Institute of Education

UCL

Development Education Research Centre

Research Paper No.20 Innovation Fund project for the Global Learning Programme

Using global data in primary mathematics

Victoria Pendry

Global Learning programme

Development Education Research Centre
Research Paper No.20

Using global data in primary mathematics

Victoria Pendry[1]
2018

Published by the Development Education Research Centre

Development Education Research Centre
UCL Institute of Education
36 Gordon Square
London WC1H 0PD

Tel: 020 3073 8309
Website: www.ucl.ac.uk/ioe-derc

First published 2018

ISBN: 978-0-9934888-7-0

Disclaimer
This paper has been written by Vikki Pendry and the content and opinions are hers alone.
The author does not speak on behalf of the GLP-E and its consortium partners.

Cover image: © Victoria Pendry

1 To contact author: pendryv@gmail.com

Contents

Acknowledgements

In conducting this report I am grateful for the encouragement, patience and support of Fran Hunt from the UCL Institute of Education London, who asked me challenging questions and promoted further research into this area of teaching and learning.

The study would not have been possible without the support and commitment from the head teachers in each of the schools I visited, who granted permission for this research to take place. The study was also made possible by the teachers of each class that I visited, who gave up their time to answer questions, share their ideas and describe their experiences of using global data in their mathematics teaching. And finally, the children, who explored with me in the demonstration lesson and told me their own stories of mathematics in the pupil interview, made this research project rich, real and relevant. I am extremely grateful to all the teachers, head teachers and pupils for all their contributions to this research.

Abstract

This research set out to explore the connections between the use of global data in primary mathematics lessons as a way of engaging and inspiring teachers and pupils and raising levels of participation from more reluctant mathematicians. The study explores to what extent teachers are keen to use this approach to teaching and learning in mathematics and how much it provides an opportunity to connect learning across the curriculum. It reveals the current levels of desire and confidence of teachers to use global data in maths lessons, examining to what extent they feel that global data provides a real, relevant and purposeful context for learning, which can in turn motivate pupils to engage further in mathematics. It also investigates how using global data can further motivate and inspire teachers. The study employed qualitative data collection methods with teachers and pupils across six schools.

1 Introduction

1.1 Overall aim

The teaching of mathematics provides many opportunities for us to explore different aspects of the world around us. We only have to think of all the different units of measurement that are required learning at Key Stage Two[2]

in England in order to remind ourselves of the way numbers describe the world around us every day. Too often, however, teaching mathematics seems limited to the systematic teaching of calculation strategies and an approach that segregates problem solving into chunks of curriculum time, rather than integrating it across maths. When we consider that children are most often introduced to concepts of number and pattern through activities such as counting the number of steps up to the door of the local shop by singing '10 Green Bottles' or by counting ducks in the pond, it seems a missed opportunity that more complex mathematical concepts are introduced through sequences of teaching that eliminate context or pay lip service to it.

There are research papers and other documents already available that describe the benefits of contextualised approaches to the teaching of mathematics, and these will be discussed in the literature review. The purpose of this research is not to further explore abstract versus concrete approaches to teaching and learning or at what stage in learning pupils should move to and from abstract to concrete or vice versa. This would require considerable further analysis. The purpose of this research is to identify why teachers do, or do not, use global data in their teaching and to explore any barriers to the planning and delivery of context-rich maths lessons with a particular focus on the attitude of teachers to this approach. The research aims to explore to what extent the use of global data has a positive effect on teaching and learning and how this connects to global learning in primary schools generally.

2 Key Stage Two refers to ages 7 to 11 years in Primary Schools

1.2 Research outline

Guiding research questions

I used the following questions to guide the research:

1. To what extent and in what ways is global data currently used in primary mathematics?

2. What existing research is associated with the use of global data to support teaching and learning in primary mathematics and what are the key findings?

3. How can global data be best used to support teaching and learning in primary mathematics?

4. What are the impacts on global learning when global data is used in primary mathematics?

1.3 Rationale

There are a range of reasons why I decided to undertake this study and why this is important to me.

Firstly, my own experiences of developing and delivering learning materials and activities for mathematics indicates that children learn better when the context that they are learning within is relevant, familiar, or in some way inspirational. During my experiences of working with teachers, however, I have found that teachers find it difficult to plan and prepare for learning to take pace in this way. I have also seen evidence in support of this as well as suggestions that a context-rich approach can create barriers to teaching and learning. This research project aims, therefore, to address this conflict and identify effective ways of embracing global data into mathematics.

In addition, there are few research studies that look specifically at global learning and mathematics, and the report will provide a source for schools trying to develop global learning. It will establish a set of core principles to support the planning and delivery of global learning in mathematical contexts. Finally, the research will provide information for the Global Learning Programme (GLP) and other related organisations trying to develop training materials and resources aimed at promoting global learning within mathematics.

1.4 Overview of paper

This paper explains and illustrates my journey through, and exploration of, the challenges and opportunities of using a context-rich approach in mathematics. I begin by outlining the context and aims for mathematics in England in relation to national standards, guidelines and expectations, and move to explain how global learning can support these aims. I then explore what literature tells us about effective learning in mathematics, particularly associated with the use of global, or 'real' data and how pupil attitudes towards mathematics influence their attainment and progress.

Finally, I analyse what the teachers and pupils who took part in this research tell us about the importance of the use of global data in mathematics. I consider how their responses could shape some further research into this area and what support teachers could be provided with in order for them to effectively develop the mathematical competencies of their pupils while also developing their knowledge, understanding and skills in relation to global citizenship.

2 Context and concepts

The next section outlines the national policy context for England.

2.1 The National Curriculum

Despite the fact that many teachers state that the expectations of the National Curriculum for England 2014 (DfE, 2014) create little time to 'get creative' in subjects, especially mathematics, there are actually some rather encouraging statements in the aims and other sections of the policy document that encourage creativity, connectedness, authenticity and the opportunity to work beyond the National Curriculum itself.

> *The National Curriculum Aims, 3.2: The National Curriculum is just one element in the education of every child. There is time and space... to range beyond the National Curriculum specifications. The National Curriculum provides an outline of core knowledge around which teachers can develop exciting and stimulating lessons to promote the development of pupils' knowledge, understanding and skills as part of the wider school curriculum.*

This statement actively encourages schools and teachers to explore and elaborate beyond the National Curriculum document, therefore giving teachers permission to teach subjects and aspects of subjects that are not included in the specifications. This feature of the National Curriculum was in direct response to the consultation process for the 2014 curriculum review, which revealed that teachers wanted to have less content in the curriculum so that they could shape a more bespoke curriculum for their own school settings. This would mean that they could choose some topics or learning outcomes that have direct relevance and importance to their own school community, in addition to those set out for all schools by the government. This feature seems to have been lost in the way that schools implemented the new curriculum, and during my work I have come across many teachers who are not even aware of this flexibility – one that gives permission for curriculum content beyond what is described in the National Curriculum document.

Section 5 of the National Curriculum document introduces the aims of numeracy and mathematics, where there are encouraging remarks about a global learning approach to teaching which promotes the use of context as a valuable vehicle for learning within the specifications themselves:

> *5.1: Teachers should use every relevant subject to develop pupils' mathematical fluency. Confidence in numeracy and other mathematical skills is a precondition of success across the National Curriculum.*

> *5.2: Teachers should develop pupils' numeracy and mathematical reasoning in all subjects so that they understand and appreciate the importance of mathematics (DfE, 2014).*

Section 5.2, furthermore, repeatedly states that pupils should be taught to apply what they have learnt. Using global data then seems like a useful context in which to apply these skills, combined with the fact that they are often described by pupils as interesting and fun, thus raising levels of engagement and achievement as previously discussed.

> *5.2: Pupils should be taught to apply arithmetic fluency... Pupils should apply their geometric and algebraic understanding... They should be taught to apply their mathematics to both routine and non-routine problems... (DfE, 2014).*

Within the purpose of study for mathematics under the Programmes of Study and Attainment, section 7 (DfE, 2014: 76), we have another commitment to the authenticity of mathematics and its importance in understanding the world:

> *Mathematics is a creative and highly interconnected discipline that has been developed over centuries, providing a solution to some of history's most intriguing problems. It is essential to everyday life, critical to science, technology and engineering, and necessary for financial literacy and most forms of employment. A high quality mathematics education therefore provides a foundation for understanding the world, the ability to reason mathematically, an appreciation of the beauty and power of mathematics, and a sense of enjoyment and curiosity about the subject.*

2.2 Ofsted

The Ofsted school inspection handbook (Ofsted, 2015) in England also makes reference to the value of adopting a pedagogy that promotes critical thinking and authenticity in mathematics:

> *161: When evaluating the effectiveness of a school's work in mathematics... inspectors will consider... how well teaching... requires pupils to think and reason mathematically for themselves.*
>
> *Pupils who grasp concepts should be challenged through being offered rich and sophisticated problems before any acceleration through new content.*
>
> *Inspectors will consider... how well teaching... enables pupils to solve a variety of mathematical problems, applying the mathematical knowledge and skills they have been taught, and... how well teaching... enables pupils to apply their mathematical knowledge and skills in other subjects in the curriculum where appropriate (Ofsted, 2015: 47).*

Within the outstanding grade descriptor for the quality of teaching and learning and assessment, Ofsted describes that:

> *Pupils love the challenge of learning and are resilient to failure. They are curious, interested learners who seek out and use new information to develop, consolidate and deepen their knowledge, understanding and skills (Ofsted, 2015: 49).*

This expectation once again encourages teachers to provide materials that ignite curiosity while enabling learners to deepen their understanding, thus building their capacity to solve problems in increasingly complex contexts. Furthermore, in the outstanding descriptor for the quality of teaching, learning and assessment, Ofsted describes that:

> *Resources and teaching strategies reflect and value the diversity of pupils' experiences and provide pupils with a comprehensive understanding of people and communities beyond their immediate experience (Ofsted, 2015: 49).*

Although many of the materials that teachers develop in order to help pupils deepen their understanding of people and communities beyond their immediate experience are literacy or geography focused, I think there is an opportunity in mathematics to provide a suitable context for this also do something similar. Global, or rich data, can illustrate differences and similarities through a different lens and give pupils an opportunity to investigate and solve problems, thus building their confidence and achievements by empowering them to analyse, evaluate and reach conclusions more independently.

Outstanding grade descriptors for personal development, behaviour and welfare also go on to expect that:

> *Pupils discuss and debate issues in a considered way, showing respect for others' ideas and points of view (Ofsted, 2015: 52).*

Children feel safe and are happier when they are confident that they have the correct information before them. By presenting them with data in mathematics, we can provide pupils with 'evidence' as the foundation of an 'argument' when they prepare to debate and present their ideas. By providing them with frequent opportunities to interrogate data to ensure that it is reasonable, we support their skills to analyse data that is presented to them in order to form solid conclusions about its validity and to identify 'fake news'.

Under the same Ofsted outstanding descriptor:

> *Pupils understand how their education equips them with the behaviours and attitudes necessary for success in their next stage of education, training or employment and for their adult life (Ofsted, 2015: 52).*

If we are clear about the use of mathematics in everyday life, its vital role in shaping history and its ability to present 'the facts' in many contexts, we illustrate to children the purpose of their learning and its relevance to the success of their future, thus further motivating them to engage in new challenges with more resilience and determination.

In 2012, Ofsted published a report that may have influenced the development of the new primary curriculum and some of the encouraging statements we have just explored. Here, inspectors describe that they found a lack of quality opportunities to develop problem-solving strategies:

> *Key Findings: Schools were more aware than at the time of the previous survey of the need to improve pupils' problem-solving and investigative skills, but such activities were rarely integral to learning except in the best schools where they were at the heart of learning mathematics. Many teachers continued to struggle to develop skills of using and applying mathematics systematically (Ofsted, 2012: 9).*

> *100: Important weaknesses in the curriculum remain. Inspectors continue to be concerned about the lack of emphasis on using and applying mathematics (Ofsted, 2012: 45).*

These survey results clearly encourage a more purposeful approach to teaching and learning in mathematics, and the report continues to set out a number of related recommendations. It will be interesting to read the next Ofsted survey of mathematics in order to explore the extent to which their recommendations were developed and what impact these have had.

2.3 Global learning and its relevance to mathematics

From my experience there is a dissonance between what global learning leaders understand this term to represent and describe, and the views of many teachers and leaders in school. One of the problems is that the term global learning is often also described by other related terms, each with a particular emphasis on an aspect of this topic. 'Sustainable Schools', for example, seems to have left a legacy of developing attitudes and a knowledge base around recycling and the outdoor classroom. 'Education for Sustainable Development' is a reasonably current term, which teachers often describe to be something to do with

environmental sustainability and 'development education' is often associated with the development of education systems in poorer parts of the world. Academic literature often focuses on understandings of terminology and suggests that the terms development education, global learning and global citizenship education are used alongside each other in practice (Bourn et al, 2016). In this section I look at various descriptors of development education and global learning, and identify how they are used in GLP and how they potentially relate to maths education.

Bourn (2014b: 4) articulates this issue of the difficulty with terminology, concluding:

> *Development education is here proposed not as a static concept but as a pedagogical approach that can continue to provide an important contribution to learning.*

The GLP (2017) explains that:

> *Global learning can be described as an approach to learning about international development through recognising the importance of linking people's lives throughout the world. In the context of the Global Learning Programme, global learning encourages critical examination of global issues and an awareness of the impact that individuals can have on them.*

To emphasise the skills element of this definition, it is further stated that:

> *Global learning supports the long-term development and success of pupils, by enhancing their critical thinking skills and boosting their relationships with peers.*

Bourn (2014a: 40), in setting out a potential framework for the GLP, states that the focus should be on:

> *encouraging an approach that moves from reproducing bodies of knowledge to one that recognises learners' engagement with this knowledge and their different starting points, influenced by a range of external factors. It also recognises that for the learning to have any lasting impact, links need to be made to the learners' own sense of place and identity in the world.*

The GLP describes one of its main aims to be enabling young people to gain a critical understanding of global poverty and development. To achieve this aim, pupils explore knowledge themes that cover, for example, Human Rights, global agreements such as the Sustainable Development Goals, and globalisation. The programme also outlines a range of skills that it believes pupils should develop as they explore these themes, such as the ability to challenge perceptions, use evidence to enquire and explore, and taking a structured approach to being

active on development issues. Through an exploration of these themes and the development of these skills, the programme suggests that pupils will have the opportunity to think about the values that underpin these issues, thus reflecting upon what these issues really mean and what effect they have on the lives of people around the world.

It is this focus on critical thinking and the predominance of the need to consider global learning as a pedagogical approach rather than a fixed-end goal, that has fuelled my commitment to developing the capacities of teachers, and subsequently their pupils, to use mathematics as a way of exploring, discovering and interpreting a variety of global issues through the use of data in a variety of forms. Mathematics lessons present a good opportunity for pupils to consider how reasonable their work is, thinking about whether it 'makes sense' or whether their answers present a confusing picture. It is only by using a real context that pupils can experience a true purpose for their reasoning skills, and they are thus more motivated to question their solutions and further their enquiries. Global data allows for some exciting global and local issues to be explored that could make useful links into other aspects of the curriculum also.

2.4 Evidence and resources on global learning and maths

This research aims to explore to what extent global data is currently used in mathematics and what the barriers and facilitators are. There is some existing research that helps describe this, but it is not extensive.

Hunt and Cara (2015) report in their baseline analysis of the GLP Whole School Audit, that over 50% of schools indicate that they are at an early level of engagement in terms of integrating global learning into the curriculum. Global learning is covered less in maths than in other curriculum subject areas, in only 4% of schools, compared to 74% in geography, and an average score of 22% for all other subjects.

Think Global[3] and OXFAM[4] (organisations which support global learning in schools) list a number of resources and activities under the title of 'Bring Data to Life'. This includes some picture resources from Gapminder, 'Dollar Street', comparing monthly incomes around the world and a book for Secondary teachers, *'Mathematics for Social Justice'*, from the Mathematical Association.

The GLP website hosts a selection of materials and their 'Introduction to global learning in mathematics and statistics'[5] begins to explain how teachers can locate and organise data in order for it to be used effectively in mathematics teaching.

3 https://globaldimension.org.uk/resource/bringing-data-to-life/
4 https://www.oxfam.org.uk/education/resources/bringing-data-to-life-11-14
5 http://glp.globaldimension.org.uk/pages/10715

They have also composed some of their own materials, including an exploration of climate change using percentages, and are in the process of composing an optional twilight session for Expert Centres that would enable schools to further access and use this data to stimulate critical thinking about Climate Change in mathematics.

2.5 Terminology

Throughout this research paper I use the term 'Global Data' to refer to a wide range of data and statistics that describe different aspects of our world, which could include population, data sets about access to clean water, average rainfall etc. When I use the term 'context-rich' I am referring to a pedagogical approach to teaching and learning that places mathematics within a framework of real data that illuminates the world and provides some opportunity for pupils to develop their skills of critical and creative thinking.

3 Literature review

This literature review aims to explore and extrapolate aspects of current research as to the effectiveness of using real or global data in mathematics and how this connects to pupil progress and achievement. The review also aims to present an explanation of the relationship between pupil attitudes and their appreciation of mathematics, and pupil progress and achievement, particularly in relation to how global data can capture their interests. The review considers evidence relating to how enjoyment and engagement in mathematics are connected and a premise for how well pupils learn and to what extent they are motivated to explore further.

3.1 Being mathematically competent

This research builds on my interest in and understanding of the mounting body of evidence that describes the need for young people to be able to demonstrate strong mathematical and other competences in order to be able to thrive in the 21st Century. That is, young people need to be able to combine their knowledge, understanding and skills effectively.

> *When education is successful, the learners are able to make use of the knowledge, understanding and skills they have acquired because they have developed the right attitudes and approaches to use them effectively. This coming together of knowledge, understanding, skills and personal development is usually referred to as a 'competency' (Male, 2012: 2).*

In the literature review I explore what enables pupils to engage with mathematics and to what extent a sense of real purpose motivates them to solve problems and build on what they know. Recognising the role that mathematics plays in the 'real world' of work and global citizenship is important in terms of supporting pupils to understand the significance of mathematics in relation to their abilities to interact competently with others and in a variety of contexts. In mathematics, there is an opportunity to create context-rich activities that enable pupils to both explore and develop a deep fascination in the world around them in order to gain a deeper understanding of the way in which the world works, and also to become confident in using a range of strategies in order to reach reasonable conclusions and possible answers to real and relevant problems associated with globalisation. This approach to teaching and learning would enable pupils to develop the desirable knowledge, understanding, skills and attitudes.

It is significant that PISA (Programme for International Student Assessment)[6], a triennial international survey, aims to evaluate education systems worldwide

6 https://data.oecd.org/pisa/mathematics-performance-pisa.htm

by testing not just the knowledge of 15-year-old students, but also the skills associated with key areas of learning. The problems presented in these tests are designed to reflect some of the kinds of thinking, tasks and activities the pupils might be expected to carry out in their day-to-day lives. The objective of the PISA testing is to determine how well students are prepared to meet some of the challenges of their future lives. In mathematics, for example, pupils are challenged to consider real data and assess validity as well as build solutions for related problems. Questions are organised into three categories: mathematics, financial literacy, and problem solving. Previous contexts for these questions include comparing, evaluating and analysing global sales for particular products, infrastructure systems, profit and loss, and risk taking. These tests reflect the need for pupils to be able to use mathematical skills, knowledge and understanding to competently solve these problems, which will only come as a result of practice in similar contexts and an appreciation of the validity of this approach to learning in mathematics.

Employers, educators and leaders at a national and international level also describe the need for young people to be competent and able to 'think on their feet' and find solutions to problems (Think Global and British Council, 2011).

The British Chamber of Commerce in their 2014 Workforce Survey state that 88% of firms describe that school leavers are not prepared for work. Firms cite a lack of soft skills such as communication, team working and resilience as the reason for this. The CBI (2014: 2) comment that:

> *The curriculum has encouraged teachers to focus narrowly, with memorisation and recall being valued over understanding and enquiry, and transmission of information over the pursuit of knowledge in its fullest sense.*

Nottingham (2017) uses 'The Pit' to describe a scenario where pupils are inspired to use what they know to investigate something that is unfamiliar to them, solving a problem and thus feeling more empowered to 'dive in' to other challenging situations in the future (See: Appendix 6). In mathematics, pupils have a strong sense of what they know (times tables, how to measure, how to subtract etc.) so we have a good opportunity to use this approach to help pupils build their confidence in mathematics by placing these known facts into a context, using a range of strategies to solve the problem and 'climb out' of the pit. Solving problems in this way is often referred to as 'lifelong learning' and reflects the kinds of competences I have previously described.

3.2 Abstract versus concrete

There have been many studies aimed at exploring which is the best way to introduce and develop mathematical concepts with children. According to my own experiences and the background research that has been done for this research study, it seems that there are a number of considerations to take into account when planning for the use of global data. There is no 'silver bullet' in terms of process or content. The nature of the context, the type of data, the way that it is introduced and the stage or ability of the pupils, all have a significant impact on the extent to which global data has a positive impact on learning.

Post and Reys (1979) explore to what extent manipulatives[7] can support learning in mathematics. They conclude that using models, symbols and images are useful, but that there is not one 'correct' version of these in any particular area of mathematics. This study supports the idea that global data has to be used flexibly and that the context of learning materials have to be closely aligned to the mathematical concepts and strategies being taught.

> *The non-uniqueness of the perceptual and mathematical variables utilized in these illustrations has been noted. Certainly some degree of discretion, professional judgment, and forethought is advised in their selection; but in the final analysis they are clearly not unique. This condition was at first disturbing to us. We naturally wanted the models developed to be "the right ones" for the concepts under consideration. When we found ourselves continually faced with alternative interpretations and/or possibilities, we felt a strong need to make definite decisions as to the inclusion of one or another embodiment or mathematical variate. It was eventually realized that there probably is no single best way to get "from here to there" and that a variety of routes are possible (Post and Reys, 1979).*[8]

The report moves on to suggest that using mathematical concepts in new situations is a real measure of how well a child has learned.

> *It seems reasonable to suggest that a child has truly learned a mathematical concept only when s(he) is able to abstract it from its physical context and generalize it to new situations (Ibid).*

A study by de Bock et al (2011: 123) draws on the result of a previous study by Kaminski, Sloutsky and Heckler (2008), which concludes that *'students may benefit more from learning mathematics through a single abstract, symbolic representation than from multiple concrete example'*. However, de Bock et al

7 Manipulatives are objects and materials that represent number and quantity and can be used in a variety of ways to explore calculations and number sequences.
8 No page number available

(2011: 123) suggest, having conducted further research, that this is only 'one side of the coin':

> *Our results confirm the basic finding by Kaminski et al. (2008): Transfer to a new abstract domain is better enhanced by an abstract learning domain than by a concrete learning domain. However, through our extended design, we were able to show that this is only one side of the coin: Transfer in a new concrete domain is also enhanced more by concrete instantiations than by abstract instantiations.*

3.3 The purpose of mathematics

Research shows that children are motivated to explore if they can see a connectedness between what they are learning and their own lives – in other words, if their learning is seen as authentic (Lombardi, 2007: 2; Har, 2013: 2). As described further in 3.5, enjoyment is a big factor in terms of achievement, and indeed there are many things that are 'fun' and come seemingly without the useful tag that describes how this specific experience will be of benefit to your life. An example in the context of mathematics would be playing games such as snakes and ladders, painting by numbers or making a cake, but, in fact, all these activities (and many like them) prepare learners for real life in a variety of ways, i.e., counting forwards and backwards, matching numbers and measuring.

A particular issue with mathematics is that its use in real life is often 'hidden' so it is difficult to see where mathematical processes have had a significant impact on design and production etc. Stewart (2009) put this rather well:

> *And the reason we don't notice it is that, entirely sensibly, the maths is kept behind the scenes. If I'm buying carrots, I don't want to have to learn about the mathematics of genetic trials. If I'm putting petrol in my car, I don't need to know how to solve the inverse problem for seismic waves. But if I want to understand how my world works, I do need to appreciate that the maths is there. Otherwise, I'll think that the subject is useless. And if too many of us do that, soon there won't be enough mathematicians to keep everything working (Stewart, 2009).*

It is the last three sentences here that are of particular relevance to this research study into the use of global data in the teaching of mathematics. Teachers should be enabled to describe the maths wherever possible. 'Where's the maths in that?', for example, is a phrase coined by Mr Keegan[9] (n.d.), which seems a popular expression with teachers to remind them of the opportunities for cross-curricular links in mathematics.

9 https://twitter.com/swimminginmaths/status/806227626612445184?lang=en-gb

Examples of potentially 'hidden maths' are shown here in photos I have taken and shared with teachers and children. My research has shown that although I am able to make these links with ease, many teachers are not able to, but given the encouragement and examples to think in this way, they do so with increasing confidence, thus having a wider repertoire to share and explore with pupils. Examples of images and artefacts from a range of places and cultures enables a discussion that compares and explores similarities and differences and builds a sense of awe and wonder about the world.



The maths in architecture: symmetry, pattern, measures, proportion, ratio and time (age).

3.4 Using contexts and concrete (global) data

Widjaja (2013: 158) confirms that the use of global data and the creation of context-rich activities have to be crafted carefully in order for them to be either truly relevant or generally interesting:

> *Students bring to classrooms different learning experiences which will affect their interpretations of the context. Studies show that students often ignore the context altogether. The openness of contextual problems allows room for diverse interpretations including misconceptions or misunderstandings. Hence opportunities to negotiate their interpretations of the context are critical to establish an appropriate link between the context and mathematical ideas.*

This study into the way that pupils react to contextualised problems demonstrates that their response is rooted in their own life experiences. If we are using global data to engage learners in mathematics and illustrate certain aspects of globalisation, the data needs to be relevant and of interest to pupils. This engagement relies on a teacher knowing their pupils well and requires the teacher to create and embrace conversations about the data in order to clarify meaning and clear up any misconceptions. This conversation is an opportunity to build 'talk for mathematics' helping pupils to feel as if they are expert mathematicians (raising intrinsic motivation) through the way that they explain and ask questions about the data. If the data set is to be an effective tool for developing and

building mathematical concepts and processes, the data needs to be selected carefully in order for it to be of true relevance. Data about sales of a particular chocolate bar around the world may be a 'tasty' topic for pupils to consider, for example, but is it likely to be a poor vehicle for year 3 pupils to practise subtraction. As the figures and amounts would be over 1,000 or represented as decimals, this would be beyond what is expected in the 2014 National Curriculum for pupils in year 3.

Further ideas about how global data and context are used in mathematics are discussed in Hoogland et al (2016: 22), where they explore the benefits of using 'image-rich' materials, rather than word problems:

> *Word problems are predominant in mathematics classrooms in assessing students' ability to solve problems in everyday life. Research on word problems, however, reveals a range of difficulties in their use in mathematics education. In our research we tool an alternative approach: we designed image-rich problems as alternatives for word problems.*

The ability of a pupil to physically read words in a problem is often a barrier to their being able to interpret and use their mathematical skills and is a reason for them to see mathematics as too difficult. It seems sensible then that images and diagrams are used to exemplify global data and real-life problems. NRICH[10] and Problem Pictures[11], for example, provide some examples of stimulating photographs and images, which often switch a child on to exploring and investigating the related numbers.

3.5 The effects of enjoyment in mathematics

My experience has shown that children enjoy mathematics more when they are exploring real data that describes a feature of the world around them that is relevant to their own lives. I think it is important, therefore, to include research that makes a connection between enjoyment and achievement in mathematics. It seems logical that enjoyment leads to higher levels of engagement and therefore greater levels of achievement, but it is useful to look evidence in support of this, such as the following quote from Guvinder (2016:12):

> *In particular, students with higher level of pleasure-oriented motivation tended to have significantly better achievement in mathematics in all the nine education systems.*

For pupils to fully engage in their learning and thus make progress and achieve, they need to be in a relaxed (or happy) state. This state of being is much more

10 https://nrich.maths.org/
11 https://www.problempictures.co.uk/

receptive to new ideas and concepts rather than the state of 'flight' which can arise from learning that is perceived to be threatening and therefore 'too difficult'. Because mathematics is so frequently about learning new strategies or about applying what is known in a new context, it is important that pupils do not feel threatened.

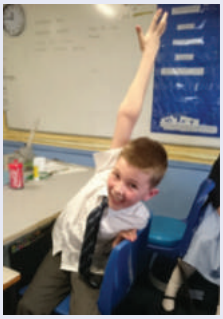
> *There is a large and growing body of research which indicates that people experiencing positive emotions perceive more options when trying to solve problems, solve more non-linear problems that require insight, [and they] collaborate better and generally perform better overall (Rock, cited in Edutopia, 2013).*

Of course there are many reasons why a child may be feeling threatened and unhappy, not least due to challenges at home or an incident in the playground, but for the purposes of this study we are considering situations in the classroom that should promote a feeling of happiness and a sense of harmony.

Therefore, in order to create this sense of harmony so that a child can be receptive to new ideas and guidance from others, we need to create situations and experiences in our lessons that offer pupils something new (unfamiliar) that is clearly rooted in something old (familiar), and provide learning that is truly relevant and purposeful and/or something that is in some way inspirational. The nuances of this approach are of course complex in terms of the individual nature and situations of every child, and the interests, experiences and expertise of individual teachers, but it is possible to reach and engage most children through a pedagogy that enables pupils to see the connectedness of their learning, inspiring them to explore new things or adding a context and purpose to existing knowledge.

Reviews of other documents, such as Lee (2008: 12), help us further to see that by using real or meaningful data, we can encourage and engage pupils:

The reason for pupils' difficulty is explained not in terms of the conceptual complexity of the subject matter, but in terms of its apparent irrelevance and/or the teacher's inability to present it in a coherent, meaningful way.



Often providing global data allows pupils to explore brand-new ideas which they can share with the rest of the class. This is empowering, motivational and has clear links to increased achievement.

Photo: Year 5 pupil from School B, keen to share his ideas about Food Miles.

Zhu and Leung (2010) also explore the issue of motivation and suggest that the balance of extrinsic and intrinsic motivation is different according to culture and tradition. Interestingly, in England, extrinsic-motivation is seen to have a detrimental effect on learning.

> *The importance of motivation in learning has been widely recognized. However, due to its multidimensional and complex nature, it appears difficult to synthesize research findings on motivation across studies. Heated debates about the effects of intrinsic and extrinsic motivation on learning and their interaction have been going on since the terms started to be used. Moreover, cultural difference acts as another crucial factor in the field. Using the Trends in International Mathematics and Science Studies' 2003 eighth grade mathematics data, this study scrutinized the relationship between pleasure-oriented (intrinsic-related) and productivity-oriented (extrinsic-related) motivation and how they collectively affect students' academic performance in East Asian education systems compared with those from Australia, England, The Netherlands, and the USA. The study found that both types of motivation contributed to East Asian students' mathematics achievement in an additive fashion, whereas extrinsic-related motivation appeared to have a detrimental effect on their Western counterparts' learning. Possible reasons were explored from a cultural perspective (Zhu and Leung, 2010: 1189).*

3.6 A mastery approach

The National Centre for Excellence in Teaching of Mathematics (2017) defines mastery in mathematics as *'acquiring a deep, long-term, secure and adaptable understanding of the subject'*. They further explain that, *'At any one point in a pupil's journey through school, achieving mastery is taken to mean acquiring a solid enough understanding of the maths that's been taught to enable him/her to move on to more advanced material.'*

In my experience, I have come across a range of teacher explanations as to the benefits and definitions of a mastery approach in mathematics. Of course, those teachers who have received in- depth training into enabling mastery in mathematics have a clear idea in most cases of the pedagogy and approach required and the benefits of doing so, but many more teachers seem confused as to the potential impact that this approach should have on their teaching methods and the related learning outcomes. Many teachers exclaim that is it an approach that decontextualises maths, as the focus is on calculation strategies and the recall of number facts, and is thus a barrier to a creative learning process and the use of global data. They also suggest that it is only possible because teachers in Shanghai have many hours out of class to prepare for such an approach, whereas in the UK we don't. There seems to be a good understanding that mastery includes the expectation that all children can achieve from a common starting point, but

a general frustration that, at present, pupils are in fact at very different 'starting points'.

Some research currently exists into the benefits of a mastery approach, but it is still relatively early to assess its impact.

> *Shanghai Math is an example of a mastery approach to teaching and learning in mathematics. There is some evidence that the Shanghai maths programme has a positive effect on teaching and learning but it is not a 'silver bullet' (Jerrim and Vignole, 2015: 19).*

Another piece of independent research, conducted by the Oxford University Department of Education, reports that this teaching method can be effective. This research noted that year 1 pupils taught with the programme for two terms made significantly more progress than students using it for a shorter period:

> *Teachers reported that the programme could boost children's motivation and engagement, and the evaluation found that it can be used creatively and flexibly (University of Exeter, 2016).*

Indeed, the DfE announced in July 2016[12] that new funding, totalling £41 million over four years, is available to support teaching for mastery. This money is being channelled through Maths Hubs on several linked projects.

However, within the context of promoting a context-rich learning environment, in view of this substantial investment from the DfE, I think there is some work to be done to explain to teachers the connections between a mastery approach and the opportunities and benefits of using global data. Teachers need a clearer understanding of how context-rich problems can be an opportunity for children to use and apply their maths skills, which can in turn develop and deepen their understanding of mathematical concepts. As PISA (2016) notes:

> *Mathematical performance, for PISA, measures the mathematical literacy of a 15-year-old to formulate, employ and interpret mathematics in a variety of contexts to describe, predict and explain phenomena, recognising the role that mathematics plays in the world. A mathematically literate student recognises the role that mathematics plays in the world in order to make well-founded judgments and decisions needed by constructive, engaged and reflective citizens.*

This can only be achieved if students are exposed to frequent activities that illustrate how data can be used to describe and interpret the world. 'Rich' is often a term used to explain what we mean by data that has a direct link to information that is relevant or interesting to students.

Pigott (2008) makes an important point about how we interpret the word 'rich':

> *In essence, rich tasks encourage children to think creatively, work logically,*

12 https://www.ncetm.org.uk/resources/49448

communicate ideas, synthesise their results, analyse different viewpoints, look for commonalities and evaluate findings. However, what we really need are rich classrooms: communities of enquiry and collaboration, promoting communication and imagination.

This, I believe, quite rightly makes the point that it is no good just having colourful images, incredible data or awesome number facts, it is the way that these are presented and explored that makes the difference to global learning and the mastery of mathematics. More about this issue is explored later, when I refer to the results of the data collection in schools.

3.7 A study of culture through mathematics

One area of study that I have found particularly interesting as I have explored research papers and global data in order to compose resources for teachers is the issue of using mathematics as a study of culture. Hall (2007), for example, illustrates how and where number systems have been developed throughout world history and their connections to art and music. Research into this area would be a useful topic for students in Key Stages 2 and 3, in order to further illustrate the connectedness of maths to many aspects of everyday life.

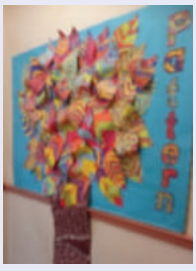
Moyer (2001) explains that by placing appropriate mathematics skills within their cultural context, teachers are able to support pupils' value diversity and that the related contributions of diverse cultures allow us to gain a rich understanding of mathematics.

Photo 1: Geometry and patterns in the arts

Sheffield Street Sculpture
May 2016

Yorkshire Sculpture Park
March 2017

Uganda Cultural Exhibition, Kampala
May 2017



Pattern Tree
York Primary School
Sept 2016

Photo selection 1 illustrates how geometry and pattern are frequently used in the arts to create beauty and engage the 'audience' in art forms. These are my own photos and illustrate the extent to which such pattern is dominant in artistic designs around the world.

4 Methodology

4.1 Approach to research

In order to conduct research into using global data in schools, I adopted a qualitative approach to data collection. This was most appropriate given the scale of the study and because I wanted to find out about how resources and materials seemed to work for pupils and teachers.

I used group interviews with pupils and teachers in order to collect data. The sample size is relatively small, with six schools involved and a total of 42 pupils and 14 teachers interviewed. The research is both descriptive and explanatory as it aims to describe current approaches and practices in relation to the use of global data in mathematics as well as offer some explanations as to how and why global data is used in this way at present. Interviews were semi-structured in order to respond to ideas and questions from teachers during the research.

Questions for visit one were pre-determined (after the visit to the pilot school) but questions for visit two were largely informed by findings after the first visit to all schools.

4.2 Data collection

There were three stages to data collection, which I outline below:

4.2.1 Stage one: Engaging schools

I sent an email to six schools I had made connections with via the GLP and all schools responded to say that they would like to take part. I invited these schools because they had previously expressed an interest in using global data in mathematics at other teacher training events I had run. I also contacted two secondary schools but both chose not to take part.

Table 1 provides a summary of key information from the participating schools.

Table 1: Background information on participating schools

School	School phase	School type	Geographical location	Number of pupils	% FSM	Previous engagement with global learning
School A	Primary	Community	Urban, North	218	49	One-off projects from external providers. Have recently joined GLP
School B	Primary	Voluntary Controlled	Urban, North West	220	5	Use International Primary School Curriculum
School C	Primary	Voluntary Aided	Village, North	83	10	Various projects associated with national events and Church-related charitable activities. Recently joined GLP.
School D	Junior	Voluntary Aided	Village, North	252	3	Fairly extensive amount of activities related to charitable events and projects. Recently joined GLP.
School E	Primary	Community	Urban, North East	415	41	Expert Centre for GLP.
School F	Primary	Community	Urban, North East	218	47	Some one-off projects and whole-school charity projects.

A more detailed project email was sent to all interested schools. This explained and outlined in more detail the research questions, expected timescales and potential outputs of the research. This communication also detailed expected commitments from the school and from myself in order to agree some parameters of engagement. I also outlined the ethical guidance for the study, which can be found in 4.3.

In order to deliver the best possible study, the first school visit (School A) was viewed as a pilot in order to provide the opportunity to modify and improve research techniques if necessary, but as few changes were necessary to the proposed programme, their data has been included in the study.

4.2.2 Stage two: School visit one[13]

The purpose of the first visit was to provide a demonstration lesson on using global data in maths, to provide information about the project and to collect data from teachers about their confidence in incorporating global data into maths.

13 During visit one I offered to lead a whole-school assembly during both visits, which was taken up by two schools. This assembly aimed to further celebrate 'Data Power' with teachers and pupils and provide a further reference point for pupils taking part in this study. The assembly also aimed to motivate other teachers across the school to consider using global data in maths lessons, although a study of this impact will not be possible during this research project.

Demonstration lesson in years 3 and 5

I designed and delivered a one-hour lesson for years 3 and 5 in each participating school. This lesson aimed to demonstrate an approach to teaching and learning in mathematics that embraced the use of global data as a way of stimulating and enabling an authentic learning experience for pupils that empowered them to use some known facts in order to solve new problems. The same lesson was delivered in each school and differentiated according to the year group. Learning objectives reflected the statutory requirements of the National Curriculum Programmes (DfE, 2014) of study as well as the aims of the GLP Curriculum Framework[14]. The intention was that this lesson would enthuse class teachers who observed the lesson to use more global data subsequently in their lessons.

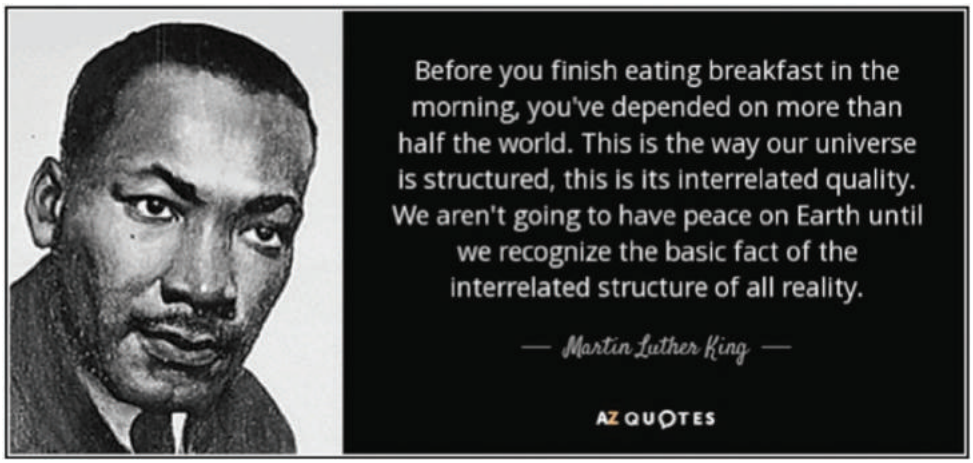
For this lesson, I used the picture story book 'The world came to my place today' (Readman and Roberts, 2002), which features a young boy called George staying with his grandfather. George's grandfather explains that everyday items come from all over the world, including breakfast cereals, rubber tyres, paper and then various items of food shopping that arrive from a delivery. I used the same text for year 3 and year 5 in order to be able to explain to teachers how materials can be adapted according to different needs and levels of prior knowledge.

The lesson began by asking pupils to explain what they thought of when I showed them the number 28 on the board. The purpose of this was to illustrate that '28' can represent many things because a number simply describes a quantity or is a label to a particular item and part of the counting/measuring process. Examples I provided them with included 28 days in four weeks, £28 for a new pair of trainers, 28g for a packet of crisps and 28 miles to Hexham (or wherever 28 miles took us to from each school).

From this starting point we read the story together and thought about the numbers involved in it, including the time of day, age of characters, distances to local shops and costs of food. The whole story highlights the fact that in the UK, we rely heavily of food and other products from around the world. I explained that this was sometimes referred to as globalisation and that we should remember that we are connected to many places and people in many different ways. I showed children the following quote and map to further explain this connectedness.

14 http://glp.globaldimension.org.uk/pages/10706

Photo 2: Martin Luther King quote



(Luther King[15]).

From this general exploration of the story, pupils were asked to explain what countries they thought various items in the story might have come from originally. This was an opportunity to talk about, for example, climate and temperature (oranges struggle to grow in Iceland); physical features, including areas and perimeters (forests in Canada); and trade routes in the present and in the past. The map (Photo 3) was shown in order to stimulate thoughts about where food comes from and the related food miles and trade costs. This then moved onto what they thought might be exported from the UK.

Photo 3: World Food Map

(Source: Jane Illustration for TES[16])

15 Source: http://www.azquotes.com/quote/867899
16 http://www.janeillustration.co.uk/blog/illustrated-maps/food-map-copy-2/)

Teacher interviews

In each school, I followed the lesson with a 20-minute session with class teachers in order to share other ideas and resources associated with the use of global data in mathematics and to reflect on the key features of the lesson. I asked teachers to tell me about their 'topics' (in mathematics and beyond) in order for me to be able to send them some related materials following my visit. I also held an informal discussion during this session with teachers in order to explore their attitudes towards the use of global data in mathematics and the extent to which critical thinking and problem solving currently featured in their lessons.

I asked teachers a set of questions in order to shape the discussion and inform the style and content of future resources that I might share with them. I made written notes during this discussion; these stemmed from the interview questions but were more flexible in the way that they responded to teacher comments.

Preparing and gathering global data as resources for teaching and learning in years 3 and 5

A range of resources were presented to teachers during visit one after the lesson and were subsequently sent to teachers. These resources ranged in style and content and provided short, medium and longer activities where pupils could work individually, in pairs, in small groups and as a whole class. Resources included existing materials described by the GLP, other resources created by partner organisations such as Oxfam[17] and Action Aid[18] and new bespoke resources that I created myself. A selection of these resources was used during the demonstration lesson so as to illustrate the principles of using global data to the teacher and to explain to the pupils what is meant by the term 'global data'. The resources in Appendix 2 illustrate the kinds of data that I shared with teachers to illustrate the opportunities for critical enquiry and mathematical challenge.

The idea was that teachers would use and adapt various resources within their teaching and learning over the coming months. I made direct email contact with each teacher on two or three occasions in between visit one and visit two in order to offer thanks, encouragement, support and provide a few further online resources in support of topics and learning areas as discussed in visit one. I designed a sample worksheet or collection of data for each school to make links between curriculum topics, global data and maths lessons. This, for example, included 'Capacity Cocktails' to explore food miles and ingredients for drinks of various sizes and 'Awesome Ocean Percentages' to stimulate conversation about global warming, surface area and species counts and changes (see Appendix 3).

17 https://www.oxfam.org.uk/education/resources/more-or-less-equal-maths
18 https://www.actionaid.org.uk/school-resources/search/s/subject/0-2374

4.2.3 Stage three: Schools undertake activities incorporating global data into maths

Table 2 shows the activities schools carried out between visit one and visit two incorporating global data in maths. The table also references whether each school is participating in the Global Learning Programme (GLP) or uses maths resources from Oxfam,[19] as this would indicate an existing potential link to global data in mathematics.

Table 2: Global data activities participating schools got involved in

School	GLP maths	Oxfam maths	Resources sent to schools	Other
School A	No	No	Facts about oceans to link to Science topic. Facts about Brazil to link to Geography topic.	Created own activities relating to pupils planning a holiday to Brazil.
School B	No	Yes	Facts about fruit – percent water and number of calories. Time for Ancient Greece – relating to topic.	
School C	No	Yes	Facts about sport to link to topic work. Most popular athletes in the world. League table of attendance at sporting events worldwide.	
School D	No	No	Volcano eruptions per decade – geography topic. Marvellous Mountain facts – link to geography topic.	Looked at 'If the world were a village'.
School E	No	Yes	Capacity Cocktails – facts relating to fruit and capacity to connect maths and science. Facts about castles – link to topics. Potion for your enemies – capacity link to castle topic.	Had used data about Fairtrade to create a game in maths.
School F	No	No	Facts about the world's biggest mammals – link to topic. Animals from China – facts and furious – link to topic.	

4.2.4 Stage four: School visit two

The aim of school visit two was to carry out data collection with teachers and pupils, to find out how global data had been incorporated into maths, to explore any issues and to discuss any emerging evidence of impact on pupils.

Teacher interview visit two

Approximately six weeks after visit one, I returned to each school to explore with teachers how they used global data and what further support they might need or want. I asked the questions in Appendix 4: Interview schedules and recorded the resulting conversation, which was subsequently transcribed.

19 E.g. https://www.oxfam.org.uk/education/resources/more-or-less-equal-maths

Pupil interview visit two

During visit two, I interviewed two groups of four to six pupils in each year 3 and year 5 class whose teacher had been involved in the project. The purpose of this interview was to explore attitudes and experiences associated with global learning as well as to develop my understanding of what motivates pupils to participate in mathematics. Each group interview was recorded and subsequently transcribed.

I began by asking pupils a few ice-breaking questions about the world in order to set the context for the interview. Pupils were then challenged to complete a circular jigsaw, which showed people from around the world wearing national costumes and holding hands. A list of the questions asked can be found in Appendix 4: Interview schedules.

4.3 Ethical considerations and confidentiality

In order to maintain transparency and professionalism throughout this research, to accompany the project summary to schools, I sent a letter to head teachers specifically about data and child protection. I also sent a letter to schools that could be used to send to parents about this project. The core elements of both of these letters were as follows:

- Confidentiality and anonymity will be guaranteed for pupils and schools. No sensitive data will be collected and pupils will not be identifiable outside the school. Any data used will ensure pupil contributions are anonymised and are confidential.

- Any photographs of children taken during visits to school will be taken in strict accordance to the photographic policy held by each school and permission was sought to use the photographs in this report.

- Inclusion in the research is voluntary. Parents and staff can withdraw pupils from the research and pupils can withdraw themselves from the research at any time.

  Parents/carers were also made aware of elements of the research study through the usual ways that schools share pupil learning and progress: class/school newsletters and displays around school buildings.

  All teachers in this project were made aware that anonymised analyses of their interview responses, as well as those of the pupils, would be used in order to inform this project.

An optional letter was provided for schools to consider sending to the parents of pupils who were involved in interviews. This letter to parents also outlined the purposes of the research project and explained issues of confidentiality, data protection and their right to 'opt out' of the study.

4.4 Data analysis

Initially, I intended to look at increases in numbers of lessons incorporating global data, how teachers engaged with the global data, increases in pupil engagement with global data and the impact of this engagement. However, although answers to these questions would have been useful, the approach moved more towards discussions in order to understand barriers and facilitators to using global data. Although pupil progress in particular is closely linked to whether or not teachers would use global data to stimulate and support learning, it became quickly evident that teachers recognised that the impact on attainment would be positive due to increased levels of engagement. Despite this, however, teachers still described a reluctance to do so, which then focused discussions on why this was the case.

The following research questions guide the analysis.

Guiding research questions

1. How important is global learning in maths?

2. To what extent and in what ways is global data currently used in mathematics?

3. What existing research is associated with the use of global data to support teaching and learning in mathematics and what are the key findings?

4. How can global data be best used to support teaching and learning in mathematics? What are the barriers and facilitators?

5. What are the impacts on global learning when global data is used in mathematics?

5 Presentation of findings

In the following sections I present the findings.

5.1 The importance of global learning in maths

Teachers I spoke to were in agreement about the importance of global learning and that mathematics is a useful place to explore global data. Much of this discussion took place during visit one, when most teachers explained that they do not naturally make links to global learning in mathematics. However, as a result of the demonstration lesson I gave, they could already think about opportunities in future areas of maths that this approach could develop.

Most pupils who were interviewed described how they found some of the data very interesting and were quite animated when describing some of what they had learnt. Pupils also agreed with teachers that learning about the world through maths was important and interesting:

> *It's more interesting. Because you're learning about the world as well as doing your maths (School B, year 5 pupil).*

> *I think it's important to learn about different people in different countries because when you get older you could maybe do something to stop... like if there's something wrong and they aren't being treated the way they should be treated. And also, if you go to that country when you're older and you take a trip there you will know about it (School C, year 3 pupil).*

Conversations with pupils revealed that they enjoyed exploring data that explained 'real things' in the world but didn't always initially mention this kind of learning when describing what they liked doing in maths lessons.

It is significant that when pupils were asked about what they enjoyed doing in maths generally, very few responded with a description of an activity relating to global data. There are a few reasons for this I think. Firstly, global data or numbers about the world are not described as a feature of the lessons that they are taking part in, so global learning is not given a title when it is happening. Secondly, unless the global data had been used within the last week, or had been a particularly high-profile activity (like the activity in School A to plan a holiday), pupils were less likely to remember it. Thirdly, and most significantly, pupils perceive that maths is a strategy (the grid method for multiplication for example) or a collection of knowledge (time table facts or number bonds). They do not think of maths as a subject that describes or explores the world, more as a collection of

methods to solve number problems. This is further illustrated by a comment from one teacher:

> *They don't see it as being maths. Because I would call it... I would say, we're doing a topic maths lesson today, or a topic lesson that will be using some maths. Because there was more than maths; an awful lot of speaking, listening... negotiating and decision making (School C, year 5 teacher).*

The Literature review illustrates a strong case for highlighting to children the relevance of mathematics to their everyday lives and the lives of others around the world. I like the idea of 'hidden maths' and think this could be developed as a theme to motivate pupils to notice maths in the world around them, supporting them to develop a positive attitude towards maths and thus acquire some intrinsic motivation to participate more fully in maths lessons. This would also support the development of key competences for global learning as data was presented in a range of formats to illustrate a range of features of globalisation. Photo 4 provides images of 'hidden maths' that I used to illustrate this to teachers.

Photo 4: Images of 'hidden maths'

The maths on the street. Speed, distance, statistics, quantity, measures.

5.2 The extent and ways in which global data is used in mathematics

Before I visited the participating schools, teachers told me that they rarely included examples of global data in mathematics.

Table 2 provides information on what activities schools were involved in between visits one and two. It shows an increase in the types of activities schools were involved in. Appendix 7.5 illustrates an activity that took place during visit one to introduce global data.

Teachers commented that they were able to make links from topics into mathematics after our discussion in interview one and by using the resources I sent them. Some teachers expressed concern that the topic element took too long in the maths lesson, but provided a good maths angle to topic lessons.

Teachers responded most positively to my descriptions of how to access data and how to adapt it into their lessons. They felt that this approach would take practice as some data needed simplifying, especially for years 3 and 4, but data sets, mostly accessed via google images, were a useful, and quick, starting point. (Search under, for example: tables about chocolate statistics; graphs to show export in Brazil; pie chart to show energy use in Scotland.)

During pupil interviews, pupils commented that they had enjoyed the activity when they were planning for a holiday to Brazil, for example, and the exploring they did about the Olympics. Interestingly, however, pupils did not see these activities as maths, more as topic work. Teachers stated in interview two that pupils were more engaged during these activities, and we discussed during both pupil and teacher interviews how this could be described as 'real learning'.

5.3 Impacts of using global data on pupil engagement, attainment and progress in mathematics

Participating teachers agreed that because pupils were interested in global data, they were therefore more engaged in their maths lessons. Teachers described how pupils were keen to find out more and looked forward to maths lessons that used real data. Some teachers also commented that less able and/or less engaged pupils were more inclined to join in lessons and activities that used global data, making greater progress and showed a greater keenness to participate in other similar lessons. There was agreement among teachers that the use of global data in mathematics is an important strategy for making maths *'real and relevant'*, which provides a significant motivator for pupils to engage in their learning.

I think it did really engage them because I remember when we did the stuff for the rainfall and the temperature and their last question was to find the total for all four countries of the UK. So they had to add all of the numbers up and they were just like, whoa, I can't believe that (School E, year 3 teacher).

It does make complete sense (to continue to use global data…) because they do see things and they enjoy it... it gives maths a purpose (School D, year 3 teacher).

One teacher in School F commented that they felt global data was a barrier to the development of mathematical competency because the context distracted pupils from the 'maths'. This teacher did, however, agree that pupils had enjoyed the global maths lesson. This teacher suggested their pupils had a relatively narrow life experience, so global data took them out of their comfort zone due to the very unfamiliar nature of the data. Although I can see the dilemma here, I think that local data could also be presented to children that would be useful in developing important attitudes towards globalisation. I also think that if the pupils were exposed to the right kind of global data more frequently, which would be achieved by exploring interests that pupils have, they would become more confident, and even inspired, to address challenges set by this contextualised approach to mathematics.

A number of teachers described the increased engagement of pupils, particularly in relation to the level of challenge that was presented:

But some children just rose to that challenge and engaged ... most of the class were really engaged and focused and enjoyed that challenge (School D, year 3 teacher).

The idea of pupils having a 'choice of challenge' is explored in some detail by Peacock (2016) and Myatt (2016). This literature provides a great deal of evidence relating to how well pupils achieve when all pupils are expected to achieve, rather than being placed in ability groupings. It would be interesting to further explore this approach in mathematics through the use of global data as a context for these challenges. Many of the pupils clearly described an appetite for challenge in their work. For example:

It's my favourite subject, but sometimes it can be tricky… I like problem solving in maths (School B, year 5 pupil).

5.4 How global data can be used to support teaching and learning in mathematics

The use of global data in mathematics seems to have an impact on engagement from both teachers and pupils. In order for data to be used effectively, however, there needs to be some routine and frequency in the way that it is presented. A 'one-off' exploration has the effect of taking the attention of pupils too far away from the mathematical concepts, which inhibits teachers from using it again. It seems that a useful approach is to illustrate links to mathematics across the curriculum so that maths is seen as relevant. In addition to this, data sets that link to topic work or relevant community/national activities/events should be used in maths lessons as the focus for enquiry. If these data sets have already been used in topic lessons, the focus in maths can be to develop mathematical processes, practices and conceptualising that data as the context.

5.5 Barriers and facilitators for teachers to use global data in maths

In this section I introduce the barriers and facilitators identified when incorporating global data into maths.

Time to prepare materials related to global data was described as the biggest barrier to continuing to design maths lessons in this way. Some teachers suggested that a collection of short starter activities related to National Curriculum outcomes would be useful and would probably provide a context for the rest of the lesson. Another teacher commented that:

> *This was actually easier than I thought and now I know where to look and have some simple activities that can be adapted, I will be able to do this kind of learning more often (School D, year 5 teacher).*

Teachers commented that I had been a motivating factor for developing these materials in terms of my support via the demonstration lesson, subsequent relevant resources and the opportunity to discuss strategies for using global data during interviews. Thus, a global data advocate, either within the school or externally, might help support such initiatives.

One issue that year 3 teachers commented on when using global data, was the size of some of the numbers, which they explained fell outside what is expected of pupils within the National Curriculum. A teacher from School D explained however, that some pupils were motivated to explore these numbers even though they were beyond what was expected of them and beyond their experience:

> *…being year 3, the numbers are maybe too big for them to handle. So there were some year 3s who just – I mean, I have got the higher maths group – but some enjoyed the challenge, they went for it and felt like let's choose the*

biggest mountains and we're going to do this. So it's kind of a bit beyond what's expected for year 3, it's beyond their curriculum, looking at these bigger numbers (School D, year 3 teacher).

Teachers described a number of different resources and strategies that would help them to further develop their teaching for global learning. A collection of varied but related numerical facts that had clear links to the curriculum seemed quite popular:

Just some facts there so you don't have go searching for them and making it all up ourselves (School F, year 3 teacher).

Teachers described a commitment overall to pursing an approach to mathematics teaching that embraced global data and the related challenges and statistical problems to solve. A significant barrier to this, however, was a description of the need for evidence in pupil books for differentiation[20] and the time that these activities take to prepare as discussed earlier. Differentiating some of this data is a challenge, but we did discuss how data can be rounded to the nearest 100, for example, and organised with images for extra support where necessary. This differentiated (ability) approach, however, is in contrast the mastery approach (equity of potential) which expects all pupils to work more collaboratively to secure a depth of knowledge and understanding before the whole group can move forward. This 'tangle' of expectations from school leaders and regional/national programmes could hinder progress in this area, which is why organisations like the Mathematica Association[21] and the Maths Hubs[22] should continue to raise the profile of their research findings and recommendations to secure a common understanding of effective strategies for raising achievements (rather than attainments) in mathematics.

In terms of global learning, all teachers agreed that, through an exploration of the data that they were presented with, pupils were enthused to talk about global issues and were not afraid of making mistakes:

The discussion was fantastic (School C, year 5 teacher).

This confidence and enthusiasm to talk about global issues is actually in contrast to how I believe teachers feel. Globalisation is complex, with a vast array of terms and definitions, key facts and moral/ethical issues in abundance. I think teachers are fearful in some contexts of presenting children with 'the wrong' facts or finding themselves in a situation where they are unable to answer questions. Teachers did not describe this to me, but from a few observations I made of their

20 Differentiation describes a process where teachers prepare different activities for different pupils to meet their specific needs rather than creating one activity for the whole class.
21 http://www.m-a.org.uk/
22 http://www.mathshubs.org.uk/

lessons and the way they spoke to groups of children in the demonstration lesson, I could see that this is a potential barrier and, of course, a motivating factor for the work of the GLP.

Discussions were described to be so rich in some maths lessons that they were seen to be a barrier to progress in mathematics. Teachers said that they would rather do this kind of learning in a topic lesson. I think that a topic lesson that uses global data is a valid and useful illustration to pupils of the value of mathematics and could also provide a reference point for strategy and skills in a maths lesson.

The value of using mathematics to explore globalisation is that related facts can be presented in a number of different formats and styles, often highlighting information in such a way that pupils are inspired to find out more. Teachers and pupils enjoyed exploring this data, especially anything map-related, and I think, through practice, will find this method of problem solving increasingly accessible. This enjoyment factor is evidenced by what teachers said to me in the interviews during my second visit. They clearly state the pupils enjoy working with global data and that it motivated them to keep exploring.

> *I think it brought out the enjoyment of the maths for them (School D Year 4 teacher).*
>
> *They just wanted to continue it. They really did enjoy doing it. They found it really satisfying. It gives them a purpose, doesn't it; a reason for doing it. And I think their understanding a number becomes real (School A year 5 teacher).*

The idea that, with practice, teachers can more regularly access and use global data in their maths teaching is summarised by what this teacher said:

> *This was actually easier than I thought and now I know where to look and have some simple activities that can be adapted, I will be able to do this kind of learning more often (School F, year 5 teacher).*

5.6 Continuing to develop global learning in mathematics

All teachers agreed that they would continue in some way to develop teaching and learning activities that used global data. A typical response from teachers to the question, 'How likely are you to continue to use these kinds of materials?' was:

> *Definitely, most definitely. There's already ones now that you think, with the resources you provided in particular, that you think, when I come round to doing that, that'll be great (School B, year 5 teacher).*
>
> *And I think that's brilliant because some of the things we were discussing with the children is the relevance and relativity of their answers (School B, year 5 teacher).*
>
> *And they enjoyed it, they really enjoyed it. It meant they had to use atlases and get atlases out as well, look at coordinates (School A year 5 teacher).*

6 Discussion and recommendations

This research has enabled me to consider to what extent teachers and pupils find using global data in maths lessons a useful strategy for building mathematical competency and deepening understanding about globalisation.

The issue of using abstract or concrete materials, as referred to in the Literature review, during maths activities seems to be very dependent on the context of the lesson. If, for example, the learning is at the start of a new topic in geography, there is a case for making the maths exciting by using concrete examples linked to that topic, but if the new geography topic coincides with a new mathematical process, then using global data may present the pupil with too many new things to consider.

Helping pupils to reach a depth of understanding in mathematics and global learning is important. Teachers and existing research explains that this mastery allows pupils to transfer their learning into other/new concepts, which thus furthers their opportunity to explore global issues and develop mathematical competency. In order to support pupils to reach that depth of understanding, the Literature review and teacher interviews in this study suggest that this is substantially connected to the attitudes that pupils have towards mathematics. If they perceive maths to be irrelevant, they have little desire to learn new things. If they perceive it to be 'hard' and associate maths with 'getting things wrong', then again, they will not put the effort in to explore, enquire and create. So supporting pupils to adopt a positive attitude to mathematics is essential to breaking down barriers to learning. Part of this support needs to focus around developing resilience, which many teachers have described to me as a key contributing factor to how children succeed. Pupils need to enjoy the opportunity to solve a problem or address a challenge because they can see its relevance and know that the success they will experience is enhanced by the fact that they overcame 'mini fails' along the way.

Addressing attitudes to mathematics should also occur in other parts of the curriculum, however. It is clear from pupil interviews that many of the global learning activities were enjoyable, but were not seen as mathematics. So teachers need to connect their observations to what pupils enjoy in mathematics, the research that backs up this approach and the conversations they are having with pupils about mathematics. This is a key finding from the research study. The National Curriculum states that mathematics is a 'creative and highly connected discipline' and that, 'Teachers should use every relevant subject to develop pupils' mathematical fluency' (DfE, 2014: 76). I believe that if aspects of mathematics were regularly referred to across the curriculum in order to highlight the relevance and purposes of mathematics, pupils would adopt a more positive attitude to the

subject and thus become more resilient through problem solving in their desire to explore and achieve.

The teacher interviews revealed that there is still considerable work to do in order to equip teachers with the skills to harness global data and turn it into valuable and effective maths activities. There are some key and relatively simple strategies that teachers can adopt to do this, however. Teachers commented that they do feel more confident to do this as a result of taking part in this research study, but unless this is done frequently teachers will lose the motivation to do so and pupils will therefore be exposed to only a small sample of global data activities, which will not have the desired impact.

Based on the findings I make the following recommendations:

Provide training for teachers to explore examples of context-rich mathematics and realise the benefits of this approach through CPD sessions or through demonstration lessons and coaching sessions

Feedback from teachers who participated in this study and other feedback from teachers who have taken part in 'Painting the world by Numbers', a related teacher-training course[23], have been extremely positive. The issue of authentic learning and/or 'hidden maths' seems to be an enticing aspect of this training and support. The GLP, for example, is in the process of composing an optional twilight[24] CPD session that will provide some extra materials to explore this approach with teachers. A focus from Ofsted this year to investigate the extent of a 'broad and balanced curriculum' should further encourage school leaders to engage with this opportunity to enrich mathematical opportunities and experiences for their pupils. As more research is gathered as to the effectiveness to a developing a mastery approach, I think we will see materials and guidance documents for teachers that illustrate the benefits of 'choice of challenge' and the need for pupils to become competent problem solvers in mathematics.

Produce supporting online 'bite-sized' materials to introduce teachers to, or support them further in developing, global learning in mathematics

There are already a growing number of photographs that are designed to inspire and stimulate an interest in global issues in mathematics. I think there should also be a wide range of statistical representations for all primary pupils that enable them to investigate and interrogate data. A frequent reference to data presented in this way would provide pupils and teachers with the opportunity to become competent in real-life problem solving skills and make firm connections between maths and other areas of learning.

23 https://glp.globaldimension.org.uk/calendar/course/10109
24 Twilight CPD sessions are teacher-led CPD that take part after the end of the school day, as part of the GLP.

I think a key area for development, in terms of producing supportive resources and training, is not only to provide data and activities that can be used in maths lessons, but also to harness the idea of 'bite-sized' materials to use across the curriculum, as we have already seen promoted through the aims of the National Curriculum. These shorter global data activities would be aimed at highlighting the relevance of mathematics and the opportunities that it presents to describe and interpret the world. These activities would be deliberately exciting and stimulating and should inspire pupils and their teachers to explore further, developing a deep understanding of how important mathematics is. 'Confidence in numeracy and other mathematical skills is a precondition of success across the National Curriculum' (DfE, 2014: 8).

Carry out further research into how global data can be used in maths teaching

When I began this study, I didn't expect to be able to draw on many other research studies into the use of global data in mathematics. My Literature review has revealed that, although there are many studies that explore some aspects of this approach (mastery, context v. abstract, problem solving etc.), very few, if any, have been conducted in order to investigate and recommend a process for developing more global data in mathematics teaching. As the Sustainable Development Goals[25] become more prevalent across the UK, and schools recognise the relevance of these goals to their curriculum, it is hoped that there will be an increasing need for teachers to plan for curriculum activities that enable pupils to critically explore globalisation and thus develop their mathematical competencies.

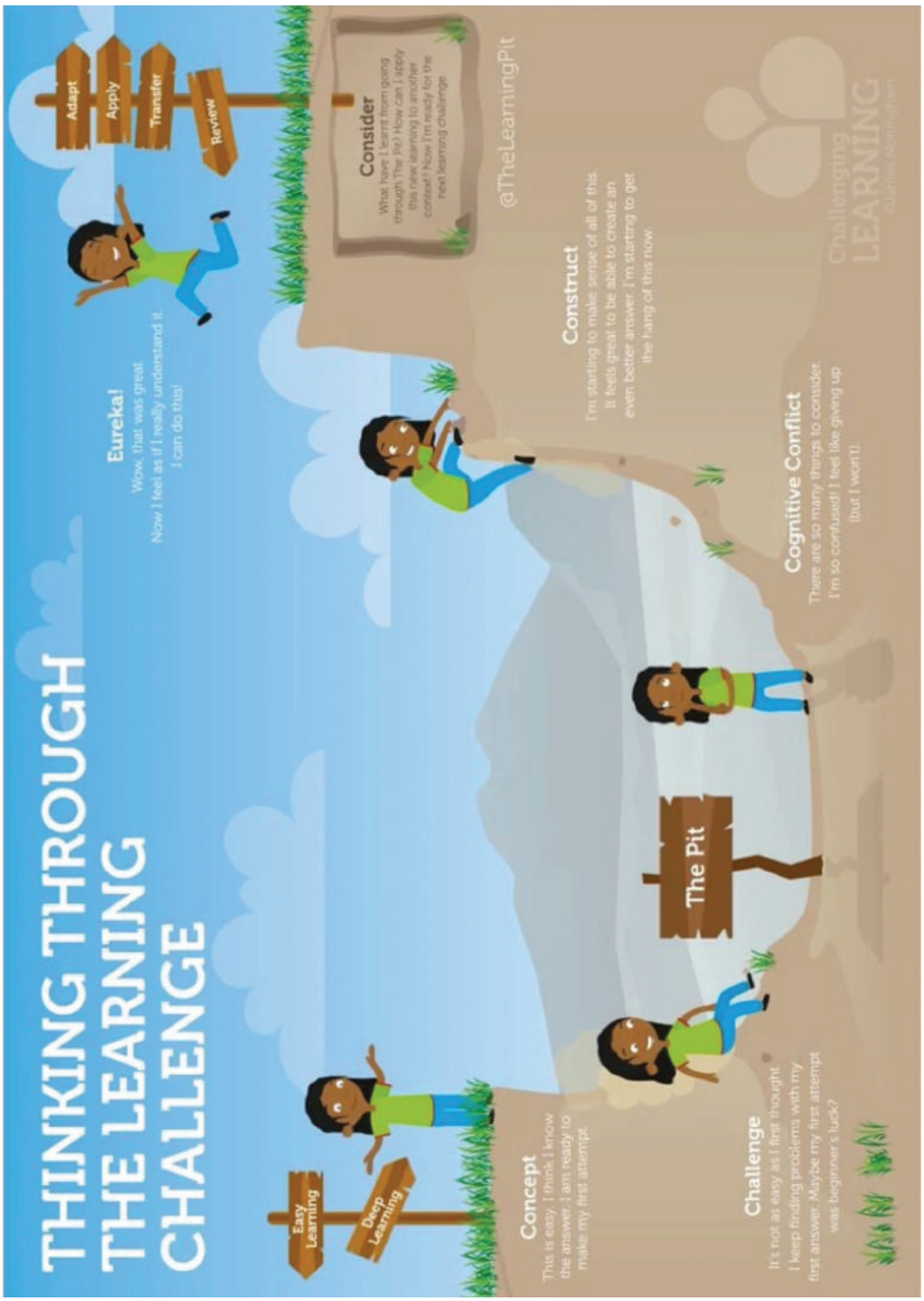
Carry our further research into the effectiveness of using global data to raise standards of mathematical competency

This was an aspect of my research that I had really hoped to develop and evidence, but I found the limited use of global data currently in use in classrooms a barrier to a proper investigation of this. A robust study of this would require an in-depth analysis of pupil progress, including a secure understanding of prior knowledge and skills. The evidence gained, if positive, which I believe it would be, would be a significant influencer in the way that teachers commit to developing their knowledge, understanding and skills in order to be able to teach in this way.

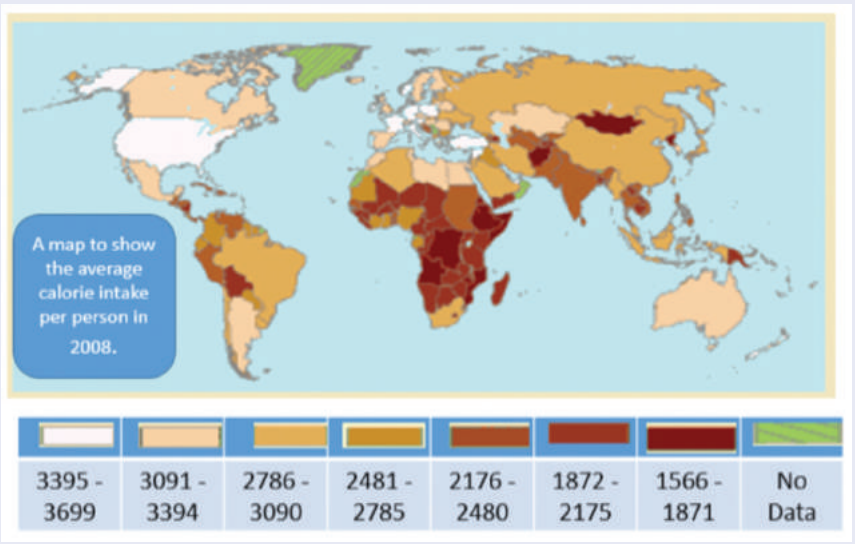
25 http://www.un.org/sustainabledevelopment/sustainable-development-goals/

7 Appendices

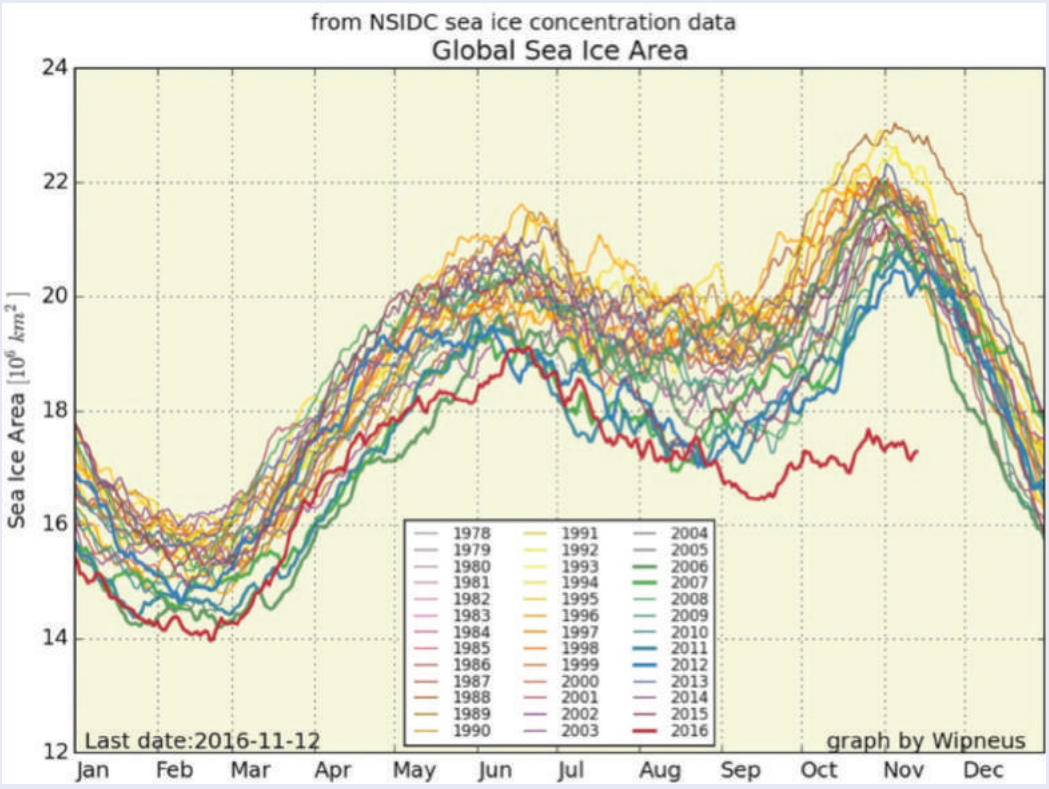
1.1 Appendix 1: The Pit – James Nottingham



7.2 Appendix 2: Examples of resources provided to teachers during visit one



Opportunities here for questions about the range of data, population and connections between calorie intake and life expectancy and geographical location. Further opportunities for exploration include questions about population density, differences in life expectancy over the last 100 years and GDP.



Opportunities for questions here include exploring how the graph is organised, what might influence the rise or fall of each line, and in which month there is, on average, the greatest change in the sea ice area. Further opportunities for investigation include how a graph about average global temperatures might compare to this graph and what differences there are between ice regions of the world.

7.3 Appendix 3: Examples of materials produced by author after visit one to each school

Linking topic work about oceans to maths in School A.

Awesome Oceans

The area of the earth's oceans is about 140 million square miles (362 million sq km), or nearly 71% of the Earth's surface. **So what percentage of the earth is NOT covered by the ocean?**

More than 97% of all our planet's water is contained in the ocean. **So what percentage of water is not contained in the ocean?**

The oceans provide 99% of the Earth's living space – the largest space in our universe known to be inhabited by living organisms. **So what percentage of the earth's living space is not part of the ocean?**

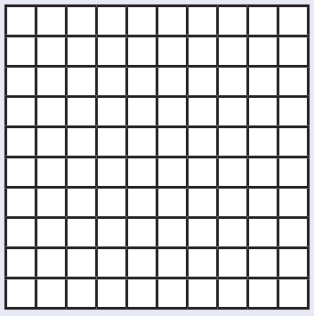
More than 90% of the trade between countries is carried by ships. **So what percentage of trade is not carried in ships?**

50% of communications between nations use underwater cables. **So what percentage of communication between nations does not use underwater cable?**

Although coral reefs comprise less than 0.5% of the ocean floor, it is estimated that more than 90% of marine species are directly or indirectly dependent on them. **So what percentage of the ocean floor is not a coral reef and what percentage of marine species do not depend on them?**

Less than one half a per cent of marine habitats are protected – compared with 11.5 per cent of global land area. **So what percentage of marine habitats are not protected and what percentage of the global land is not protected?**



If all of these boxes were filled, you would have 100 out of 100 boxes filled.

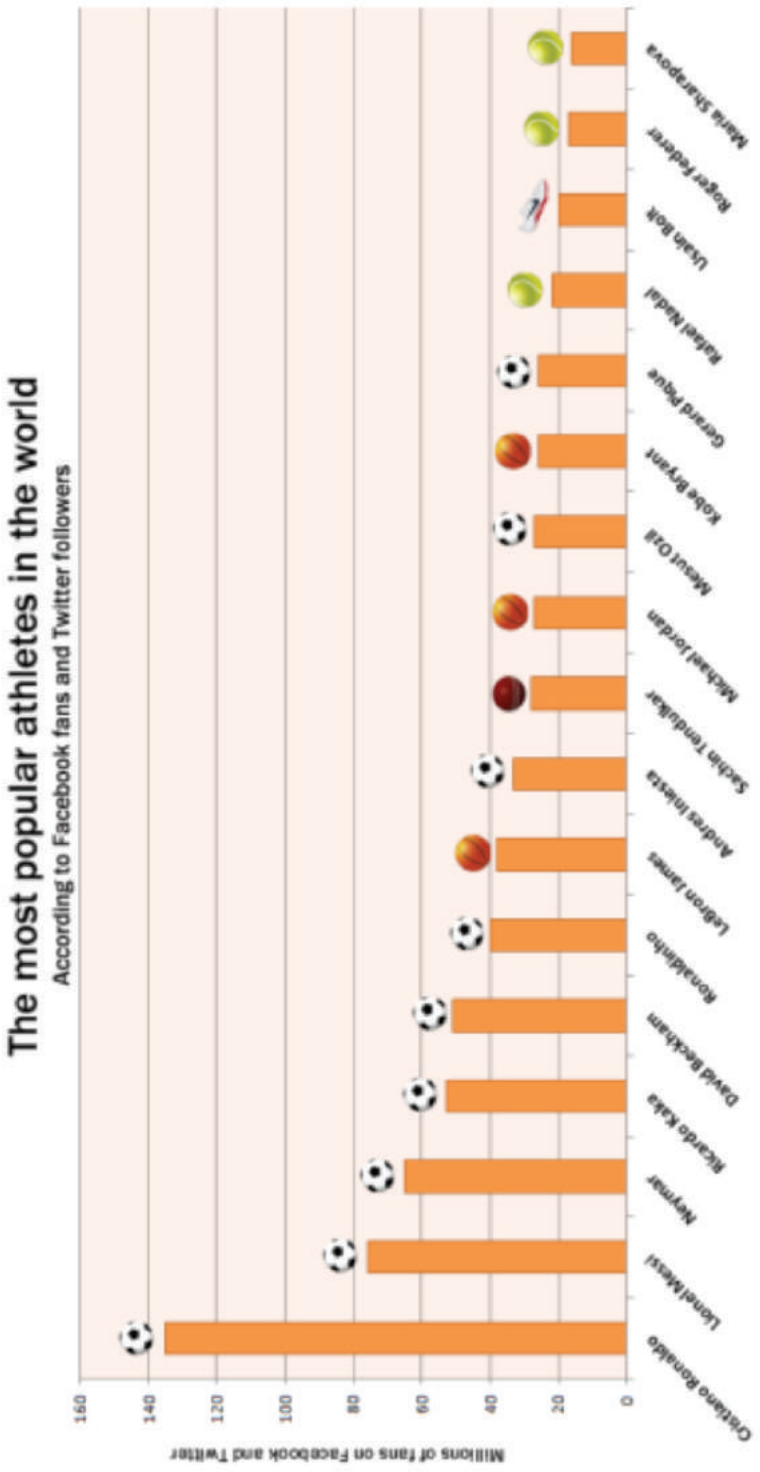
We can describe that as 100 per cent or 100%.

We could have everything!

If we filled 23 of the boxes, we would have 23 out of 100 boxes filled. We can describe that as 23 percent or 23%

We would have a portion of the whole square.

Linking topic work about sports to maths in School C.



Linking capacity work in maths to food miles and where food comes from in school E

Capacity Cocktails

Look at each of these recipes.

1. Work out how much liquid you would need for one glass of each cocktail.
2. Work out how much liquid you would need for 30 glasses of each cocktail.
3. Create your own idea for a cocktail.
4. Can you find out where these ingredients usually come from? How many miles have they travelled? Can you work this out for one, 30 people and 300 people drinking these cocktails?

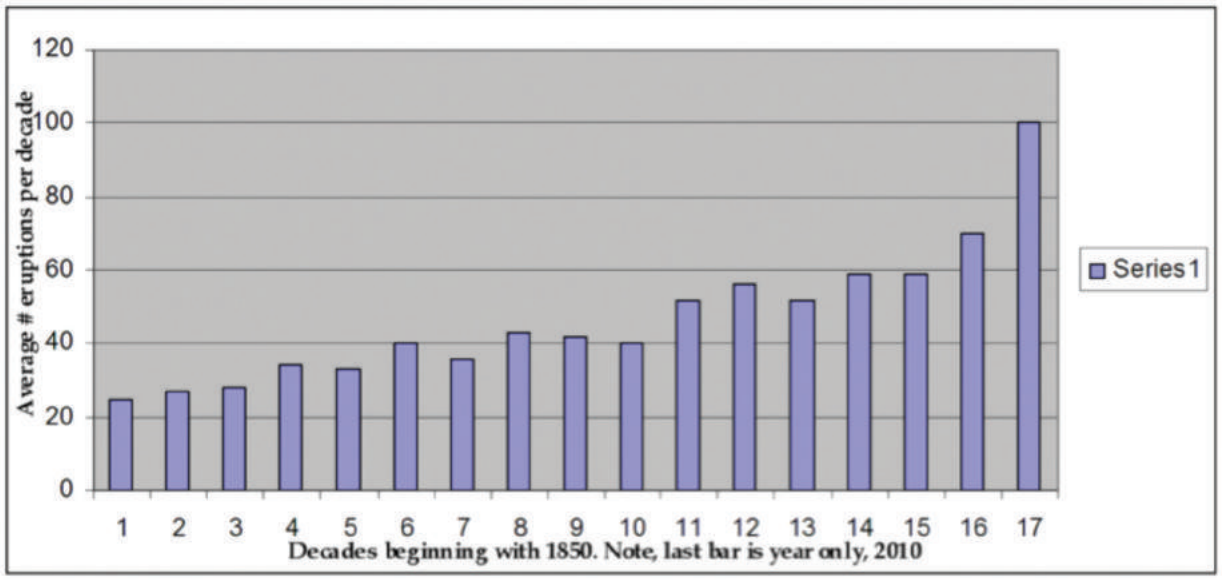
Tropical Fizz – for 5 people

10 strawberries – hulled and halved
1 kiwi fruit, peeled and chopped
2 pineapple rings, chopped
500ml sparkling apple juice
500ml tropical fruit juice
500ml soda water

Blood Orange Punch – for 6 people

10g cranberries
12 thin slices of orange
120ml cranberry juice
60ml juice from 1 or 2 limes
600ml blood orange juice
600ml sparkling apple juice
6 small sprigs of mint

Linking geography work about mountains to maths in School D.



7.4 Appendix 4: Interview schedules

Teacher interview schedule: Visit one

1. What do you see as important features of teaching and learning in maths at your school? How does this support your school ethos?
2. How important do you think it is to incorporate real-life (global) data and statistics into maths lessons? How do you currently do this?
3. Where do you get most of your ideas from to plan for your maths teaching generally? Why do you use these resources?
4. How do you feel about using more global data in maths? *(Exploring here barriers and possible facilitators.)*
5. What do you hope to get out of taking part in this project?

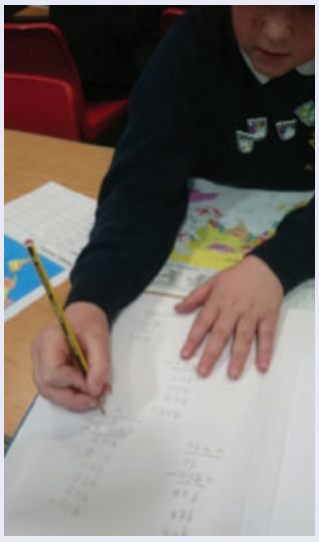
Teacher interview schedule: Visit two

1. Have you used any of the resources that I gave you since my last visit? Why and how? (Including any changes that were necessary.)
2. How well do you feel these resources supported your teaching in mathematics? What worked well and what didn't?
3. How well do you feel these resources supported learning in mathematics? Do you have any comments about how engaged or motivated the children were in their maths learning while using these resources? Do you have any comments about how much the children achieved while using these resources?
4. How much do you think that the use of global data in maths lesson adds to the levels of knowledge, skills and understanding of global issues?
5. How likely are you to use resources, or resources like these, in the future?

Pupil interview schedule: Visit two

1. What do you like learning about? Can you give some (two) examples and explain why?
2. Can you describe some different ways of learning? Which is you favourite way and why?
3. What kinds of things do you like doing in your maths lessons? Why?
4. Can you think of any learning you have done recently about the world or 'global issues' in any subject? Did you enjoy that? Why?
5. Can you think of any global learning that you have done in maths? Did you enjoy that? Why?
6. Do you think learning about global issues is important? Why?
7. Can you ask me a question about the world or global issues that mean I have to give you a number in my answer? Practise with a partner and then test me! (One from each pupil.)

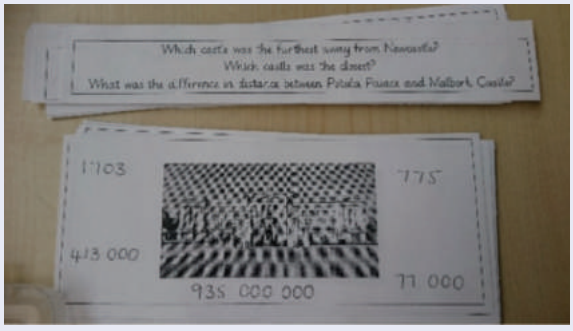
7.5 Appendix 5: Annotated photos of pupils using global data in demonstration lesson during visit one and subsequent lessons by teacher

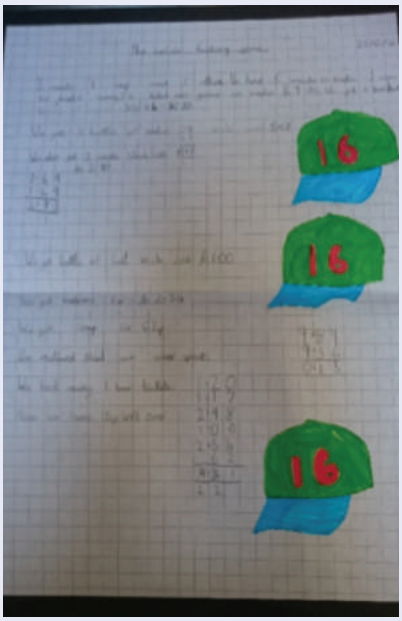


Pupils create the 'Global Village Jigsaw' as a starter activity during pupil interviews in order to orientate their thinking towards globalisation and to create a conducive environment for a group discussion.

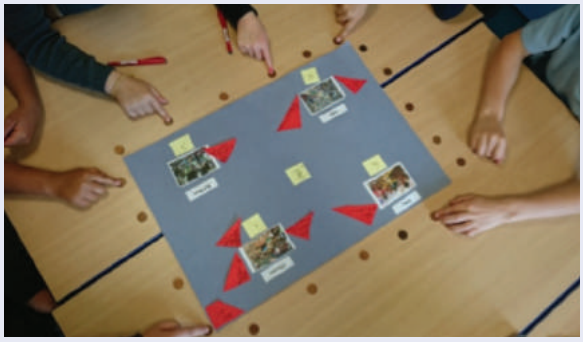
Pupils in two schools use 'The World Came to my Place Today' to consider distance and where food comes from.

Teacher in School E develops her own global learning materials to share with me during visit two.

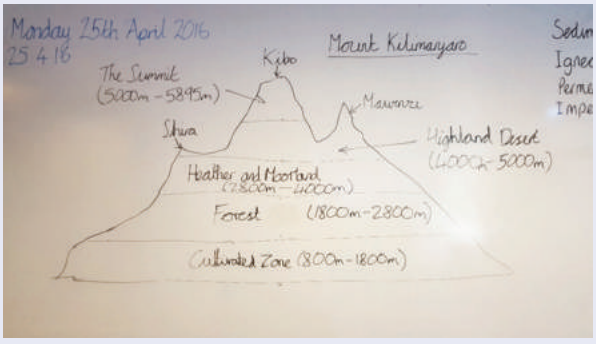




Global data work completed by pupils/ teacher in School C in between visit one and visit two relating to Fairtrade and Globalisation from Oxfam.



Global Wealth activity from Oxfam completed by School B in between visit one and visit two.



A geography lesson in School D prior to visit one – not recognised by the teacher as an opportunity for mathematics.

7.6 Appendix 6: Example of materials produced by teachers

Linking Brazil topic to maths in School A.

Brilliant Brazil

City	Distance in miles from London.	Distance rounded to the nearest mile.	Time in hours taken to fly.
Rio	5766.49		12 hours.
Sao Paulo	5902.09		15 hours
Salvador	5013.85		11 hours
Brasilia	5459.51		13 hours
Manaus	5139.44		16 hours
Fortaleza	4430.03		20 hours
Belo Horizonte	5596.59		14 hours
Curitiba	6088.64		16 hours

1 Round all the distances to the nearest mile. (Fill in on chart)

2 Order the cities from nearest to furthest. (Fill in on chart)

City	Cities in order from nearest to furthest.	Distance from London in miles.	Distance from London in km.
Rio			
Sao Paulo			
Salvador			
Brasilia			
Manaus			
Fortaleza			
Belo Horizonte			
Curitiba			

3 What is the difference in miles between the nearest and the furthest city?
Write your answer here.

_____

4 Why do you think that some of the nearer cities take longer to get to? Use an atlas for clues.

5 Find the co-ordinates of each city and write them here. Locate the cities in your atlas.

Rio

Sao Paulo

Salvador

Brasilia

Manaus

Fortaleza

Belo Horizonte

Curitiba

6 Find the average speed of an aeroplane flying to each of these cities using the information you have. (Fill in on the chart.)

7 Convert the distances from miles to kilometres. (Fill in on the chart.)

Top tip
There are 1.6km in a mile. Use this space for your working out and your books if needed. Keep it neat.

8 References

Acar Guvendir, M. (2016) Students' Extrinsic and Intrinsic Motivation Level and Its Relationship with Their Mathematics Achievement. *International Journal for Mathematics Teaching and Learning.* [Online] http://www.cimt.org.uk/journal/guvendir.pdf (Accessed July 2017).

Bourn, D (2014a) *The Theory and Practice of Global Learning.* DERC Research Paper no. 11. London: UCL Institute of Education.

Bourn, D. (2014b) 'What is Meant by Development Education?' Sinergias ed, Vol. 1, pp. 7–23.

Bourn, D., Hunt, F., Blum, N. and Lawson, H. (2016) Education for Global Learning and Sustainability. CPRT Research Survey no. 5 (new series). York: Cambridge Primary Review Trust.

British Chamber of Commerce (2014) Workforce Survey. London: British Chamber of Commerce.

De Bock, D., Deprez, J., Van Dooren, W. and Verschaffel, L. (2011) 'Abstract or Concrete Examples in Learning Mathematics? A Replication and Elaboration of Kaminski, Sloutsky, and Heckler's Study.' *Journal for Research in Mathematics Education,* Vol. 42 (2), pp. 109–26.

Department for Education (DFE) (2014) *The National Curriculum for England.* London: DFE.

Edutopia (2013) 'How are happiness and learning connected?' [Online] https://www.edutopia.org/blog/happiness-learning-connection-rebecca-alber (Accessed July 2017).

Fuson, K. C. and Geeslin, W. (Eds.) *Explorations for the Modelling of learning mathematics.* Columbus, OH: ERIC/SMEAC.

Global Learning Programme (GLP) [Online] www.glp-e.org.uk (Accessed July 2017)

Guvendir, M. A. (2016) 'Students' Extrinsic and Intrinsic Motivation Level and Its Relationship with Their Mathematics Achievement.' *International Journal for Mathematics Teaching and Learning,* Vol 17 (1).

Hall, R.W. (2007) *A Course in Multicultural Mathematics.* [Online] http://people.sju.edu/~rhall/multi.pdf (Accessed July 2017).

Hall, R. (n.d.) *A Course in Multicultural Mathematics.* Philadelphia: Saint Joseph's University. [Online] http://people.sju.edu/~rhall/multi.pdf (Accessed July 2017).

Har, L. (n.d.) *Authentic Learning*. Hong Kong: The Hong Kong Institute of Education. [Online] Available: https://www.eduhk.hk/aclass/Theories/AuthenticLearning_28June.pdf (July 2017).

Hoogland, K., Pepin, B., Bakker, A., de Koning, J. and Gravemeijer, K. (2016) 'Representing contextual mathematical problems in descriptive or depictive form: Design of an instrument and validation of its uses.' *Studies in Educational Evaluation,* Vol. 50, pp. 22–32.

Hunt, F. and Cara, O. (2015) *Global Learning in England: Baseline analysis of the Global Learning Programme Whole School Audit 2013–14.* DERC Research Paper no. 15. London: UCL Institute of Education. [Online] http://discovery.ucl.ac.uk/1473866/1/franhuntGlobal_Learning_in_England_Baseline.pdf (Accessed July 2017).

Jerrim, J. and Vignole, A. (2015) *The causal effect of East Asian 'mastery' teaching methods on English children's mathematics skills?* [Online] http://www.ieb.ub.edu/files/Jerrim.pdf (Accessed July 2017).

Johnston-Wilder, S. and Lee, C. (2010) *Developing Mathematical Resilience. BERA Conference Paper,* 1st–4th September 2010, University of Warwick. [Online] http://oro.open.ac.uk/24261/2/3C23606C.pdf (Accessed July 2017).

Kaminski, J., Sloutsky, V. M., and Heckler, A. (2008) 'The advantage of abstract examples in learning math.' *Science,* Vol. 320, (5875), pp. 454–455.

Keegan, K. (2015) *Swimming in Maths.* [Online] http://www.swimminginmaths.com/ (Accessed July 2017).

Lombardi, M. (2007) *Authentic Learning for the 21st Century. ELI Paper 1.* Washington, DC: EDUCAUSE Learning Initiative.

Male, B. (2012) *The Primary Curriculum Design Handbook.* London: Continuum.

Moyer, P. (2001) 'Making Maths Culturally Relevant.' *Mathematics Teaching,* 176. [Online] https://www.atm.org.uk/write/MediaUploads/Journals/MT176/Non-Member/ATM-MT176-03-05.pdf (Accessed July 2017).

Myatt, M. (2016) *High Challenge, Low Threat.* Suffolk: John Catt Education Limited.

National Centre for Excellence in Teaching of Mathematics (NCETM) (2017)

Mastery. [Online] https://www.ncetm.org.uk/resources/47230 (Accessed July 2017).

Neuro Leadership Institute (2017) [Online] https://neuroleadership.com/ (Accessed July 2017).

Nottingham, J. (2017). *Challenging Learning.* [Online] http://www.challenginglearning.com/ (Accessed July 2017).

Ofsted (2012) Made to Measure. London: Ofsted.

Ofsted (2015) School Inspection Handbook. London: Ofsted.

Oxfam (n.d.) *Bring Data to Life for 11 to 14 year olds.* [Online] https://www.oxfam.org.uk/education/resources/bringing-data-to-life-11-14 (Accessed July 2017).

Peacock, A. (2016) *Assessment for Learning without Limits.* London: Open University Press.

Piggott, J. (2008). *Rich Tasks and Contexts.* [Online] https://nrich.maths.org/5662 (Accessed July 2008).

PISA (2016) Mathematics Performance [Online] https://data.oecd.org/pisa/mathematics-performance-pisa.htm (Accessed July 2017).

Post, T. & Reys, R. E. (1979). 'Abstraction Generalization and Design of Mathematical Experiences for Children.' In: K. Fuson & W. Geeslin (Eds.), *Models for mathematics learning.* (pp. 117–139). Columbus, OH: ERIC/SMEAC. [Online] http://www.cehd.umn.edu/ci/rationalnumberproject/79_2.html (Accessed July 2017).

Readman, J. and Roberts, L. H. (2014) *The world came to my place today*. Cornwall: Eden Project Books.

Stewart, I. (2009) 'How maths makes the world go round.' London: The Telegraph. [Online] http://www.telegraph.co.uk/news/science/6439621/How-maths-makes-the-world-go-round.html (Accessed July 2017).

Think Global and British Council (2011) *The global skills gap.* London: Think Global.

University of Exeter (2016) Research reveals that 'Singapore' approach to teaching maths can work in UK classrooms. [Online] http://www.exeter.ac.uk/news/featurednews/title_550537_en.html (Accessed July 2017).

Widjaja, W. (2013) *The Use of Contextual Problems to Support Mathematical Learning.* Melbourne: Deakin University. [Online] http://files.eric.ed.gov/fulltext/EJ1078956.pdf (Accessed July 2017).

Zhu, Y. and Leung, F. (2011*) International Journal of Science and Mathematics Education* 9(5) pp. 1189–1212. [Online] https://link.springer.com/content/pdf/10.1007/s10763-010-9255-y.pdf (Accessed July 2017).

About the Development Education Research Centre

The Development Education Research Centre (DERC) is the UK's leading research centre for development education and global leaning. DERC conducts research on Development Education and Global Learning, run a masters' degree course, supervises doctoral students and produces a range of reports, academic articles and books. Further information on the centre go to: www.ucl.ac.uk/ioe-derc

About the Global Learning Programme

The Global Learning Programme (GLP) in England is a government-funded programme of support that is helping teachers in Primary, Secondary and Special schools to deliver effective teaching and learning about development and global issues at Key Stages 2 and 3. It is being delivered by a team of organisations with complementary experience in supporting development education, the wider development sector and peer-led CPD for schools. For further information on the Global Learning Programme in England go to: www.glp-e.org.uk Information about the GLP in Wales, Scotland and Northern Ireland can be found at: https://globaldimension.org.uk/chooseglp

About the author

Vikki worked as a Deputy Head Teacher in a York Primary School and as an Advanced Skilled Teacher for Development Education until she moved to her role as a freelance consultant, supply teacher and associate of the Curriculum Foundation in 2015. Her work features supporting schools to review and design bespoke curriculum frameworks to ensure experiences for pupils are rich, relevant and purposeful within the context of national (and international) guidelines and expectations. Vikki has a particular interest in mathematics having worked previously as a specialist teacher for mathematics. Her specially developed 'Painting the World by Numbers' teacher training course resulting, brings together her commitment to developing context rich learning experiences for pupils and her interest in Development Education.

The UCL Institute of Education is a world-leading school for education and social science. Founded in 1902, the institute currently has over 7,000 students and 1,000 staff making up an intellectually rich learning community. In the 2016 QS World University Rankings, the UCL Institute of Education was ranked number one for education worldwide.

Development Education Research Centre
UCL Institute of Education
London International Development Centre
36 Gordon Square, London WC1H 0PD