Moving to mainstream ....
developing computing for all

Sue Sentance
Raspberry Pi Foundation

@suesentance
sue@raspberrypi.org
This is our mountain - a WIPSCE mountain?

Computing taught well in every school to every child

Where are you in your country now?
Moving to mainstream - outline of talk

- The Computing context
- The National Centre for Computing Education
- Being research-informed
- Progression
- Supporting teachers’ pedagogical content knowledge
- Diversity and inclusion
- A research agenda for a whole country
Background
Computing education in England

1970s – 1985
Computer Studies
Elective
14-18 years

1988 – 2013
Information and
Communications
Technology
Mandatory
5-16 years
Elective CS 16-18

2014 – date
Computing
Mandatory
5-16 years
Elective CS 14-18
Computing for all
Computing for everyone

Figure 1 – Structure of the national curriculum

<table>
<thead>
<tr>
<th>Age/Year groups</th>
<th>Key stage 1</th>
<th>Key stage 2</th>
<th>Key stage 3</th>
<th>Key stage 4</th>
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</thead>
<tbody>
<tr>
<td>Core subjects</td>
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<td>English</td>
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<tr>
<td>Mathematics</td>
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<tr>
<td>Foundation subjects</td>
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<tr>
<td>Art and design</td>
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<td>✔</td>
<td>✔</td>
<td>✔</td>
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<tr>
<td>Citizenship</td>
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<td>✔</td>
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<tr>
<td>Computing</td>
<td>✔</td>
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<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>Design and technology</td>
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<tr>
<td>Languages⁴</td>
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<tr>
<td>Geography</td>
<td>✔</td>
<td>✔</td>
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<tr>
<td>History</td>
<td>✔</td>
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<tr>
<td>Music</td>
<td>✔</td>
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<tr>
<td>Physical education</td>
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</tbody>
</table>

*Teach Computing*
So why every child?

A foundational subject discipline that every child should learn

A subject that will equip our children for the jobs of the future
Computing for all

A foundational subject discipline that every child should learn

A subject that will equip our children for the jobs of the future

An understanding of how to make computing inclusive and accessible

Research
Our young people need ...

... to understand the impact of AI on society on a world we haven’t met yet
... to have the computational thinking skills needed to solve problems, apply logic and generalise from patterns
... to know how to use computers to model and make predictions about the future
... to understand ethical issues around privacy and security and how technology impacts those
... to be able to create the tools they need for the tasks they have to do
... to be empowered by technology not a slave to it
... to be independent learners who can adapt to technological developments of the future
Challenges for schools

- 75% existing teachers of GCSE computer science (elective course offered at age 14-16) do not have academic background in Computer Science.

- There are not enough computing teachers: only 53% secondary schools currently offer GCSE computer science.
“our evidence shows that computing education across the UK is patchy and fragile. Its future development and sustainability depend on swift and coordinated action by governments, industry, and non-profit organisations”.

Recommendations relating to:
1. Computing for all & improving gender balance
2. Support for teachers & increasing supply
3. Improvement of computing education through research

https://royalsociety.org/topics-policy/projects/computing-education/
Why a focus on research?
• Pedagogies for computing are less developed than other subjects
• Lack of effective sharing of knowledge between researchers, teachers and teacher trainers.
• Lack of school-level research studies
The National Centre for Computing Education
New funding!

- In December 2017 the Treasury announced £100m funding for computing education in UK (meaning £84m for England)
- In November 2018 the Department for Education announced the National Centre for Computing Education to support teachers, with a separate programme on gender balance research
- Teach Computing was launched at http://teachcomputing.org
- The programme runs from Nov 2018 - July 2022
Our vision is for every child in every school in England to have a world-leading computing education.

http://teachcomputing.org
Professional development opportunities

- Face-to-face CPD being delivered all over England
- School-led model
- Bursaries available for GCSE teachers and priority schools
- Online courses for teachers tailored to the curriculum
- Leading to certification
- Regionally delivered
Teaching Programming in Primary Schools
Understand key programming concepts and apply them using Scratch, with this introductory course for primary or K-5 teachers.
4 weeks  2 hrs per week
Join free

An Introduction to Computer Networking for Teachers
Build your knowledge and understanding of computer networks as a computer science teacher.
3 weeks  2 hrs per week
Join free

Understanding Computer Systems
Understand how the components of a computer system interact with each other on this online course for computing teachers.
3 weeks  2 hrs per week
Join free

Understanding Maths and Logic in Computer Science
Improve your understanding and ability to teach maths and logic in computing while building elements of an escape room.
3 weeks  2 hrs per week
Join free

Object-oriented Programming in Python: Create Your Own Adventure Game

How Computers Work: Demystifying Computation

Teaching Physical Computing with Raspberry Pi and Python

Build a Makerspace for Young People
Find out how to create and run a makerspace for young people, backed by

35 online training courses (16 now)  https://teachcomputing.org/courses
Collaboration and engagement in online courses

Programming 101: An Introduction to Python for Educators

Explore the basics of Python. Guided by the Raspberry Pi Foundation, you'll learn to code your first program. Supported by Google.

Videos demonstrate each step

Teachers share their progress and ask questions

A range of online courses are available
Face-to-face training

**Algorithms in GCSE computer science** CP200

Develop your understanding of algorithms to successfully teach this topic in GCSE computer science.

- View dates & locations

**GCSE Computer Science – developing outstanding teaching** CP205

This course helps teachers of GCSE to develop their classroom practice and deliver outstanding teaching of GCSE computer science

- Computing
- Key stage 4

**KS4 computing for all** CP207

This action-oriented professional development course explores the options available to computing teachers in different school contexts

- Ashington
- 27 November–27 November 2019

**Networks and cyber-security in GCSE computer science** CP202

Develop your knowledge of networks, computer security and guarding against threats to successfully teach your students

- View dates & locations

**Primary programming and algorithms** CP003

Discover engaging and effective ways to help children use computational thinking.

- View dates & locations

**Python programming essentials for GCSE computer science** CP203

Discover the fundamentals of programming and develop your skills to teach GCSE computer science.

- View dates & locations
Regional support

- 30 Computing hubs
- Delivery of CPD and support
- Local “subject matter experts” supporting schools
- Toolkits to help school leaders advance their Computing provision
Full curriculum resources for Computing

A comprehensive collection of material to support 500 hours of teaching materials, facilitating the delivery of the computing curriculum age 5-16 by July 2020.

All resource repository content is free, and editable ensuring the resources can be tailored to each individual teacher and school setting.

More later!
Physical computing kits on loan

Computing hub schools will have class sets of hardware to loan
All resources will be available with training provided

Crumbles  Microbits  Raspberry Pis
Dedicated support for students 16-18
Isaac Computer Science

- A Level computer science
- Complete specification coverage
- Students learn using content and questions
- Teachers can set up groups and set assignments
- Events for students and teachers

http://isaaccomputerscience.org
Certification

NCCE Certificate in Primary Computing Teaching
NCCE Certificate in Secondary Computing Teaching
NCCE Certificate in GCSE CS Subject Knowledge
Hello World!

Free magazine for Computing teachers
5 issues per year
http://helloworld.cc
Research-informed
Professional learning opportunities

Draw on research from professional development
- Link to pupil outcomes
- Sustained and collaborative
- Research-informed
Creating materials - principles

Ten Key Principles

<table>
<thead>
<tr>
<th>Pedagogy - general</th>
</tr>
</thead>
</table>
| (including programming, data, communication & networks, systems architecture, IT and digital literacy)  
| Techniques |  
| 1. Collaboration |  
| 2. Discourse |  
| 3. Unplugged |  
| 4. Semiotics |  
| 5. Storytelling |  
| 6. Models |  
| 7. Choosing tools |  
| 8. Cross-curricular |  
| 9. Exploring |  
| 10. Guided practice |  
| 11. Making |  
| 12. Target |  
| 13. Self-regulating |  
| 14. Tutoring |  

Pedagogy - specific to programming

Techniques & Approaches - how to realise the principles

1. Pair programming
2. Peer instruction
3. Modelling/ Live coding
4. Design as a software building process
5. Models and frameworks such as Use-Modify-Create, PRIMM, FACT, UDL, ATT, LOA
6. Cognitive apprenticeship
7. Reading/tracing code
8. Worked examples & sub-goal labelling
9. Targeted tasks - eg debugging, sabotage, fill in the gaps, annotation, Parson's problems
10. Physical computing

Large development team – including contractors. All resource writers follow key principles
Progression
<table>
<thead>
<tr>
<th>Computing Taxonomy</th>
<th>5-7</th>
<th>7-11</th>
<th>11-14</th>
<th>14-16 Core</th>
<th>14-16 Elective</th>
<th>16-18 Elective</th>
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<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Creating Media</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>(✓)</td>
</tr>
<tr>
<td>Computer Networks</td>
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<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
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<tr>
<td>Computer Systems</td>
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<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Data &amp; Information</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Design &amp; Development</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Effective use of tools</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Impact of technology</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
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<tr>
<td>Programming</td>
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<td>✓</td>
<td>✓</td>
<td>(✓)</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Safety &amp; Security</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>(✓)</td>
</tr>
</tbody>
</table>
Progression in Computing - when do you teach what?

Goal
- Develop a learning journey from 5-16, sequencing all topics

Process
- Reviewed curriculum, specs, products, text books, existing resources
- Reviewed research, where available
- Created a high level taxonomy of concepts and skills
- Use taxonomy strands to begin creating concept maps and learning trajectories
Mapping and trajectories

- **Concept maps** are graphical tools for organising and representing knowledge. They include concepts, usually enclosed in circles or boxes of some type, and relationships between concepts indicated by a connecting line linking two concepts.

- Children follow natural developmental progressions in learning and development which we can call **learning trajectories**, made up of a goal, a developmental path, and a set of instructional activities or tasks matched to each of the levels of thinking in that path that help children develop higher levels of thinking.

Andreas Mühling (2016) Aggregating concept map data to investigate the knowledge of beginning CS students, Computer Science Education, 26:2-3, 176-191

Learning Graph
Year 8 - Representations

A representation is a pattern of symbols.

List examples of representations.

A coding scheme is a set of rules for converting from one representation to another.

Recall that characters can be represented as sequences of symbols and list examples of character coding schemes.

A representation is a pattern of symbols.

Recall that representations are used to store, communicate, and process information.

Symbols are abstractions and independent of their physical carriers.

Provide examples of how symbols are carried on physical media.

Measure the length of a representation as the number of symbols that it contains.

Provide examples of how different representations are appropriate for different tasks.

Recall that binary digits are used to represent all information that is stored, transmitted, and processed by computers.

Provide examples of the different ways that binary digits are physically represented in digital devices.

Measure the size or length of a sequence of bits as the number of binary digits that it contains.

Convert between different units of representation size.

Convert a decimal number to binary and vice versa.

Describe how natural numbers are represented as sequences of binary digits.

Describe how characters are represented as sequences of binary digits.

Follow-up unit: binary representations of images and sounds.

This resource is available online at ncre.gov/rgdt. Resources are updated regularly — please check that you are using the latest version.

This resource is licensed under the Open Government Licence, version 3. For more information on this licence, see ncre.gov/ogl.
### Key Stage 3 (11 - 14 years old) Units

<table>
<thead>
<tr>
<th>Year 7</th>
<th>Year 8</th>
<th>Year 9</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Collaborating Online Respectfully</strong></td>
<td><strong>Media Unit</strong></td>
<td><strong>Impact of Technology</strong></td>
</tr>
<tr>
<td><strong>Lab Introduction Responsible Use Cyberbullying Security</strong></td>
<td><strong>Computing systems</strong></td>
<td><strong>E.g. animations (blender) E.g. video editing</strong></td>
</tr>
<tr>
<td><strong>Media Unit: Gain support for a cause</strong></td>
<td><strong>Networks systems</strong></td>
<td><strong>Databases and Cyber Security</strong></td>
</tr>
<tr>
<td><strong>Word Processing Licensing Plagiarism Source Credibility</strong></td>
<td><strong>Web HTML, CSS Search</strong></td>
<td><strong>Big Data SQL queries Security GDPR Social Engineering</strong></td>
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<td><strong>Networks I</strong></td>
<td><strong>Representations I</strong></td>
<td><strong>Representations 2</strong></td>
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<tr>
<td><strong>Networks Internet Web Cybersecurity Safety</strong></td>
<td><strong>Representation s Binary Numbers Text Units</strong></td>
<td><strong>Images Sounds Manipulation</strong></td>
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<tr>
<td><strong>Spreadsheets</strong></td>
<td><strong>Programming 1</strong></td>
<td><strong>Programming 5</strong></td>
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<tr>
<td><strong>Basic Formulas Basic Functions Formatting (incl. conditional)</strong></td>
<td><strong>Scratch PRIMM Form. Assessment Id. Misconceptions</strong></td>
<td><strong>Physical Computing Algorithms Data Apps Web</strong></td>
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<tr>
<td><strong>Programming 2</strong></td>
<td><strong>Scratch Lists Subroutines Deeper dive</strong></td>
<td><strong>Programming 6 Projects</strong></td>
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</tbody>
</table>

- **Teach Computing**
- E.g. animations (blender) E.g. video editing
- **Databases and Cyber Security**
  - Big Data SQL queries Security GDPR Social Engineering
- **Images Sounds Manipulation**
- **Physical Computing Algorithms Data Apps Web**
### 14-16 years old - Key Stage 4 Units

<table>
<thead>
<tr>
<th>Theory Oriented</th>
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<tr>
<td>Data Representation</td>
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<tr>
<td>Binary, Hex Conversions &amp; Ops. Text Images &amp; Sound Data Capacity Compression</td>
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</table>

<table>
<thead>
<tr>
<th>Computer Systems</th>
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<tbody>
<tr>
<td>Components Architecture Storage Software Boolean logic</td>
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<table>
<thead>
<tr>
<th>Networks</th>
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<tbody>
<tr>
<td>8 hrs</td>
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<tr>
<td>Components Classifications Protocols Layers</td>
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<table>
<thead>
<tr>
<th>Security</th>
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<tbody>
<tr>
<td>6-8 hrs</td>
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<tr>
<td>Vulnerabilities Forms of Attack Techniques for: Identification Protection</td>
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<table>
<thead>
<tr>
<th>Impacts</th>
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<tbody>
<tr>
<td>6-8 hrs</td>
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<tr>
<td>Ethical Legal Environmental (inc. privacy and cyber security)</td>
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<table>
<thead>
<tr>
<th>Algorithms</th>
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<tr>
<td>12-14 hrs</td>
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<tr>
<td>Tracing &amp; Exec. Representation Searching Sorting Efficiency Comp. Thinking</td>
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</table>

<table>
<thead>
<tr>
<th>Programming</th>
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</thead>
<tbody>
<tr>
<td>30-36 hrs</td>
</tr>
<tr>
<td>Tracing &amp; Exec. Prog. constructs Data types, structs Modularity Quality Translators</td>
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</table>

<table>
<thead>
<tr>
<th>Project (NEA)</th>
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<tbody>
<tr>
<td>30 hrs</td>
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<tr>
<td>Preparation Implementation</td>
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</tbody>
</table>

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**Teach Computing**
Computer systems and networks Strand - Primary

**Year 1**
Technology around you
6 hrs
Learners become familiar with the different components of a computer by developing their keyboard and mouse skills

**Year 2**
Information technology around you
6 hrs
Learners will be looking at information technology at school and beyond, in settings such as in shops, hospitals and libraries. It will investigate how information technology improves our world

**Year 3**
Connecting computers
6 hrs
Introduction to computer networks, including devices that make up a networks infrastructure, such as wireless access points and switches

**Year 4**
Data storage and the internet
6 hrs

**Year 5**
Online collaboration
6 hrs

**Year 6**
Searching and online communication
6 hrs

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Teach Computing
Research and evaluation

- Iterative development of learning graphs with teachers
- How are learning graphs used?
- What does progression look like in the Computing classroom?
Supporting teachers’ PCK
Where we were … in 2013

Exclusive focus on subject knowledge
Where we are now ... in 2019

Short summaries of research around topics such as cognitive load, worked examples, pair programming

Examples of application to practice

Built into resources
Helping teachers put evidence into practice

Welcome to issue 4 of Research Bytes produced by the Raspberry Pi Foundation for the National Centre for Computing Education. Each half-term we’ll present a selection of current research and evidence, hear from teachers embedding this evidence in their practice, and show you ways in which you can get more involved in computing education research.

In this issue:
- Can physical manipulatives improve learners’ concept of a computer
- Techniques for teaching programming
- Download our first Pedagogy "Quick Read"

We need your input to make Research Bytes as useful as possible: please tell us what you want to see here via this feedback form.

News and updates

Welcome to issue 3 of Research Bytes from the National Centre for Computing Education. Each half-term we’ll present a selection of current research and evidence, hear from teachers embedding this evidence in their practice, and show you ways in which you can get more involved in computing education research.

In this issue:
- Contribute to an international research project into computing education provision
- Discover how to use Learning Objective Graphs to plan for progression
- Learn about misconception-sensitive teaching

We need your input to make Research Bytes as useful as possible: please tell us what you want to see here via this feedback form.
Teach Computing podcast

Episode #1: Why teach computing?

To kick off our podcast series, we’re exploring the reasons why computing education is so important to the lives and education of all our students. There are many reasons why we might want our young people to be confident and literate, not only in how to use technology, but also in how it works and is created.

- First and foremost, computing should be tremendous fun and is one of the most creative disciplines; it enables our learners to create, invent, explore and simulate the world around them.
- Exposing students to computing skills and concepts is incredibly empowering, giving them new ways to solve problems, represent their world, and express their ideas.
Research and evaluation

• Which pedagogical approaches impact learning in the K-12 classroom?
• How does professional learning around Computing pedagogy impact student learning?
Diversity and inclusion
A new programme of research to investigate which interventions may be effective in school to both engage female students and to increase numbers selecting computer science at GCSE and A level.

Trials will run from 2019–2022 in key stages 1–4, and over 15,000 students and 550 schools will be involved. It will be the largest national research effort to tackle this issue to date.
Five interventions + an innovation strand 2019-2022

Intervention 1: Teaching approach
Intervention 2: Timetabling
Intervention 3: Belonging
Intervention 4: Relevance
Intervention 5: Non-formal learning
Intervention 6: Innovation strand

All interventions are randomised control trials in schools except timetabling
Inclusion and support

Online course for teachers out soon to support teachers to:

- Recognise the barriers faced by a range of students with special educational needs and disabilities in the computing classroom.
- Evaluate and use a range of general technology to support students with SEND. Identify effective strategies for supporting individuals in computing.
- Identify effective strategies for supporting individuals in computing.
- Recognise the range of specific computing resources available to support students with SEND.
- Understand the benefits for all students in developing inclusive practice.
Socio-economic inclusion

- A significant focus of the National Centre is on reaching schools in “Opportunity areas”
- Opportunity areas are defined as having low social mobility and capacity to improve
- In these areas there are less opportunities for young people to achieve
- The NCCE is focusing on reaching these areas
Research and evaluation

- Which interventions have a measurable impact on interest, engagement and motivation in computing?
- Which approaches are effective in making computing accessible to students with special educational needs?
- To what extent does incentivising and external support impact take up of computing in areas of low social mobility?
Challenges
What are the challenges?

Reach and Scale
• Early adopters & enthusiasts have all been reached
• How to reach schools where Computing is not a priority

Getting schools started from a low base
• Teachers shortages and retention
• Training takes time

Research
• Not currently being explicitly funded
Research agenda
Research agenda - Part 1

As already discussed:

- How can we frame the learning journey in computing through a progression framework?
- Which pedagogical approaches are most appropriate for different topics, contexts, educational phases?
- What interventions have an impact on gender balance in computing
Research agenda - Part 2

Scale
- How can countries develop professional development journeys that are appropriate, at scale?
- What online support for teachers has impact in the classroom?

Hard to reach
- What interventions support schools and teachers who are motivationally challenged by computing?

Computing for all
- How do we ensure the subject is accessible to all our children (All 8 million of them!)
Research agenda - Part 3

What do you think..... ?
This is our mountain - a WIPSCE mountain?

Computing taught well in every school to every child

Where are you in your country now?
This is our mountain - a WIPSCE mountain?

Computing taught well in every school to every child

Where are you in your country now?
Find out more - get involved!

- Read all our news at http://teachcomputing.org
- Try our A Level platform at http://isaaccomputerscience.org
- Explore our beta teaching resources http://teachcomputing.org/resources
- Write for Hello World! http://helloworld.cc
- Sign up for online courses http://rpf.io/courses
- Enter our international Coolest Projects competition https://coolestprojects.org/international/
Questions?

Sue Sentance
Raspberry Pi Foundation

@suesentance
sue@raspberrypi.org