

Initial teacher education of teachers of mathematics at primary and secondary: have your say

A Initial teacher education and mathematics

Why is students' achievement in mathematics consistently higher in some countries than it is in England?¹ To what extent does the initial teacher education (ITE) of those who teach mathematics play a part in explaining these differences?

To consider this, ACME aims to identify the key components of ITE that will lead to high-quality mathematics teaching and learning. As a first step, ACME has undertaken a review of some of the elements of the ITE system in four jurisdictions (Germany, Massachusetts, Shanghai and Singapore) in addition to England. These jurisdictions were chosen for their known improvement in education performance and higher achievement in mathematics than England in recent years (see sections C and D).

In this phase of the study we focus on the training of teachers of mathematics at primary and secondary level.² If the aims of the National Curriculum³ are to be realised, then high-quality mathematics teaching for all students will be required.

How can trainee teachers become effective and inspirational teachers of mathematics who have a firm grasp of pedagogy and mathematics? What do teachers need during their training to ensure that they can support high-quality mathematics learning in primary and secondary education? How can trainees develop

the key aspects of good teaching such as deep subject and pedagogical content knowledge?⁴

This paper sets out some of the issues in England before summarising the findings of the international review. From the emerging themes we have formulated a set of questions on which we invite you to share your views (see sections F and G).

International comparisons

ACME states in its *Maths Snapshot* 'International comparisons and maths education'⁵ that education policy systems are complex and policy effectiveness is linked to a country's historical, cultural, political and economic context. Use of international comparisons in policy development must be underpinned by analysis and research and adoption of any policies must follow expert evaluation, design and trialing. The themes in section D of this paper may not be the only components that are important in mathematics ITE and further research will be needed to explore their significance.

1. <http://www.oecd.org/pisa/>.

2. The growth in the number of primary school students and concerns about the subject expertise of teachers during Key Stage 3 demonstrates the urgent need to look at the training of primary and secondary teachers. Further study will be needed to investigate needs of teachers specialising in early years or post-16 education.

3. <https://www.gov.uk/government/publications/national-curriculum-in-england-framework-for-key-stages-1-to-4/the-national-curriculum-in-england-framework-for-key-stages-1-to-4>.

4. <http://www.suttontrust.com/wp-content/uploads/2014/10/What-makes-great-teaching-FINAL-4.11.14.pdf>; <https://www.mpib-berlin.mpg.de/coactiv/en/main-findings/>.

5. <http://www.acme-uk.org/media/20269/internationalcomparisons.pdf>.

B Why is mathematics ITE a concern?

ITE system

ITE in England has undergone a lot of change in the past 40 years. In recent years, there has been a rapid shift from teacher education in higher education institutions (HEIs) to school-led training.⁶ This rapid change in the system has led to concerns that long-term provision of ITE could be destabilised.⁷ At the request of the Department for Education a review of teacher education in England was undertaken by Sir Andrew Carter.⁸ The review aimed to define effective initial teacher training (ITT) practice, assess the extent to which the system currently delivers effective ITT and recommend where and how improvements could be made. The review looked across all subjects and noted the importance of subject specialism in teacher education. ACME's project will look specifically at mathematics teacher education.

Supply of mathematics teachers

There will be around 900,000 more pupils in schools in England within the next ten years, which will mean more demand for teachers of mathematics.⁹ The increase in pupil numbers will place more demand on a system where already many primary schools have no teachers with specialist training and expertise in teaching mathematics. In addition a quarter of those currently teaching 11 – 14 year olds do not hold a mathematics-relevant qualification.¹⁰ It is estimated that there is currently a need for an additional 5,500 mathematics teachers at secondary level.¹¹

Curriculum demands

More and better qualified teachers of mathematics will be needed to meet the increased requirements of the National Curriculum, the larger GCSE Mathematics and new post-16 Core Maths qualifications.¹²

Professional development

ITE is not the end of teacher education but the first step in every teacher's professional learning journey. In *Empowering teachers: success for learners*¹³ ACME noted the importance of ongoing training and education for all teachers of mathematics throughout their careers.



6. Allen, R., Belfield, C., Greaves, E., Sharp, C & Walkers, M (2014). The Cost and benefits of Different Initial Teacher Training Routes. London: IFS, <http://www.ifs.org.uk/uploads/publications/comms/r100.pdf>.

<http://www.universitiesuk.ac.uk/highereducation/Documents/2014/ImpactOfITTreformsOnEnglishHEIs.pdf>.

7. *Ibid*.

8. <https://www.gov.uk/government/publications/carter-review-of-initial-teacher-training>.

9. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/384699/Ofsted_Annual_Report_201314_HMCI_commentary.pdf.

10. <https://www.gov.uk/government/statistics/school-workforce-in-england-november-2013>.

11. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/268206/DFE-00289-2013.pdf.

12. Core Maths describes a range of Level 3 mathematics qualifications for post-16 students who have achieved a C at GCSE Mathematics but are not studying A level Mathematics. Further information on Core Maths can be found on the Core Maths Support Programme website: <http://www.core-maths.org/>.

13. <http://www.acme-uk.org/media/19381/etsfllreport2014.pdf>.

c Jurisdiction profiles

The boxes in this section highlight some key aspects of the ITE systems in each of the jurisdictions reviewed: England, Germany, Massachusetts, Shanghai and Singapore.

England

- ITE is given by multiple providers, or provider partnerships, including both schools and universities.
- Most students do an undergraduate degree and then apply to ITE as postgraduates.
- England was ranked 26th in the 2012 Programme for International Student Assessment (PISA) tests.¹⁴ England is considered to perform better in the Trends in International Mathematics and Science Study (TIMSS); in 2011 England was ranked 9th for children aged 9 – 10 and 10th for children aged 13 – 14.¹⁵
- In recent years the Government has looked abroad to inform education policy changes and is undertaking national projects based on international teaching and learning. These include trialing Singapore-style textbooks and exchanges with Shanghai teachers.¹⁶
- There is no requirement to study mathematics beyond the age of 16. However, students who do not gain a C grade in GCSE Mathematics pre-16 are now required to work towards achieving this. Approximately 20% of those in post-16 education study mathematics at a more advanced level.¹⁷

Germany

- To become a teacher, students usually undertake two phases of training, the first spent in university (3 – 4 years) and the second in an in-school induction programme (1.5 – 2 years).¹⁸ Applicants to ITE are selected from the top third of high school graduates.
- Germany's education system underwent major changes over the last decade in response to below average scores in PISA in 2000. Germany's performance in PISA has since improved from 21st (in 2000) to 16th (in 2012). Germany also performs above average in TIMSS, ranking 16th in 2011 for students aged 9 – 10.¹⁹
- Over 90% of students study mathematics post-16.²⁰

14. The Programme for International Student Assessment (PISA) is an internal survey of student attainment. PISA aims to evaluate education systems worldwide by testing 15 year olds. Tests have been carried out every 3 years since 2000 and are designed to assess students' application of knowledge to real-life situations.
<http://www.oecd.org/pisa/>.

15. The Trends in International Mathematics and Science Study (TIMSS) is a series of international assessments of the mathematics and science knowledge of students aged 9 – 10 and 13 – 14. It has been carried out every 4 years since 1995.
<http://timssandpirls.bc.edu/>.

16. <http://www.mathshubs.org.uk/what-maths-hubs-are-doing/>.

17. http://www.nuffieldfoundation.org/sites/default/files/files/ENGLAND%20country%20profilev_FINAL.pdf.

18. [http://www.nuffieldfoundation.org/sites/default/files/files/GERMANY%20\(R-P\)%20country%20profilev_FINAL.pdf](http://www.nuffieldfoundation.org/sites/default/files/files/GERMANY%20(R-P)%20country%20profilev_FINAL.pdf).

19. Germany did not take part in TIMSS 2011 for students aged 13 – 14.

20. http://www.nuffieldfoundation.org/sites/default/files/files/Is%20the%20UK%20an%20Outlier_Nuffield%20Foundation_v_FINAL.pdf.

Massachusetts (United States)

- Massachusetts can be considered a ‘near neighbour’ to England in terms of culture.
- Usually, teachers need to gain a bachelor’s degree, full state certification and subject knowledge for each subject they teach. To teach in Massachusetts teachers require a specific licence for the state and must re-certify this on a regular basis.
- ITE is given by multiple providers, including universities and community colleges.
- Compared to the United States average, Massachusetts performs well in international league tables. In the 2012 PISA tests Massachusetts ranked the same as Germany (16th). The United States overall was ranked 27th. Massachusetts was a benchmarking participant in TIMSS in 2011 for the ranking on 13 – 14 year olds, where it out-performed the United States average. In this assessment Massachusetts was only out-performed by the top five jurisdictions. The United States came 9th.
- Mathematics is compulsory post-16 in the United States when working towards the High School Diploma.²¹

Shanghai (China)

- ITE in Shanghai is provided by three types of specialist institution.²² Recruitment to ITE is highly competitive.
- ITE forms the first step on an ongoing teacher education and development journey.
- Shanghai has consistently performed well in international league tables. In the 2009 and 2012 PISA tests Shanghai was ranked first. Shanghai did not take part in TIMSS 2011.
- All students post-16 study mathematics.²³

Singapore

- All ITE is provided by the National Institute of Education and teachers are recruited by the Ministry of Education through several routes. Candidates are selected from the top third of high school graduates. Though the national examination is a high-stakes assessment used for selection of students, the Ministry of Education has introduced direct school exercises, which gives flexibility to a range of institutions to look at students’ achievements and talents other than those assessed in final examinations.²⁴
- Like Shanghai, Singapore has consistently performed well in international league tables, ranking 2nd in PISA in both 2009 and 2012. Singapore also performed well in TIMSS. In 2011 it was ranked 1st for students aged 9 – 10 and 2nd for students aged 13 – 14.
- The majority of students study post-16 mathematics.²⁵

21. Post-16 education is compulsory in some states in the USA, but it is not compulsory in Massachusetts. However, in Massachusetts 84% of the age cohort study for the High School Diploma, http://www.nuffieldfoundation.org/sites/default/files/files/Towards_universal_participation_in_post_16_maths_v_FINAL.pdf.

22. <http://www.ncee.org/programs-affiliates/center-on-international-education-benchmarking/top-performing-countries/shanghai-china/shanghai-china-teacher-and-principal-quality/>.

23. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/340021/report-on-research-into-maths-and-science-teaching-in-the-shanghai-region.pdf.

24. http://www.nuffieldfoundation.org/sites/default/files/files/SINGAPORE%20country%20profilev_FINAL.pdf.

25. *Ibid.*

D Comparison of some key ITE themes internationally

The table below identifies some elements of ITE practice identified in ACME's review. This was based on available policy documentation and academic literature from England, Germany, Massachusetts, Shanghai and Singapore.

Each of the international jurisdictions recently performed better than England in PISA in mathematics. The table does not seek to encapsulate the whole spectrum of variation with each jurisdiction. Statistics produced by each jurisdiction are not absolutely comparable and are collected in different ways. Instead this broad and non-comprehensive overview shows

some contrasts and similarities, in order to pose further questions about England. The review revealed that the picture of ITE practice in each jurisdiction is complex, situations on the ground can be in flux and individual systems are constantly undergoing change and development, something that is not always acknowledged in policy debates.

Applicants to ITE (mathematics)				
England	Germany	Massachusetts	Shanghai	Singapore
<p>Primary To enter ITE students must have a grade C in GCSE English and Mathematics (or equivalent) and be educated to degree level. A numeracy test must be taken for entry to ITE courses. Some providers offer primary training with mathematics specialism; entry criteria may stipulate certain degree subjects or relevant professional experience.</p>	<p>Primary To enter the first phase of ITE (i.e. university) students must have completed the <i>Abitur</i>, which includes the study of mathematics at post-16. After university students complete a state examination testing their subject knowledge before they enter in-school training.</p>	<p>Primary All post-16 students study mathematics for the High School Diploma that is required for entry to a degree programme. A degree must be completed prior to ITE.</p>	<p>Primary Applicants with post-16 junior secondary education or above must pass a national entrance examination, including mathematics, before entry to a 3 to 4 year programme.</p>	<p>Primary To enter for a Diploma (2 years) or a Bachelor's (4 years) in Education, O and A Level Mathematics (Singapore-Cambridge GCE) are required respectively. Mathematics specialists must have grade B in A Level Mathematics or pass the Mathematics Qualification Test.</p>
<p>Secondary Providers often seek mathematics candidates with a strong background in mathematics, i.e. A level Mathematics and an undergraduate degree in mathematics or a related subject. Non-specialist graduates may take a subject knowledge enhancement (SKE) course in mathematics.²⁶</p>	<p>Secondary The entry requirements to train as a secondary teacher are the same as for primary. However, trainee teachers work towards one of six certificates, some of which are focused on secondary teaching, split into academic and non-academic tracks.</p>	<p>Secondary The entry requirements to train as a secondary teacher are the same as for primary. However, to enter ITE applicants must have a degree in mathematics, education (with a mathematics concentration) or a closely related content area.</p>	<p>Secondary Secondary school teachers must have completed post-16 schooling before applying and must pass a national entrance examination for entry to 4 year Bachelor's Diploma/ Bachelor's Degree and Certificate of Teacher Training (2 years). Some routes recruit trainees with a Master's degree in pure mathematics.</p>	<p>Secondary The entry requirements to train as a secondary teacher are the same as for primary. However, depending on the level of mathematics to be taught, there are different mathematics qualifications requirements.</p>

26. <http://www.education.gov.uk/get-into-teaching/subjects-age-groups/age-groups/teaching-secondary/boost-subject-knowledge>.

Mathematics-specific training

Mathematics-specific training includes subject knowledge and research-informed pedagogical content knowledge.

England	Germany	Massachusetts	Shanghai	Singapore
<p>Primary The maximum time dedicated to mathematics-specific training is typically a few days. Most primary school teachers are trained to teach all subjects. Students gain more mathematics training on the primary specialist mathematics teacher route.</p>	<p>Primary The time dedicated to mathematics-specific ITE is on a similar scale to England. Teachers may earn a certificate to teach primary or a certificate to teach primary and lower secondary level.</p>	<p>Primary The time dedicated to mathematics-specific ITE is on a similar scale to that of England. Most primary school teachers are trained to teach all subjects.</p>	<p>Primary The time dedicated to mathematics-specific training can add up to a number of weeks. Many primary school teachers are trained as mathematics specialists.</p>	<p>Primary The time dedicated to mathematics-specific training can add up to a number of weeks. Primary teachers, like in England, are trained to teach all subjects. However, many primary school teachers subsequently (after ITE) are trained as mathematics specialists.</p>
<p>Secondary Many trainees will have a degree in mathematics or a related subject. During ITE most time is dedicated to pedagogical content knowledge and will be for a maximum of a few weeks in total, with the exception of trainees on additional SKE courses.</p>	<p>Secondary There is an emphasis on content knowledge during the university phase of teacher training, assessed during the first state examination. In mathematics those training to teach the academic track take mathematics degrees alongside other students following different professional routes.</p>	<p>Secondary The time dedicated to mathematics-specific ITE is similar to England. New teachers must pass the Massachusetts Tests for Educator Licensure (MTEL). If teaching beyond Grade 6 (11 – 13 year olds), this includes a mathematics subject knowledge test.</p>	<p>Secondary Trainees will usually have gained a degree in mathematics or a related subject. Some trainees study advanced mathematics to a high level over several years.</p>	<p>Secondary Trainees will usually have gained a degree in mathematics or a related subject. Some trainees have months or years of mathematics-specific ITE.</p>

School-based mentoring

School-based mentors are those who provide guidance and support to trainees and new teachers in a school setting.

England	Germany	Massachusetts	Shanghai	Singapore
<p>School-based mentors have no training or qualification requirement beyond being a qualified teacher.</p>	<p>School-based mentors are experienced 'master teachers'.</p>	<p>School-based mentors require training beyond a teaching qualification.</p>	<p>School-based mentors often require experience and training beyond a teaching qualification.</p>	<p>School-based mentors require training beyond a teaching qualification.</p>
<p>New teachers are usually mentored for their first year of teaching.</p>	<p>Trainees undergo mentoring during their 1 to 1.5 years of student training.</p>	<p>New teachers are mentored for their first year of teaching.</p>	<p>New teachers are mentored during the first 5 years of the profession.</p>	<p>New teachers enter the Structured Mentoring Programme. This continues through the first year of teaching.</p>

Practitioner research and evaluation skills

England	Germany	Massachusetts	Shanghai	Singapore
The development of practitioner research and evaluation skills is at the discretion of the provider.	Like in England, providers decide whether to include practitioner research and evaluation skills in ITE.	Like in England, providers decide whether to include practitioner research and evaluation skills in ITE.	Trainees and fully qualified teachers are required to join subject-specific practitioner research groups.	Teachers are supported by, and sometimes collaborate with, the Ministry of Education to engage in action research projects in the classroom.

Early stage professional learning

England	Germany	Massachusetts	Shanghai	Singapore
Professional learning is mandatory but there is no requirement for subject-specific professional development.	Professional learning is mandatory but, like England, there is no requirement for it to be subject specific.	Teachers are licensed on a 5 year renewal cycle and are required to engage in sustained professional development to re-certify. A professional career ladder for STEM teachers is supported and promoted by the state.	Extensive professional learning is mandatory and teachers take 240 hours of professional development within 5 years in a carefully structured programme of professional development.	Teachers are entitled to 100 hours of professional development per year. Subject-specialist career pathways are supported by professional development.

E Comparing English and international practice

Some important overlapping elements were identified in the review of ITE practice. However, the review showed more variation within ITE systems than is acknowledged in political and policy discourse. This highlights the need for more in-depth research for each of the elements, for example the nature of subject-specific training and the content of ITE courses.

The review also highlighted that the English system seems to leave much more discretion to ITE providers and the training is more varied than in other countries.

Applicants to ITE

In England, there are scholarships and bursaries to attract potential primary specialists of mathematics and secondary mathematics teachers.²⁷ Recruitment targets have not been met.²⁸ In contrast, in many of the other jurisdictions, including Shanghai and Singapore, there is strong competition to enter teacher education programmes. Whereas many students in England do not intend to become teachers when beginning their university degree, in other jurisdictions there is a clear pathway for teachers from when they leave secondary schooling.

Mathematics-specific training

The importance of deep subject and pedagogical content knowledge in ITE has been noted in educational research.²⁹ There is variation in the amount of subject-specific and research-informed pedagogical content knowledge training in each jurisdiction. In Shanghai, some trainees enter ITE with many years of subject-specific study that is then supplemented by research-informed pedagogical content knowledge during

training. The amount of mathematics-specific training can also vary depending on the number of subjects taught by a teacher. In England, primary teachers are usually generalist teachers who teach all subjects. However, primary teaching in some other jurisdictions is more subject specific, with examples of specialist mathematics teachers in primary schools in Shanghai and Singapore. However, this is not always the case within all the jurisdictions reviewed; some primary mathematics teaching is undertaken by generalist teachers.

School-based mentoring

School-based mentors can guide trainees and new teachers through their early development as teachers. There is much variation in the qualifications and training of mentors within jurisdictions. It is often at the discretion of the school. In Shanghai and Singapore, mentoring is seen as a key part of a teacher's professional journey. In Singapore, trainee teachers are enrolled into the Structured Mentoring Programme, which guides them through training and the first year of teaching. The amount and quality of mentoring received by trainees and new teachers in England is variable and school-based mentors require no further training or qualification beyond qualified teacher status.³⁰

27. <http://www.education.gov.uk/get-into-teaching/subjects-age-groups/teach-maths>.

28. <http://www.universitiesuk.ac.uk/highereducation/Documents/2013/InitialTeacherTraining-Nov2013.pdf>.

29. The Carter Review of ITT noted the importance of subject knowledge and subject-specific pedagogy. It recommended that subject knowledge development and issues in subject-specific pedagogy should be part of a framework for ITT content. The review also recommended that all ITT partnerships should rigorously audit, track and systematically improve subject knowledge throughout the programme and ensure that trainees have access to high-quality subject expertise.

<https://www.mpib-berlin.mpg.de/coactiv/en/main-findings/>;
<http://www.suttontrust.com/wp-content/uploads/2014/10/What-makes-great-teaching-FINAL-4.11.14.pdf>.

30. The Carter Review of ITT recommended the development of national standards for mentors and noted that mentoring should have should have greater status and recognition within the ITT system.



Practitioner research and evaluation skills

The engagement of teachers with research has been noted as a core aspect of good teaching practice.³¹ Internationally, the extent to which teachers are required to engage with or in research is variable. Developing practitioner research and evaluation skills during ITE in England is not mandatory, whereas teachers in Shanghai are required to participate in subject-specific practitioner research groups throughout their careers. The Ministry of Education in Singapore provides teachers with support to enable them to engage with action research in the classroom.

Early stage professional learning

Professional development enables teachers to develop and refine their practice following ITE. Engaging with professional development is especially crucial during the first few years of teaching to help embed the skills developed in ITE. Opportunities for teachers to engage in professional development in England are variable and although professional development is mandatory there is no minimum requirement or entitlement for teachers regarding subject-specific professional development.³² Massachusetts provides a more structured career pathway for teachers, requiring them to engage in sustained professional development. Teachers require professional development to renew their license to teach every 5 years.

31. The Carter Review of ITT recommended that evidence-based teaching should be part of a framework for ITT content and the development of a central portal of synthesised executive summaries, providing practical advice on research findings about effective teaching in different subjects and phases.

<https://www.bera.ac.uk/wp-content/uploads/2013/12/BERA-RSA-Research-Teaching-Profession-FULL-REPORT-for-web.pdf>.

32. The Carter Review of ITT recommended that schools should include subject knowledge as an essential element of professional development.

F Discussion questions

Reflecting on the insights above, ACME would appreciate your views on the questions set out below. They are drawn from the common themes identified. We invite you to consider what the findings of our review might mean for ITE in England. Please share your perspectives, whether gained from education research, experience in schools and colleges, teacher education or other areas.

1. Entry qualifications of applicants to ITE

Primary

What mathematical qualifications should be required for starting training as a primary school teacher? Why are these qualifications important?

Is there scope for encouraging potential primary school teachers to study a level 3 post-16 mathematics qualification such as Core Maths?³³ Should it be a requirement?

Secondary

What mathematical qualifications should be required for starting training as a secondary school teacher? Why are these qualifications important?

What should the role of SKE courses³⁴ be in providing applicants to ITE with subject-specific qualifications?

2. Mathematics-specific training

Primary

How much subject-specific training is needed to enable primary school teacher trainees to have a sufficiently deep understanding of relevant mathematics and mathematics pedagogy?

Secondary

How much subject-specific training is needed to enable secondary mathematics trainees to have a sufficiently deep understanding of relevant mathematics and mathematics pedagogy?

3. School-based mentoring

What experience should school-based mentors have?

How should mentors be trained for their role and what qualifications should they have?

For how long should new teachers be mentored?

How frequent and sustained should mentoring be in terms of number of hours per week or per month?

4. Practitioner research and evaluation skills

How important is the development of practitioner research and evaluation skills in ITE?

What proportion of ITE should be dedicated to this?

How can the development of practitioner research and evaluation skills during ITE be improved?

33. See footnote 12.

34. <http://www.education.gov.uk/get-into-teaching/subjects-age-groups/age-groups/teaching-secondary/boost-subject-knowledge>.

5. Early stage professional development

What proportion of professional development should be subject specific during the first 5 years of teaching and why?

How much mathematics-specific knowledge should be gained during ITE and how much should be gained during early stage professional learning?

What structural changes in the school system are needed to support this?

In addition to the themes explored in the review ACME is also interested in hearing views more broadly on the ITE landscape and the key components of mathematics ITE.

6. The ITE landscape and mathematics

In the current landscape of ITE, what structural changes are needed to ensure that there is a good supply of high-quality teachers of mathematics for the future?

7. The key components of ITE

Are there other key components of ITE that you believe lead to high-quality mathematics teaching?

What aspects of ITE urgently require further research to inform practice?

What aspects of ITE in particular require long-term ongoing research to inform practice?

G Submission

Your thoughts on these questions can be submitted online via Survey Monkey [here](#) or can be emailed to acme@royalsociety.org by 15 April 2015, at the latest. Early responses are very welcome.

ACME will collate and discuss the responses to the questions. After the responses have been analysed, some of the themes set out will be explored in more detail. The responses to the questions will be used to inform ACME about the key components of good mathematics ITE and will feed into a final report. This report will provide more analysis on ITE practice and formulate recommendations for policy.

A record of individuals and organisations who have submitted views may be listed in our website. Quotations from the submissions may be published but these will not be attributed to individuals by name. If you are submitting information on behalf of an organisation, please include details of the relevant person to contact should we wish to discuss issues raised in your submission. If you would not like your name or organisation listed on the ACME website please select the option to opt out of identification on the survey. If you would like to submit your views but are unable to meet the deadline, or if you have any questions, please contact us at acme@royalsociety.org.

We kindly ask you to circulate this document to other interested parties.

H Further reading

ACME drew upon a range of national and international sources to produce this document.

To explore the issues set out in this paper further a list of sources is included on the ACME website [here](#).

