Research to Support Understanding of Evolution and Inheritance in the National Curriculum at KS2 and KS3: Teachers' views of the impact of involvement in the project on their practice

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Contents

1.1 Background

The feedback from teachers reported here relates to their involvement in the Nuffield Foundation funded research entitled 'Understanding of Evolution and Inheritance in the National Curriculum KS2-3', (Nuffield Foundation EDU/42298). The project ran from September 2016 to December 2017. This was the second of two linked pieces of research involving two different, non-overlapping samples of teachers (referred to as Study 2 here). The project undertook to conduct research that would inform and support all stakeholders' understanding of the implications of Evolution and Inheritance in the KS2-3 National Curriculum: teachers, pupils, policymakers, assessment developers and others. Three specific areas were identified as the intended foci of Study 2 research.

Focus i): Macroevolution. The project explored the extent to which encouraging pupils' metacognitive reflection on the meaningfulness to them of a variety of 2-D and 3-D representations might support a 'big picture' or macroscopic view of Evolution.

Focus ii): DNA. The intention was to explore pupils' informal understandings about DNA as garnered from entertainment and other broadcast media. This information would be used to consider the implications for understanding of inheritance together with any implications for the curriculum.

Focus iii): Working scientifically using argumentation. The intention in this aspect of the research was to explore what can be learned about the successes (and ways of building on these) and difficulties (and ways of obviating or finding positive solutions to these) of managing scientific discourse activities across KS2-3 in the conceptual domains of this enquiry.

1.2 Project teachers

Twelve teachers, across Years 5 to 9, participated in the project. The nine schools were situated in Fylde and Lancashire in North West England. The proposal had set out our intention to involve ten teachers, two in each of years 5, 6, 7, 8 and 9. The distribution of teachers across the classes was in practice more uneven in order to ensure a prompt implementation of the research. Our priority became the need to recruit sufficient teachers to cover the year 5-9 age range as soon as possible after the grant had been awarded, bearing in mind the need for sensitivity to teachers' pre-existing planned curriculum coverage. One head of science decided in the first month of the project that the demands on the two staff she had nominated would be too great and withdrew from the project. More positively, one of the secondary teachers was keen to work with both Y7 and Y8 pupils. A primary school wanted both its Y6 teachers to be involved so that they could continue their joint planning and to ensure that both parallel classes would have the experience of being involved in the project. The project was able to accommodate these preferences. During the project, there were further minor changes to participating staff. In one school, a Y8 class was timetabled for a different teacher mid-year as their programme of work shifted to genetics. The school and the new teacher kindly agreed to continue the pupils' participation in the project. As the result of these various accommodations, although the funding had been agreed for ten teachers, the project worked with more teachers and classes than had been projected, with a less than 'ideal' profile but within the agreed budget.

Table 1. Teachers and pupils participating in the project

	Y5	Y6	Y7	Y8	Y9	total
Number of classes	2	3	3	3	1	12
Number of teachers	2	3	3	3	1	12
Number of pupils	41	76	77	83	21	298

1.3 Evaluation approach

The intention of this evaluation was to report on teachers' views of the impact of the Study 2 project on their practice. This feedback has to be seen in the context that the project was not designed to attend primarily to the professional development of the participating teachers. In fact, the participating teachers' *pre-existing* professional experiences were invaluable in making an essential contribution to the delivery of project activities and outcomes.

A brief questionnaire was developed (see Appendix 1) and the agreement of respondents to provide feedback was established. Data were collected through school visits in cases in which direct face-to-face contact with individuals could be arranged, otherwise by email. All twelve teachers provided feedback. The questionnaire comprised both closed and open-ended questions. Responses to the closed rating scale items are reported in section 2. Responses to the qualitative open-ended questions are reported in sections 3, 4 and 5.

1.4 Aims of the questionnaire

The questionnaire probed teachers' views of the impacts of involvement in the project on i) their practice of teaching science in general and ii) on their specific approach to teaching evolution and inheritance. Additionally, questions explored any perceived impacts on pupils' learning and any wider influences involvement in the project might have had across the school.

2.0 Teachers' responses to the closed (rating scale) questions

2.1 Ratings of the impact of the project on their science teaching generally

Teachers (n=12) were invited to respond to a series of question in the form of four-point rating scales. The statements teachers were asked to consider referred firstly to their reflections on the project's impact on their teaching *in general* and then the influence on their teaching of Evolution and Inheritance *in particular*. The seven statements relating to teaching in general were assumed to be fairly tightly focussed on the construct of impact on effectiveness as a teacher. Thus the span of impact from 'strongly agree' to 'strongly disagree' might be considered as broadly commensurate, though stopping short of providing equal interval data. Quantifying and averaging teachers' ratings was further justified by the fact of their being overwhelmingly positive, the means allowing the small differences between agreements to be teased out. In similar manner, the four statements pertaining to the project's influence on pedagogy relating to the teaching of the relevant concepts are assumed to cluster around a core construct. Means are again offered for the ordinal data, but interpreted with the support of the qualitative comments requested. In response to each question a choice was offered between 'strongly agree', 'agree', 'disagree' and 'strongly disagree'. These choices were scored +2, +1, -1 and -2 respectively and overall means from responses were generated. (See Table 2, where mean ratings have been ordered from the more to less positive.)

Table 2. Teachers' ratings of the impact of the project on their science teaching generally (n=12)

Statement	Mean score
Involvement in the project was beneficial for me as a teacher	1.8
The project helped me to recognise the importance of children's ideas as starting points for my teaching.	1.8
Asking for the reasons behind ideas and using 'argumentation' helped to develop children's 'working scientifically'	1.8
The project gave me new ideas for teaching science	1.8
The project offered opportunities to network with other teachers to develop my practice	1.7
I have shared some of the activities with other teachers in my school	1.5
The project activities have helped my teaching of science generally	1.4

Views about the project's impacts on their teaching were entirely positive. There was almost unanimity in the 'strong agreement' (mean score of 1.8) that the project had been beneficial to them as teachers with 10 teachers expressing 'strong agreement'. The same pattern of overwhelmingly 'strong agreement' was associated with the view that the project helped teachers recognise the importance of pupils' ideas as starting points for teaching and in relation to views about the project giving them new ideas for teaching science confirming the novelty of the practices created in the course of the project. The majority of teachers 'strongly agreed' and a further three 'agreed' that the argumentation practices created in the course of the research had helped to develop children's 'working scientifically'. This was felt to be very encouraging given teachers' and pupils' initial lack of familiarity with this way of working in science.

There was widespread agreement that the project had helped networking with colleagues. Two thirds (8) 'strongly agreed' and a third (4) 'agreed' that the project had fostered networking with teachers in other schools. One or two teachers elaborated during interview their positive view of the opportunity to network with colleagues.

While all agreed that the project had helped their teaching of science generally, only five of the twelve respondents 'strongly agreed' with this possibility (mean 1.4). Notwithstanding the teachers' overall positivity and their unanimous agreement with the view that the project helped their teaching of science generally, the mean when compared with the other six statements is lower than might have been expected, given teachers' descriptions elsewhere in the interviews of very rapid generalisation of the practical strategies across science. For example, there was evidence of the speaking and listening practices associated with argumentation being adopted across science lessons and across more cross cutting initiatives such as Speaking And Listening All Day (SALAD days). However, there was also a very much domain-specific intention to address Evolution and Inheritance specifically, and no project remit to enhance professional development in the teaching of science in general.

2.2 Teachers' ratings of how the project has influenced their teaching of Evolution and Inheritance

Teachers were invited to respond by rating each of four statements associated with the helpfulness of the project to four aspects of their teaching: the teaching of evolution; the use of representations to teach evolution; their teaching of DNA and finally, their use of argumentation as a mode of working scientifically. A similar four-point scale was used as in the earlier questions, with an invitation to add particularizing comments alongside each rating. All teachers responded by indicating that they 'strongly agreed' or

'agreed' that involvement in the project had been helpful to their teaching in each of the four aspects. Table 3 summarises mean ratings using the same scaling as previously explained (+2, +1, -1, -2). All teachers agreed that the project had helped their teaching of evolution and DNA and helped their use of argumentation as a mode of working scientifically. Despite the slightly lower mean when compared with the other three statements, all teachers expressed positivity towards the representations used in the project and this was endorsed by their qualitative comments during the interview (reported in section 3.2)

Table 3. Teachers' ratings of the value of the project to their teaching of evolution and inheritance (n=12)

Statement	**Mean rating**
The project has helped my teaching of evolution	1.8
The project has helped my use of argumentation as a mode of working scientifically	1.8
The project has helped my teaching of DNA	1.7
The project has helped my use of alternative representations when teaching evolution	1.6

3.0 Teachers' qualitative views on the impact of project involvement on their practice

In their responses to the open-ended questions all the respondents mentioned ongoing changes to their practice as a result of project involvement. These changes took the form of i) the adoption of new approaches such as argumentation; ii) novel representational techniques to support the communication and construction of understandings; iii) and formative assessment strategies to elicit and use pupils' ideas as starting points for learning. The project was also acknowledged to have iv) impacted on teachers' own science understanding (particularly so in the case of primary teachers).

3.1 Use of argumentation.

The project encouraged argumentation - that is, science discourse or discussion sessions during which pupils exchanged ideas as 'claims', with the requirement to support these with evidence. The features of those discussions that were emphasised by the project were the importance of

*listening to others,

* providing evidence to support ideas

* learning to challenge each other's ideas and their evidential basis.

Throughout the project, teachers managed these qualities of interaction in pairs, in small groups and in whole class discussions. Teachers were asked to encourage direct exchanges between pupils rather than interactions mediated via the teacher. Science argumentation was observed by the researchers to be novel and challenging for teachers and children, though other discussion techniques (for example, philosophy for children or P4C) might have been familiar to some. All teachers suggested that the project supported the development of specific approaches that enhanced the possibility of argumentation practices.

> *It has also given me an insight into the types of open-ended questions that can be used in science and their effects on class discussions.* (Y5)
>
> *I found it difficult as usually we conduct discussions of this sort when there are opposing opinions about a subject matter (e.g. Do we agree with zoos?) and children choose a 'side' and prepare supporting evidence, whereas this felt more like a 'sharing of ideas' to support the statement presented. This has highlighted to me as a teacher the importance of throwing in more of this type of thing into sessions every now and then, e.g. "Plants are incredibly important… what do you think about this?" open-ended type exercises.* (Y6)

This has made me think carefully about how discussion/debating is something that should be modelled and practised throughout school, as it is such a powerful tool for learning. I can imagine that some practitioners would find the 'undefined/unknown journey/destination' of this type of exercise unsettling – it requires some subject knowledge on their part, as well as the ability to adapt and think on your feet! However, I think it is good for children to know that you don't know all the answers all of the time either! It made me listen more carefully to what the children were saying and gave me valuable insights into their understanding. On one occasion, I missed the point of what a child was saying and my TA picked up on it. I think having adults to facilitate discussion is very useful. (Y6)

Class discussion so that children can continue to develop the confidence with arguing their viewpoint with supporting evidence (using an age appropriate question as a starting point). We are focusing on how to build their arguments and confidence in sharing them. (Y7)

Improve debating and backing up points with evidence. We have gone on to use these in wider groups through SALAD (speaking and listening all day) days and debating club. (Y7)

Getting pupils to discuss more without input from me to get their ideas out and to improve debating more. (Y7)

The discussions and ascertaining previous knowledge before debate has been important. We have designated 'debate' days once a term and also engage in more 'thinking time' for pupils during lessons. (Y7)

I feel that the idea of presenting the students with ideas that they have to 'argue' about has developed their deeper understanding and required more thinking. I will often present an opinion and ask the students to justify it or argue against it. (Y9)

In the course of giving feedback, several teachers acknowledged the importance of encouraging pupils to use, respond to and critique each others' ideas so that they could learn from one another.

Using others' views and discussing them /exploring them. (Y8)

Feel that an area to really develop with upper KS2 is the use of counter-claims. (Y6)

The wider implications for pupils' development across science and in primary schools, more widely across the curriculum, were recognised. The feedback suggested that some teachers had already begun to use their argumentation practices with other year groups, in other conceptual domains of science and more generally in other subject areas.

3.2 Use of novel representational strategies

Nine of the twelve teachers referred to the fact that, following the project, they were able to draw on the wide range of creative strategies developed during the research to encourage consideration of some of the different ways knowledge might be represented. The project emphasised the importance of introducing pupils to different representational modes in combination so that they might explore, communicate and construct understandings as they interacted with and translated between each mode (Karmiloff-Smith, 1992). For example, during their study of macroevolution, pupils were introduced to several representations of the tree of life metaphor: a real tree branch; a reproduction of Darwin's tree of life notebook sketch; a simplified hominid cladogram; a narrative story and an image of the 'ascent of man'. Using different representations in an open-ended rather than didactic manner to elicit ideas and to help pupils construct and reflect on their own understandings was a novel approach for all the teachers. During the project, teachers were encouraged to invite pupils to work across these different representational modes (diagrams, models, narrative, images, etc.) as they discussed their ideas. Teachers' evaluation feedback suggested that the use of different representational formats was valued and seen as a particularly novel, fruitful, creative and reusable pedagogical approach that had been readily adopted.

The modelling before debate has been important. I am taking time out to try different approaches to ideas and using them every day in lessons. (Y7)

A new way of discovering a topic. As opposed to 'This is what we have to learn'. Giving students models and having them reason what evolution is. (Y7 & 8)

A fresh eye inspired me to try new ideas. (Y8 & 9)

During the project, teachers' use of narrative fiction in the form of One Smart Fish (Wormell, 2011) was encouraged as a way of stimulating pupils' discussion of some of the difficult ideas associated with macroevolution. The story was used across the Years 5-9. Teachers read the story to younger pupils while older students were invited to consider the suitability of the story as an introduction to ideas about evolution for younger children. Evaluation feedback suggested that initial concerns about introducing 'misconceptions' had been set aside in favour of greater use of narrative fiction in science.

I personally loved the book - such a great stimulus for discussion and a great way at a primary school level to introduce an abstract concept such as evolution. (Y6)

Use of stories to deliver scientific ideas to then be discussed – e.g. One Smart Fish. Use of 3 representations/models to convey scientific ideas. (Y7)

Half of the teachers were unfamiliar with cladograms at the outset of the project and all confirmed that cladograms were not included in the curriculum for their pupils, yet all project teachers viewed their introduction positively. A recommendation for the earlier introduction of cladograms was made explicit in some of the feedback.

Best model for the pupils – not on syllabus but pupils had not seen before either. Many understood the concept already and I knew for some it would aid in their understanding of speciation in humans. Good understanding of time and branching and 'sharing an ancestor'. Good questions surrounding the unlabelled parts in the centre. Cladograms could be introduced at primary – different models need to be explored in different ways earlier. (Y7)

Pupils looked at the cladogram last and a lot commented on how this helped their understanding. (Y8)

A simple branch used as a 3-D model of the tree of life was regarded as a particularly useful way of helping challenge some of children's expressed idea that evolution occurs in a linear way. Teachers found the real branch a readily accessible and useful way of asking pupils to consider common descent and the gradual evolution of new species. In some instances, the teachers referred to the evidence of pupils' reactions to the models to support their feedback.

Lots of the children liked the physical tree branch and one child said, 'It helps me to see how things came from other things and that they all came from one main one'. (Y6)

I use tree of life now when teaching evolution. (Y7 & 8)

Have used it with Y10 biology group who 'all' had an 'Aahhhh!' moment. (Y8 & 9)

I think using the tree branch as a model was an excellent tool. (Y9)

Teachers' views of the impact of using different representations to teach evolution were overwhelmingly positive. While they identified particularly useful individual representations, their feedback also revealed their awareness of the value inherent in the reflective and metacognitive use of representations in combination, together with science discourse practices that encouraged the expression and sharing of ideas.

We had a great discussion about the timeline image of hominid evolution and this is when I feel that the cladogram and the tree branch representation really helped children to unpick misconceptions and see a 'less linear' approach to evolution. After discussing this, the children had lots of ideas about what they wanted to get across in their own models. For instance, many liked how Darwin's tree of life showed how many species evolved from a previous one but didn't like how it wasn't clear if there was a chronology of events through time. (Y6)

I think comparing all of the different representations helped to draw out all of the key ideas about evolution as not one model perfectly shows them all. I would definitely do again and apply to other areas. I would consider the order of how to represent though, rather than 'free choice'. (Y6)

Teaching it using several representations has helped more children to understand in a way that makes sense to them. (Y6)

Comparing representations is a very good approach especially when combined with allowing pupils to peer question each other's views. It allowed pupils to access a model that was most pertinent to their way of understanding. It is a technique that would work for many topics and allows independent working. (Y8)

I would change by allowing pupils to view and analyse the representations at different paces and orders. (Y8 & 9)

There was some evidence that, by the end of the project, teachers had identified how they could use these approaches in other areas of science.

I will use these approaches when teaching other units of Science. (Y6)

(Representations) Really helped with developing view of evolution. I would apply to other concepts. (Y8)

3.3 Use of formative assessment strategies

Three-quarters of the teachers explained that the project techniques, such as questioning and adopting a more open-ended approach to the elicitation of pupils' ideas prior to teaching, had opened a window on pupils' understanding that could be used to inform teaching. The impression given in feedback was that these approaches yielded rich information about pupils' understanding that could inform teaching and learning. It was asserted that this style of more open questioning would continue to be a feature of the participating teachers' practice and, in some instances, an expectation of the staff in the department or school.

One of the things that I will include in my own teaching is using intial questions to establish a starting point.(Y6)

The project has introduced me to more of pupils' misconceptions. (Y8 & 9)

It has also given me an insight into the types of open-ended questions that can be used in science. (Y5)

Showing different models to pupils and allowing them to come up with their own ideas first, or sharing existing knowledge has allowed us to address any misconceptions and also discuss different models. Ascertaining previous knowledge before debate has been important. We now as a department have incorporated a 'previous knowledge' lesson into every topic where knowledge and misconceptions are addressed. We also engage in more 'thinking time' for pupils during lessons. (Y7)

It has allowed me to structure and question the pupils in a way that encourages peer learning and deeper thinking. (Y8)

Allowed me some time and space to really plan for depth of understanding. A strength of this is misconceptions are easily spotted and discussed, often dealt with a lot faster than if I had asked for a piece of written work, marked it and asked the student to change some of the work, taken it back in and remarked it. (Y9)

Some pupils already had strong ideas about DNA and its importance, whereas some pupils had no ideas at all. It was good to spend time ascertaining what knowledge there was already then sharing and allowing some pupils to lead on those ideas. (Y7)

While the impact for many teachers was their increased awareness of pupils' ideas and how they might be used as starting points for teaching, several teachers mentioned additionally that the sharing of ideas and pupils' increased awareness of their own and other's ideas encouraged students to adopt a more active and self-directed role in their own learning.

3.4 Increased science content and pedagogical knowledge

Evolution is understood to be a complex area for teachers and pupils (Evans, 2012). Research (Sadler et al., 2013) suggests concerns about teachers teaching content that they themselves find challenging. By the end of the project, half the participating teachers mentioned they had gained improvements in their own understanding of evolution and how it might be taught. Furthermore, some identified how this improved knowledge coupled with improvements in pedagogy would help their teaching in subsequent years.

> *I believe that I have gained a vast knowledge of the subject matter during the project. This will help me when I teach evolution in Year 6 next year.* (Y5)
>
> *Some really good ways of teaching a very difficult subject. A good basic structure on which to build future planning of this and related topics in science lessons*. (Y5)
>
> *I still have lots more to discover and show the children about Evolution*. (Y6)
>
> *This process has really made me think as a teacher on how I teach particular areas of the curriculum and in what order!* (Y6)

All the teachers indicated strongly that project involvement had brought about ongoing changes to their practice. One teacher describing permanent change to her practice included a more enquiry-oriented approach to her pre-existing repertoire.

> *I have changed elements of my teaching, for example, a more enquiry-based open-ended approach. I have found this is more engaging, purposeful, and has lasting impact on children's learning*. (Y6)

A Y5 teacher described how his early scepticism about the teaching of evolution to Y5 had been replaced by a conviction that it should be taught to young children in the primary age range.

> *I had my own reservations on such a deep and new topic being taught to 10 year olds. But the outcome provided much needed reassurance that it is a topic that needs to be taught at a younger age to widen the mind on the understanding of macroevolution.* (Y5)

It is argued by Coe et al. (2014, p.2) in their examination of what makes 'great teaching', that effective teachers include those that have a sound subject and pedagogical knowledge of the content being taught coupled with an awareness of pupils' misconceptions. *'As well as a strong understanding of the material being taught, teachers must also understand the ways students think about the content, be able to evaluate the thinking behind students' own methods, and identify students' common misconception.'* It appears from teachers' feedback that the project impacted positively on some of the elements of practice judged by Coe et al. (2014) to be at the heart of effective teaching.

4.0 Teachers' qualitative views of impact of project involvement on pupils

4.1 Impact on pupils' understanding

Notwithstanding the recent evidence that teachers' involvement in research may not be an effective way to improve pupils' learning outcomes (Collins, 2017), all teachers involved in the project described how they believed their project experience had impacted positively on pupils' achievement.

> *The pupils gained knowledge on the subject area of evolution and DNA.* (Y5)
>
> *The challenge of the topic has expanded their ways of thinking not only about evolution but also about what science is and its relevance*. (Y5)
>
> *Use of the twig model and use of discussion and peer learning has helped the class to become more adept verbally at explaining evolution*. (Y8 & 9)
>
> *It's had a lasting impact on pupils - they still refer back to things they have learned now!* (Y6)
>
> *I try to make science sessions practical/hands-on whenever possible and was worried about the heavy oral weighting of this project – however, the children have thoroughly enjoyed it and learnt so much. A group of children actually moaned when I said we were starting a new topic. The peer discussions, leading onto enquiries stimulated by themselves, really motivated them.* (Y6)

The monkey turning into a human seemed to be challenged by the cladogram. The cladogram really helped. (Y7 & 8)

One or two teachers mentioned pupils' improved wider understanding of associated science concepts and an appreciation amongst them of the relevance of science to everyday life. The project highlighted pupils' tendency to focus on examples of evolution in the animal kingdom and one teacher reported her pupils' increased appreciation of plant evolution as a result to of the project.

Increased understanding of life on earth and around them - can link to forest schools – more appreciation of plant life. (Y5)

I feel that it made them very aware of the impact of Science in our everyday lives. (Y6)

4.2 Impact of project involvement on pupils' working scientifically

The project emphasised the importance of pupils working scientifically using science discourse, a priority consistent with the contemporary extended view of the constituent aspects of science education as including social, communicative and epistemic processes (Duschl & Grandy, 2013). Almost all the teachers reported impacts on pupils' skills associated with science discourse. Improvements in pupils' confidence to express ideas were reported along with increases in pupils' abilities to listen to and to respond to each other.

They have also gained skills in class discussions within science. (Y5)

The activities have helped develop confidence in expressing ideas verbally. (Y5)

It provided them with visual, speaking and listening, discussion opportunities that have really supported working scientifically. (Y6)

Allowing pupils to lead the learning at the beginning of each topic, encouraging discussion and debating skills as well as presentation confidence. (Y7)

The benefits to students of being able to express their ideas and having someone listen to them and question them. (Y7 & 8)

A key learning aim was on turn-based discusions during learning. Clearly, social skills have been enhanced. Before that project, they were generally more cautious when listening and speaking. (Y8)

Gave them some new skills and new ways of learning. Improved their manners. (Y9)

An important feature of science discourse practices developed during the research was the encouragement of pupils' evaluation of evidence. In all classes, pupils were required to support their thinking with evidence. One or two teachers mentioned that these opportunities had a valuable impact on pupils' abilities to think critically about ideas and evidence and brought about a reconsideration of earlier views of science as simply a body of knowledge.

They have their own opinions about science facts or opinions. (Y7)

Helping students to evaluate the discovery of DNA. It gives the students the ability to evaluate their ideas based on evidence. Use of discussion prompts was very useful to help students structure arguments and evaluate in a manner that they will have to do in a GCSE exam. Better development and understanding on leading discussions/arguments. (Y7 & 8)

Students have been able to greater develop their abilities to evaluate a topic. (Y7 & 8)

4.3 Impact of project involvement on pupils' motivation and engagement

More than half the teachers reported that the project activities had motivated and engaged pupils. Some primary pupils were described as eagerly approaching the teacher to ask when they were having more science and older pupils were reported to have requested a continuation of the project approaches following completion of the project. Feedback suggests that motivation and engagement translated into active participation in which pupils challenged, questioned and investigated each other's ideas**.**

Children seemed to enjoy experiencing different representations and were able to develop understanding through this way of repeating information – because they knew what they were looking for it helped them understand how to read such representations. (Y5)

Children very much enjoyed engaging with the two topics Evolution and DNA. Children very much enjoyed all of the activities. (Y6)

The children have been amazing - they have loved this topic and keep asking when they see me around school if it is science again soon! They have so many ideas and questions - it's fantastic! I just wish I could answer them all. (Y6)

Clear engagement in their learning. The majority of pupils expressed a desire to do more of this type of learning. (Y8 & 9)

The critique of representations and contrast/comparison motivated/encouraged the children and raised questions to investigate/discuss. (Y6)

The project promoted students' independence and challenge. (Y8)

One of the teachers anticipated that the emphasis on discussion skills within the project may have a positive impact on a particular group of pupils – those underachieving pupils identified as entitled to Pupil Premium. (The pupil premium is additional funding for publicly funded schools in England to raise the attainment of disadvantaged pupils of all abilities and to close the gaps between them and their peers. https://www.gov.uk/guidance/pupil-premium-information-for-schools-and-alternative-provision-settings)

Raising the attainment of this group is important for its contribution to the assessment of school effectiveness. This informant predicted that the specific benefits of the project's discussion approaches to this group might include increased confidence, improved aspirations and increased achievement.

These skills are particularly important to the encouragement of pupil premium students. Encouraging their confidence in these areas should over time, contribute to raising their aspirations and achievement. (Y7)

Several teachers described pupils as enjoying their learning. Gorard, See and Davies (2012) report that increased motivation does not of itself result in improved learning outcomes. It may be that, while the activities were acknowledged to be challenging, the open-ended enquiry style of some of the events that allowed for exploration of pupils' questions gave them experiences of success which in turn improved participation and engagement.

4.4 Impact of project involvement on pupils' later learning

The project took a long-term developmental view of teaching and learning Evolution and Inheritance across KS2-3. Several of the teachers described pupils' achievements during the project as providing a suitable foundation for later learning. In Y5 classes, the project was understood to support learning in Y6, where Evolution and Inheritance was a newly introduced domain. Others described the project achievements at the end of KS2 as offering excellent preparation for pupils moving to KS3. Still others remarked that the project had provided pupils with an appropriate background and skills for further study beyond KS3.

Good introduction for thinking about the topic for next year. (Y5)

I feel that this has prepared them for their journey at High School and KS3 Science. A great foundation to build on as they still have so many questions to ask and so much new information and ideas to process as they mature as learners. (Y6)

Allowed pupils time to question their ideas. This will benefit their skills for further higher learning. (Y9)

Despite the researchers' background and commitment to progression, on this occasion the evaluation did not specifically probe teachers' views as to the extent to which project activities provided a foundation for later learning. The fact that teachers judged the project activities and associated learning as providing an appropriate foundation at key points across KS2 and 3 and beyond was particularly welcome.

5.0 Teachers' qualitative views of impact of project involvement on the whole school

5.1 Sharing practices across the school

The evalution probed teachers' views of the wider benefits of project involvement to the school. All but one of the teachers mentioned that the practices developed during the project would be shared in staff training across the school. In some instances, the wider adoption of project approaches was to be formalised and embedded in whole school/department subject planning and schools' curriculum development days. The importance of such structured arrangements within schools to follow up and build on teachers' CPD opportunities was highlighted in a review of evidence of effective profeessional development for teachers undertaken by Cordingly et al., 2015.

> *These will be repeated with furture cohorts of children. We will use the research activities as part of training for the staff at my school and look at ways that they can be used in other units of work in Science at KS1 and KS2.* (Y6)
>
> *I still feel that argumentation needs to be developed within school so will be looking at delivering this as part of staff development and how we can develop this across the whole school as part of our 'working scientifically'.* (Y6)
>
> *Share at whole school INSET and training in the future. Hopefully use whole school next year*. (Y8)
>
> *Appropriate ways to converse with others will be modelled across the school.* (Y8)
>
> *The project represents a culture shift - quality teaching and learning rather than teaching to test. As science subject leader it is going to be an approach I will set as a target for other teachers in my subject action plan for the year ahead*. (Y6)
>
> *Sharing of ideas and enthusiasm. This will be further developed to form part of our school's curriculum days.* (Y8 & 9)

5.2 The importance of schools being involved in research

There are national initiatives to encourage schools to be actively involved in research. In 2017, the Research Schools Network comprised 22 schools, each in receipt of funding to enable them to support evidence-based practice in local schools. Almost half of the teachers involved in the project indicated in their feedback that they were aware of the significance of research involvement for their school and their governors.

> *Also, it's added to the Science involvement for the subject and to impress the Governors*. (Y5)
>
> *Good to be associated with this research project (OFSTED, and improved profile of school within Trust.)* (Y5)
>
> *Having a project to complete and research has allowed us to take some time to focus on different ways of learning for the pupils*. (Y7)
>
> *For the school, it's important we are involved in research and development.* (Y8)

A message emerging from the feedback in several responses was a determination to share the project approaches through professional development activities. This was occasionally reinforced by a strategic aim to make the research approaches an explicit target in whole school/department planning.

6.0 Conclusion

The project was deliberately timed to meet schools' and teachers' need for guidance in the operationalisation of a new area of national curriculum science in England (DfE, 2014). It must be borne in mind that the project was *not* designed to prioritise the professional development of the collaborating teachers. Rather, their participation was to draw upon and bring to the project their pre-existing professional expertise, to inform the development and 'field testing' of curricular and instructional thinking in the face of novel demands across KS2-3. The collaboration in research was based on our view of the complementarity of the skills held by the teachers and the university-based researchers. This principle, which we believe assures the practical utility of the outcomes, was central to our proposal to the Nuffield Foundation. In the

context of the expanding Research Schools Network in the UK and emphasis on research led practice, Firth (2017) calls for collaborative research involving HE and practising school teachers which recognises the different skill sets the different sectors bring to research. A greater involvement for teachers in collaborative research could, it is argued, make them co-creators of research evidence with developing critical skills rather than remaining as just consumers of research evidence. Drew et al. (2016) describe teachers involved in a school-university research initiative as having '*fostered the development of criticality – a more constructive critical engagement with practice – through engagement with academic literature and research, and working with external partners'.* (op. cit., p.99).

Teachers' feedback, immediately following completion of classroom activity, suggests the project's successful instantiation of some of the practices found to be associated with effective teaching by Cordingly et al., 2015.

i) developing teachers' **pedagogical content knowledge:** by creating generic and domain specific approaches, such as argumentation and representational redescription

ii) developing teachers' **formative assessment practices:** by increasing awareness of some of the ideas pupils held in relation to macroevolution and DNA

iii) developing the quality of instruction by **creating domain-specific approaches**, practical modelling and representational strategies that supported pupils' understanding of macroevolution

iv) developing teachers' **confidence and science content knowledge**: associated with macroevolution and DNA

v) the strong focus on pupils' learning within the project helped to raise **teachers' awareness of their pupils' achievements** and increased some of the challenges presented to pupils in the course of teaching and learning.

***Note**. This feedback report of teachers' views of the impact of Study 2 on their practices links to a similar report of teachers' views of the impact of Study 1 on teachers' practices (Russell & McGuigan, 2017). The accumulating evidence from the two samples of teachers reveals a common strongly held perception that the research project activities have, in each case, made a valuable contribution to the development of professional practices.*

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Appendix I : 'Evaluation of impact' questionnaire protocol

Your view of involvement in the Nuffield project on Evolution & DNA

(Terry Russell & Linda McGuigan)

We are required to report on the impact of the Nuffield 'project on the teachers involved. Please would you be so kind as to complete this questionnaire as fully as possible?

Teacher name School:

Age group of children in participating class (Tick the box (es) that apply)

Year 5	Year 6	Year 7	Year 8	Year 9

1. What lasting impact on your practice do you consider your involvement in the project has had?

2. What do you think have been the benefits of being involved in the project ?

i. for your practice?

ii. for your pupils' learning?

iii. for the school?

3. Please give your impression of the impact of the project on your teaching generally.

(Please tick one box in each row.)	strongly agree	agree	disagree	strongly disagree
Involvement in the project was beneficial for me as a teacher.	☐	☐	☐	☐
The project offered opportunities to network with other teachers to develop my practice.	☐	☐	☐	☐
The project activities have helped my teaching of science generally	☐	☐	☐	☐
The project helped me to recognise the importance of children's ideas as starting points for my teaching.	☐	☐	☐	☐

The project gave me new ideas for teaching science	☐	☐	☐	☐
Asking for the reasons behind ideas and using 'argumentation' helped to develop children's 'working scientifically'	☐	☐	☐	☐
I have shared some of the activities with other teachers in the my school	☐	☐	☐	☐

4. Please give your impression of how the project has influenced your teaching of Evolution and Inheritance

(Tick one box in each row and add a comment below each statement.)	strongly agree	agree	disagree	strongly disagree
The project has helped my teaching of ***evolution***	☐	☐	☐	☐
Comment:				
The project has helped the use of alternative represention of ideas when teaching evolution.	☐	☐	☐	☐
Comment				
The project has helped my teaching of ***DNA***	☐	☐	☐	☐
Comment:				
The project has helped my use of **classroom argumentation** as a mode of working scientifically.	☐	☐	☐	☐
Comment				

Any other observation of impacts you would like to add?

Thank you for the time you have spent completing this questionnaire. Your responses will be used to evaluate the longer term impacts of the project. All responses will be confidential.