Identity		
Career advice (navigating the field)		
Knowing someone who works in science		
Symbolic knowledge about the transferability of science		

Appendix X: Kaiser-Meyer-Olkin Measure of Sampling and Bartlett's Test of Sphericity SPSS output

KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.816
Bartlett's Test of Sphericity	Approx. Chi-Square	3194.509
	df	120
	Sig.	.000

Appendix XI: Rotated component matrix SPSS output:

Rotated Component Matrix^a

	Component			
	1	2	3	4
How much do you agree with the following statements? - I know how to use scientific evidence to make an argument	.810			
How much do you agree with the following statements? - I am confident giving answers in science lesson	.777			
How much do you agree with the following statements? - I know quite a lot about science	.761			
How much do you agree with the following statements? - Other people think of me as a science person	.717			.357
How much do you agree with the following statements? - I don't think I am clever enough to study any of the sciences at University	.445			
How much do you agree with the following statements? - People who are like me, work in science	.418			.381
How much do you agree with the following statements? - It is useful to know about science in my daily life		.855		
How much do you agree with the following statements? - Getting young people to understand science is important for our society		.842		
How much do you agree with the following statements? - Scientists need to be imaginative in their work		.826		
How much do you agree with the following statements? - Science creates new jobs so more people can have work		.792		
How much do you agree with the following statements? - A science qualification can help you get many different types of job			.807	
How much do you agree with the following statements? - It is important to study science even if you don't want a science job in the future			.793	
How much do you agree with the following statements? - Anyone can become a scientist			.573	
How much do you agree with the following statements? - I want to become a scientist	.338			.754
How much do you agree with the following statements? - When I grow up, I would like to be a doctor or work in medicine				.745
How much do you agree with the following statements? - I would like a job that uses science				

Extraction Method: Principal Component Analysis.

Rotation Method: Varimax with Kaiser Normalization.

a. Rotation converged in 5 iterations.

Appendix XII: Wilcoxon signed rank sum summary table

Questionnaire item	Z	Asymp. Sig. (2-tailed)
How much do you agree with the following statement? - People who are like me, work in science	-0.028 ^b	0.978
How much do you agree with the following statement? - When I grow up, I would like to be a doctor or work in medicine	-0.640 ^b	0.522
How much do you agree with the following statement? - I want to become a scientist	-2.293 ^b	0.022*
How much do you agree with the following statement? - It is important to study science even if you don't want a science job in the future	-0.340 ^b	0.734
How much do you agree with the following statement? - A science qualification can help you get many different types of job	-0.512 ^c	0.609
How much do you agree with the following statement? - Other people think of me as a science person	-2.919 ^b	0.004*
How much do you agree with the following statement? - I know how to use scientific evidence to make an argument	-0.365 ^b	0.715
How much do you agree with the following statement? - I know quite a lot about science	-0.647 ^b	0.518
How much do you agree with the following statement? - I am confident giving answers in science lesson	-0.057 ^c	0.954
How much do you agree with the following statement? - I don't think I am clever enough to study any of the sciences at University	-1.183 ^b	0.237
How much do you agree with the following statement? - Scientists need to be imaginative in their work	-0.996 ^c	0.319
How much do you agree with the following statement? - Science creates new jobs so more people can have work	-0.666 ^b	0.505
How much do you agree with the following statement? - It is useful to know about science in my daily life	-0.299 ^b	0.765
How much do you agree with the following statement? - Getting young people to understand science is important for our society	-0.830 ^b	0.406

* $p < 0.05$, indicating statistical significance at this level

Appendix XIII: Components and science capital paired samples t test summary table

		Mean	N	Std. Deviation	Std. Error Mean	t	df	Sig. (2-tailed)
Component 1	Science affinity score Pre (/10)	5.5285	263	1.92367	0.11862	-1.677	262	0.095
	Science affinity score Post (/10)	5.8175	263	2.02205	0.12469			
Component 2	Utility of science qualifications score Pre (/10)	7.2989	261	2.97469	0.18413	0.791	260	0.430
	Utility of science qualifications score Post (/10)	7.0920	261	3.10198	0.19201			
Component 3	Self-efficacy in science score Pre (/30)	16.0478	263	3.51611	0.21320	-0.088	271	0.930
	Self-efficacy in science score Post (/30)	16.0735	263	3.41936	0.20733			
Component 4	Valuing science and scientists score Pre (/20)	16.1217	263	3.45754	0.21320	-0.335	262	0.738
	Valuing science and scientists score Post (/20)	16.2205	263	3.43823	0.21201			
Science capital	Science capital score pre (/70)	50.0379	264	7.51567	0.46256	-0.409	263	0.683
	Science capital score post (/70)	50.3144	264	7.90026	0.48623			

* $p < 0.05$, indicating statistical significance at this level