Institute of Education

UCL

Programming and Mathematics
Insights from research in England

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UCL Institute of Education
University College London
U.K.

NCCE online seminar June 2020

Inspiration…….

Eric Schmidt
Chief Executive of Google visited England 2011

"I was flabbergasted to learn that today Computer Science isn't even taught as standard in UK schools"

"Your IT curriculum focuses on teaching how to use software, ***but gives no insight into how it's made".***

Royal Society reports

- Shut Down or Restart 2012
- After the Reboot: Computing Education in Schools 2017

From slaves of technology to its master
From consumers to creators

New statutory primary National Computing Curriculum 2014 in England for pupils age 6 to 16 years

Key aspect: pupils should **design, build & debug programs**

National Centre for Computing Education NCCE

https://teachcomputing.org

How does **programming** fit with the rest of the curriculum?

My background

1. **Mathematics** and **mathematics education**

2. Inspired by **constructionism**; vision of **Seymour Papert** around the potential of **Logo programming**

3. Involvement in

- **Logo: 50+ years of research (with Richard Noss)**
- **Huge conferences at MIT 1984/5**
- **Logo Maths movement**

Hoyles C. and Noss, R. (1992) (eds) *Learning Mathematics and Logo*. Cambridge MA: MIT Press.
Noss, R. and Hoyles, C. (1996) *Windows on Mathematical Meanings: Learning Cultures and Computers*. Dordrecht:
Monaghan, J, Trouche, L, Borwein, J. (2016) *Tools and Mathematics* Springer

1. Learning effective when making an artefact that is **personally** or **socially meaningful**; can be **shared** with others; **reflected upon**, **debugged** (see for example Kafai & Resnick, 1996)
2. Importance of
    - **powerful ideas** embedded in well-designed constructionist activity
    - **personal meaning** and **emotional connection…**

What does it mean to program & why program?

To understand how something works

- build
- trace
- debug
- share…..

UCL ScratchMaths project 2014-20……

SM developed a 2-year curriculum with teacher and pupil materials for 9-11 year olds in England

- aligned to the National Computing *and* National Mathematics primary curricula
- supports the teaching of carefully selected **core ideas of computer programming** alongside **specific fundamental mathematical concepts**

We acknowledge the generous funding of the Education Endowment Foundation

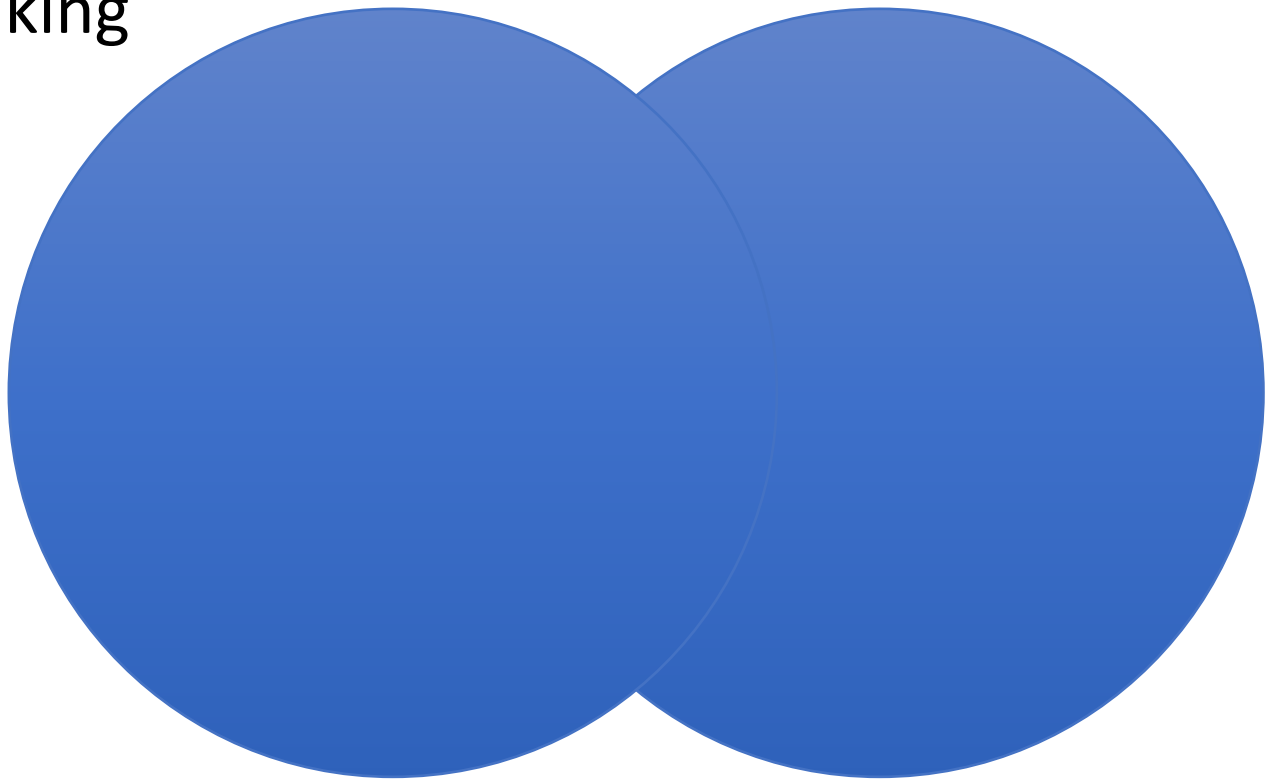
UCL ScratchMaths project 2014-20…ctd

- **supported schools in addressing computing curriculum** using specially devised materials in Scratch

- **supported mathematical learning** by teaching some of the mathematics involved through programming in **Scratch**

Computational Thinking alongside Mathematical Thinking

Computational thinking



Mathematical Thinking

Computational thinking

- seeing a problem and its solution at many levels of detail (abstraction)
- thinking about tasks as a series of logical steps (algorithms)
- understanding that solving a large problem can involve breaking it down into a set of smaller problems (decomposition)
- appreciating that a new problem is likely to be related to other problems the learner has already solved (pattern recognition)
- realising that a solution to a problem can be made in ways that can solve a range of related problems (generalisation)

Phases of UCL ScratchMaths

Phase 1. Iterative Design

- computer tools
- materials tried with small number schools/teachers
- professional development for the teachers

Phase 2. Implementation at scale

- > 100 schools across country
- PD in regional 'hubs'
- formative evaluation

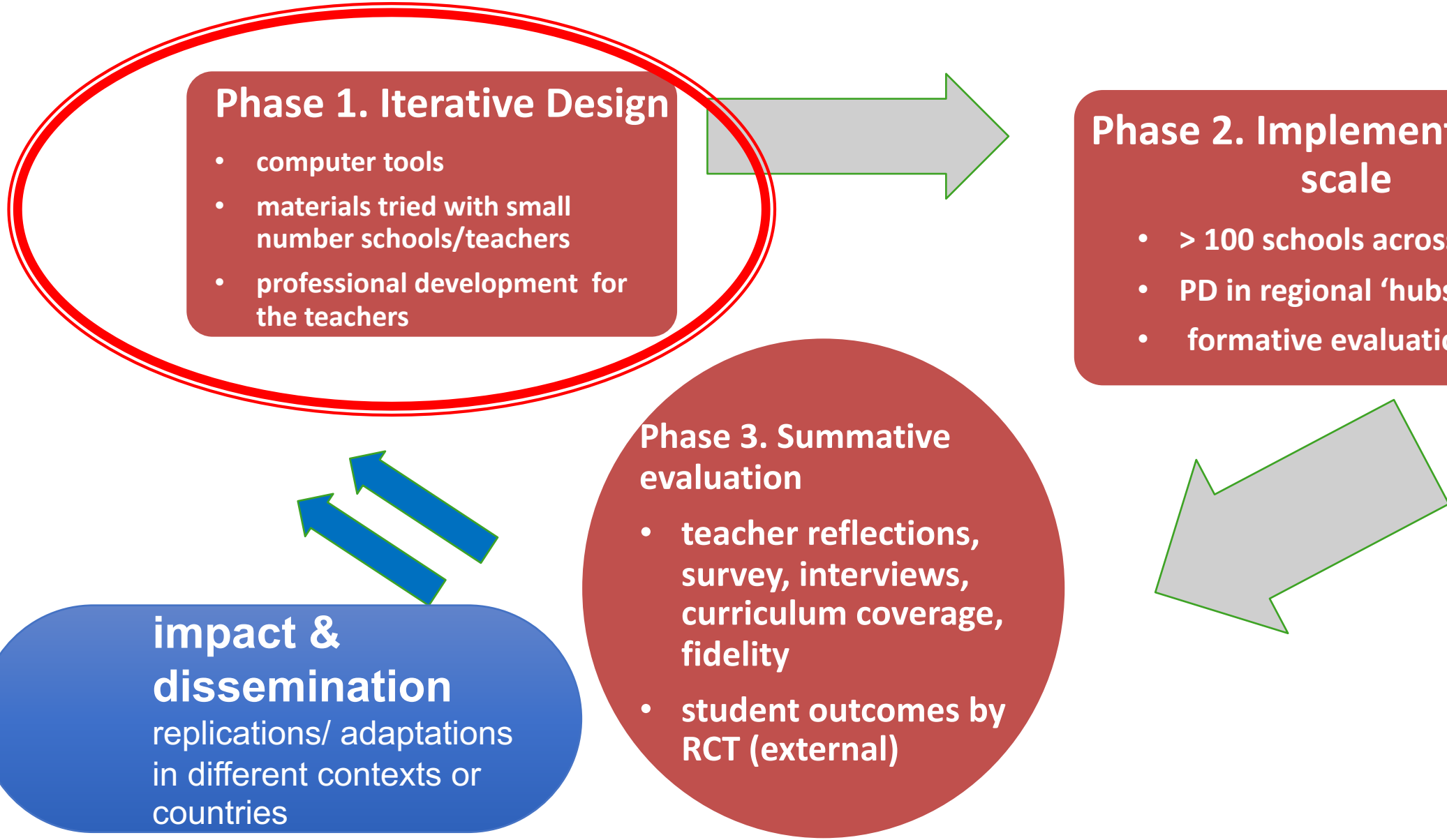
Phase 3. Summative evaluation

- teacher reflections, survey, interviews, curriculum coverage, fidelity
- student outcomes by RCT (external)

impact & dissemination

replications/ adaptations in different contexts or countries

Phases of UCL ScratchMaths



UCL ScratchMaths project team

Interdisciplinary team led by

- Professor Dame Celia Hoyles (Mathematics) & Professor Richard Noss (Mathematics) UCL Knowledge Lab

- Professor Ivan Kalas, (Computing)
  Comenius University, Bratislava, Slovakia
- Dr Laura Benton (Computing) & Piers Saunders, (Mathematics) UCL Knowledge Lab
- Prof Dave Pratt (Mathematics) UCL Institute of Education

Phase 1. Iterative Design

4 design schools

- Intensive work with teachers over two years: design workshops, observations
- Trials in design schools

Evolved **principles to guide design** of

- **pedagogical framework**
- **instructional sequence** (9-11 year students, Year 5 and Year 6) & **professional development framework**
- **curriculum materials** for Years 5 & 6

Outcome 1. Pedagogical framework (5Es)

Explore: Investigate, try things out yourself, debug in reaction to feedback

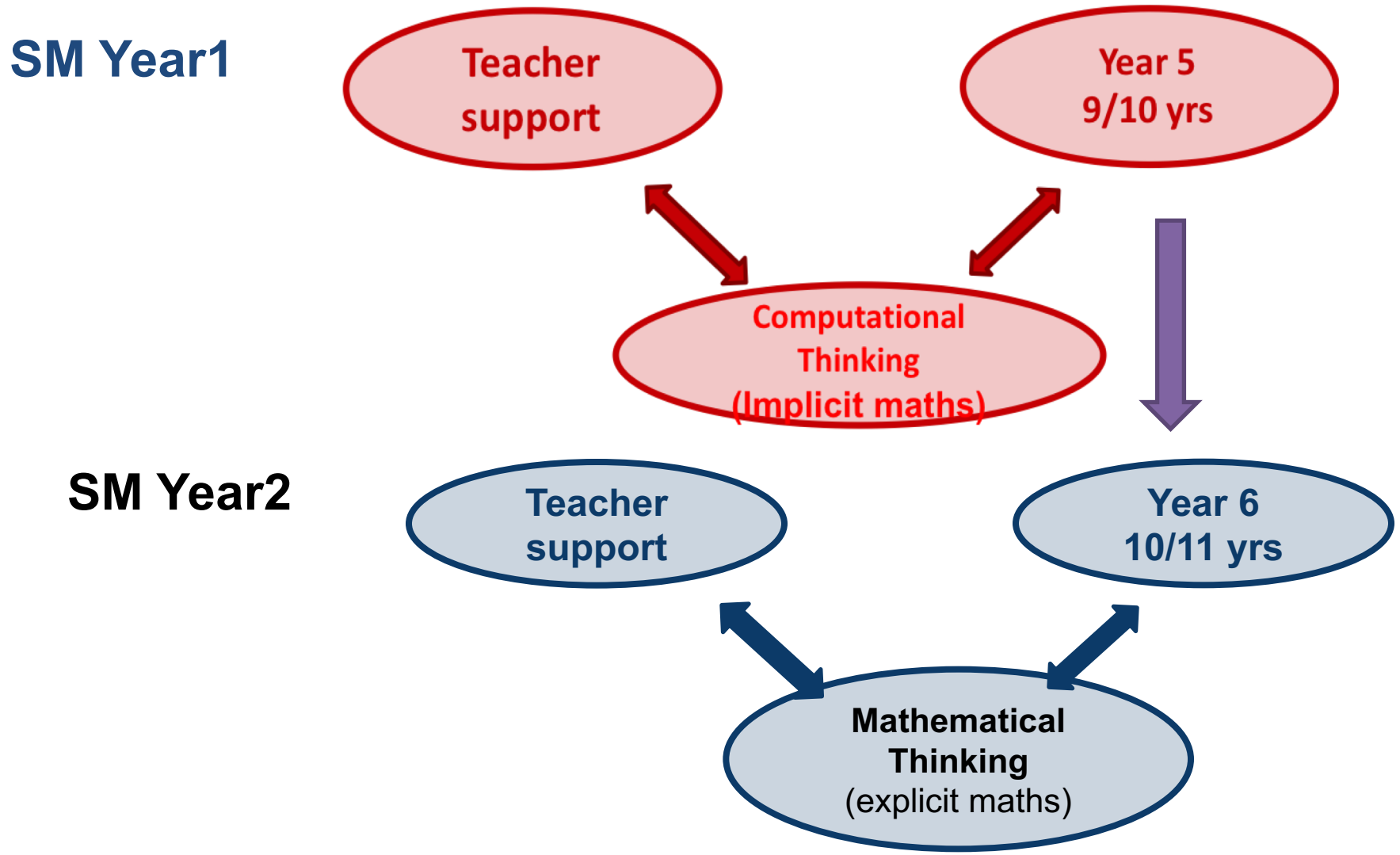
Envisage: Have a goal in mind, predict outcome of program *before trying*

Explain: Explain what you have done, articulate reasons behind your approach to yourself & others

Exchange: Collaborate & share, try to see a problem from another's perspective as well as defend your own approach and compare with others.

bridgE: Make **explicit** links to the mathematics curriculum

Outcome 2: Two-year instructional sequence & Professional Development



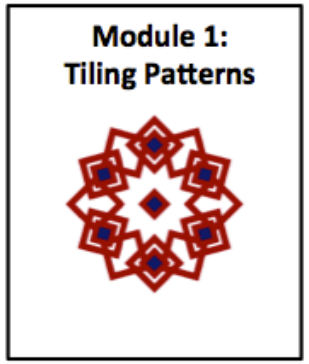
2 days of Professional development per year

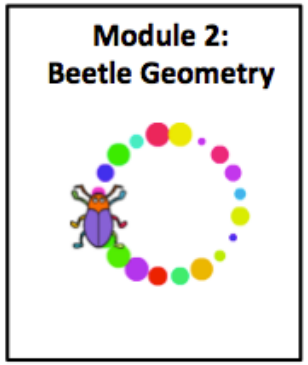
- orienting day
- use in school (online support, visits, gap task)
- reflections & further orientation

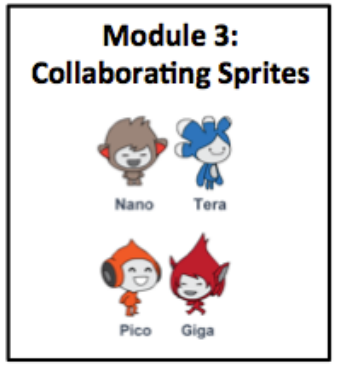
–NOTE: At the end of Year 6 all students in England take a high-stakes National Mathematics Test, Key Stage 2 test

Year 5 (9-10 yrs) – Computing focus (20+ hours)

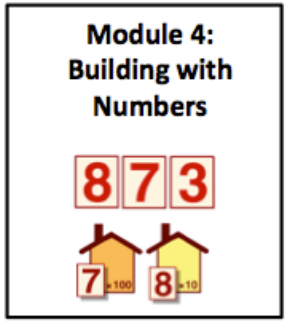
Outcome 3. student & teacher curriculum & support materials

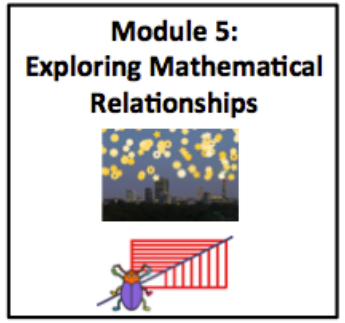


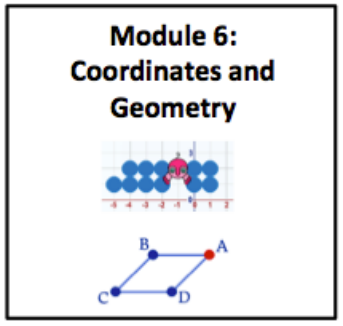




Year 6 (10-11 yrs) – Mathematics focus (20+ hours)



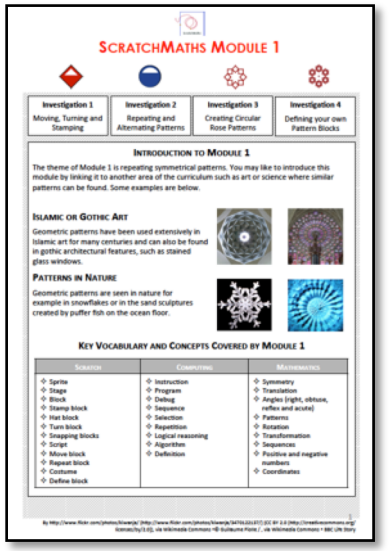


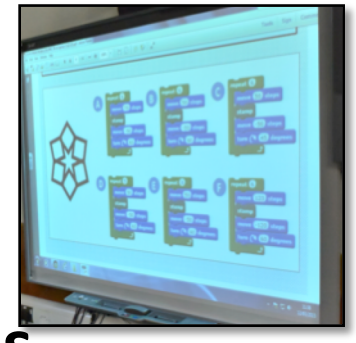


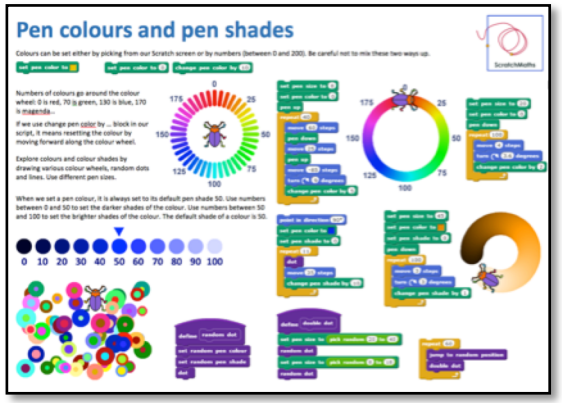
Freely available through UCL website http://www.ucl.ac.uk/scratchmaths

Outcome 3. Student & teacher curriculum & support materials (ctd)

- **Teacher materials for each module:**
  - Detailed description of each activity
  - Starter projects
  - Additional support including example scripts
  - Unplugged pupil worksheets
  - Suggested discussion points
- **End of module assessments**
- **SmartBoard presentations for all activities**
- **Supporting videos**
- **Reference posters**
- **Additional challenges**







–blended learning

- on- and off- computer
- different modes of classroom interaction to support E’s

Module descriptions

Module 2: Beetle Geometry

Investigation 1	Investigation 2	Investigation 3	Investigation 4
Exploring Pen	Drawing Polygons	Discovering Dots	Pen Project: Nature Scenes




Introduction to Module 2

Module 2 is focused around creating different drawings using the pen tool including numerals, patterns, polygons as well as entire scenes. This module could potentially be linked with several different areas of the Key Stage 2 curriculum including history and geography.

History: Romans and Morse Code

The first investigation looks at drawing Roman numerals which could link to history projects around the Roman empire.

The third investigation requires pupils to create Morse code messages, which could link to work on the history of communication.

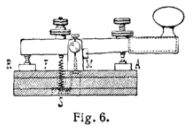



Fig. 6.

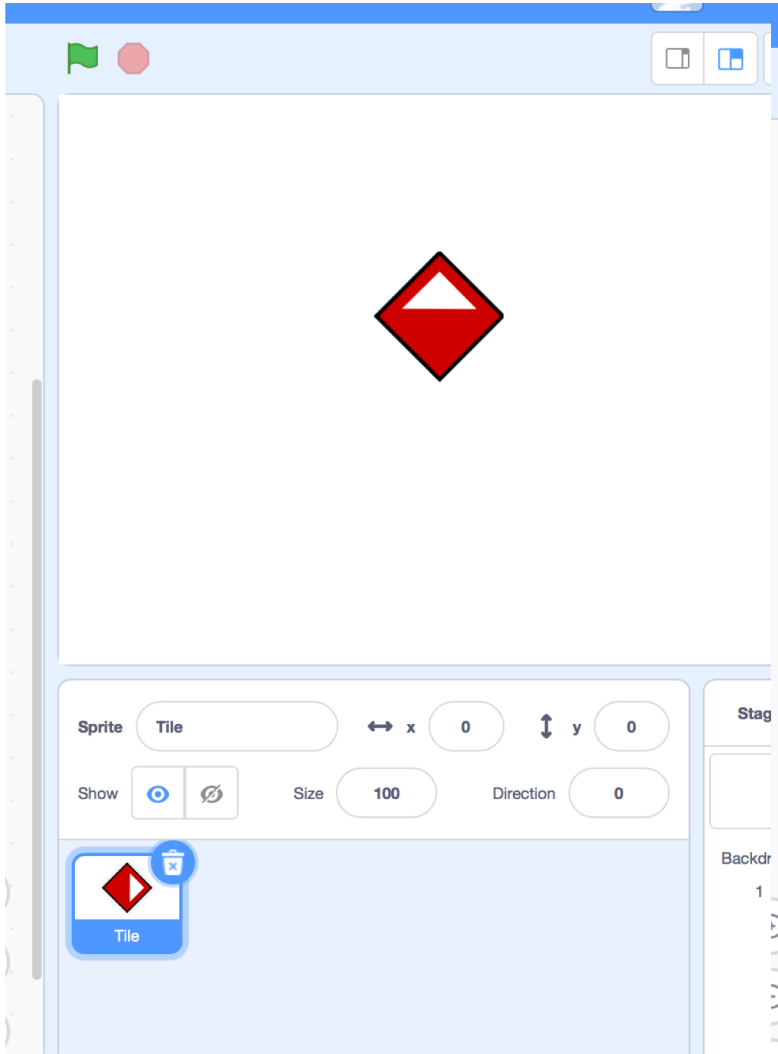
Geography: The Natural World

The final project in this module looks at creating different scenes found in nature including forests and beaches. This investigation could be linked in with geography topics exploring different elements of the natural world.

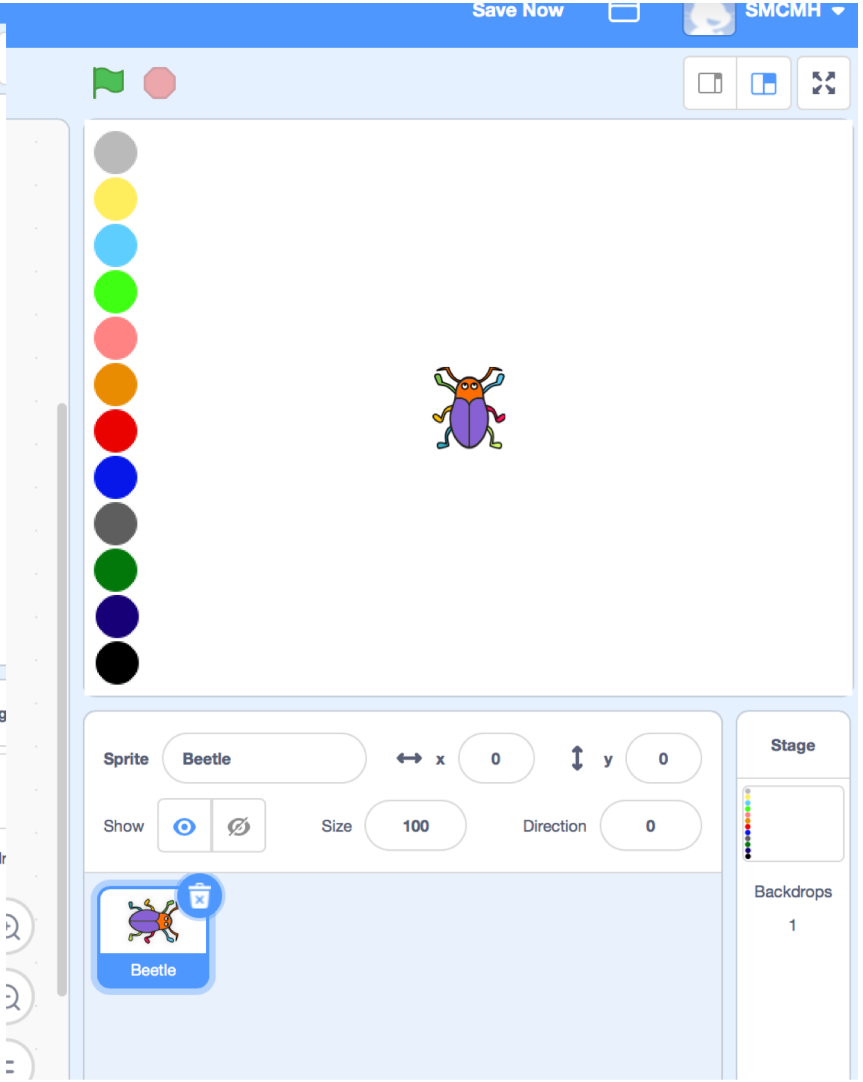

Key Vocabulary and Concepts Covered by Module 2

Scratch	[illegible]	Mathematics
▶ Pen down, pen up blocks ▶ Pen colour blocks ▶ Pen shade blocks ▶ Pen size blocks ▶ Backdrop ▶ Pre-defined blocks ▶ Pick random ▶ Repeat block ▶ Define block	▶ Initialisation ▶ Expressions ▶ Debugging ▶ Sequence ▶ Repetition ▶ Logical Reasoning ▶ Algorithm ▶ Definition	▶ Roman numerals ▶ Perimeter ▶ Regular and irregular polygons ▶ Multiplication and division ▶ Angles ▶ Rotation ▶ Positive and negative numbers ▶ Coordinates

Computer tools: Scratch or ScratchMaths ☺
What looks different?

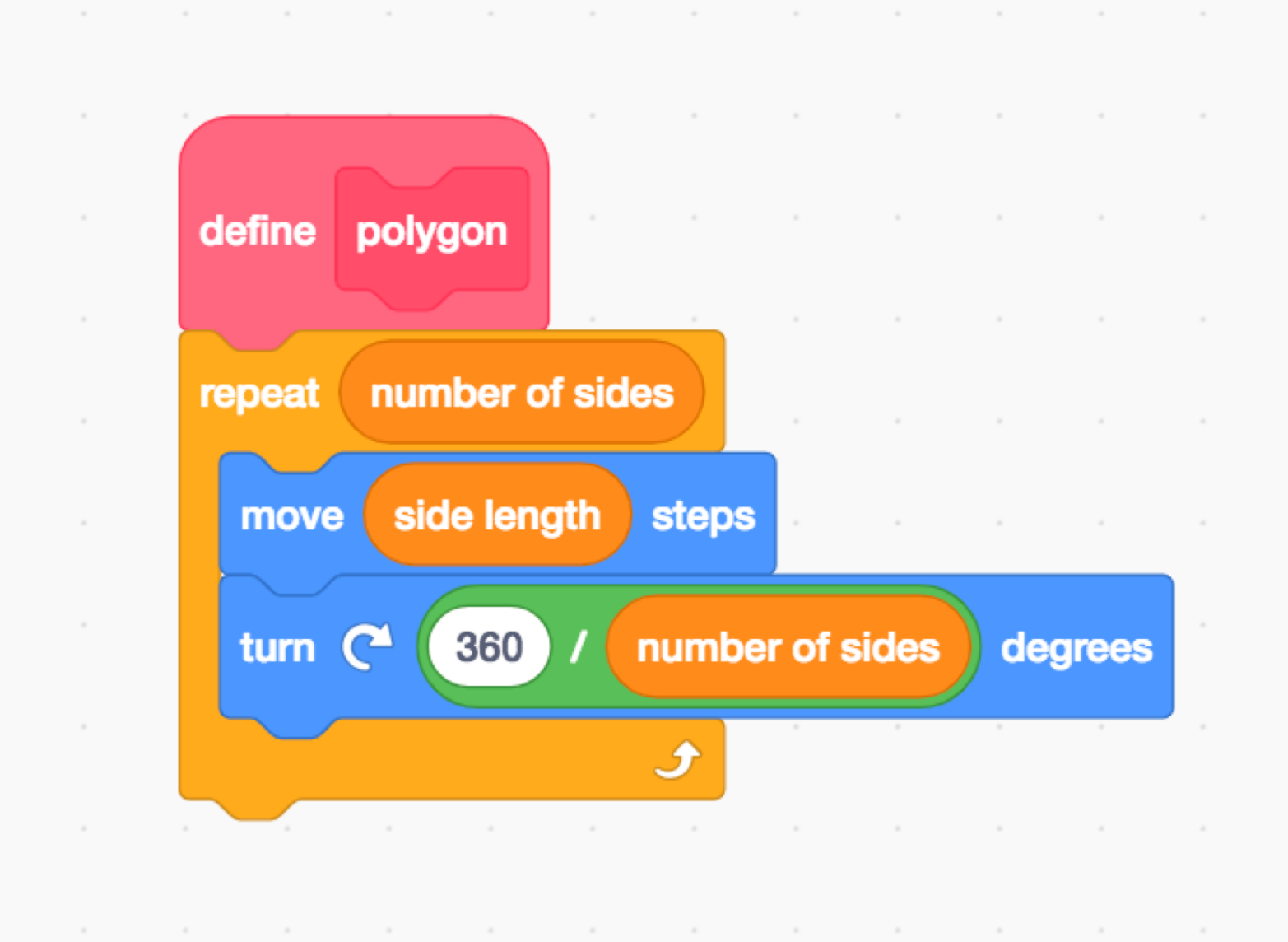


Module 1. Tiles



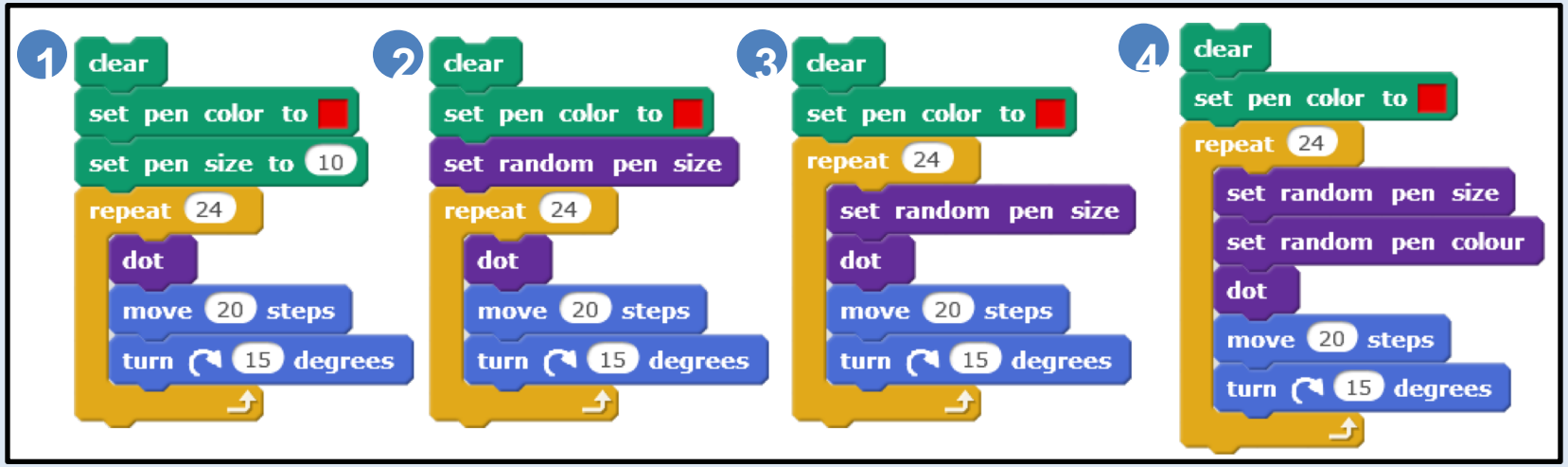
Module 2. the Beetle

A Scratch Program



Unplugged: Predictions

☐ Read each of the scripts. Draw and/or explain in words the picture that it will create.



?	?	?	?

Module 2: Investigation 3

Activity 2.3.2 – Unplugged: Picture Predictions

☐ Read each of the scripts. Draw and/or explain in words the picture that it will create.

1

```
clear
set pen color to
set pen size to 10
repeat 24
    dot
    move 20 steps
    turn 15 degrees
```

2

```
clear
set pen color to
set random pen size
repeat 24
    dot
    move 20 steps
    turn 15 degrees
```

3

```
clear
set pen color to
repeat 24
    set random pen size
    dot
    move 20 steps
    turn 15 degrees
```

4

```
clear
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    set random pen size
    set random pen colour
    dot
    move 20 steps
    turn 15 degrees
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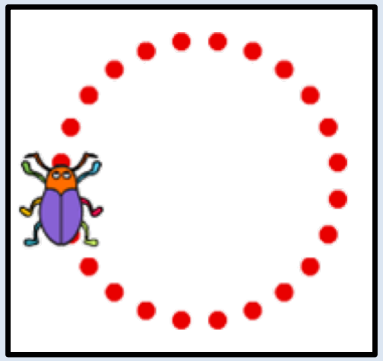

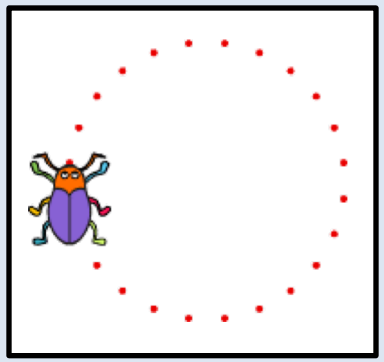

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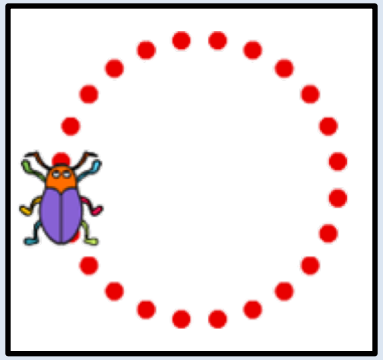
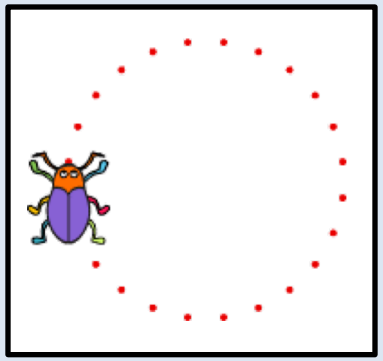
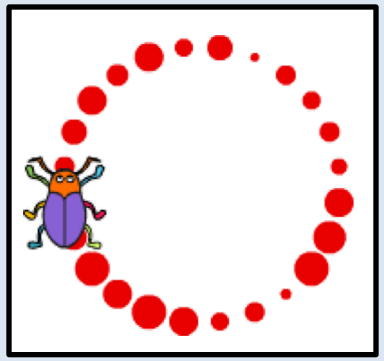
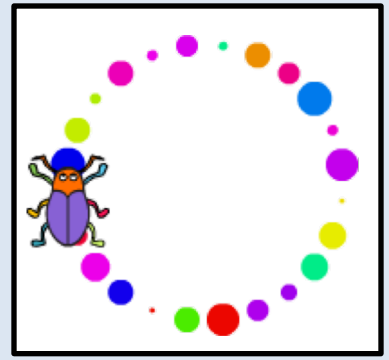








Polygon Fireworks

Three Phases of UCL ScratchMaths

Phase 1. Iterative Design

- computer tools
- materials tried with small number schools/teachers
- professional development for the teachers

Phase 2. Implementation at scale

- > 100 schools across country
- PD in regional 'hubs'
- formative evaluation

Phase 3. Summative evaluation

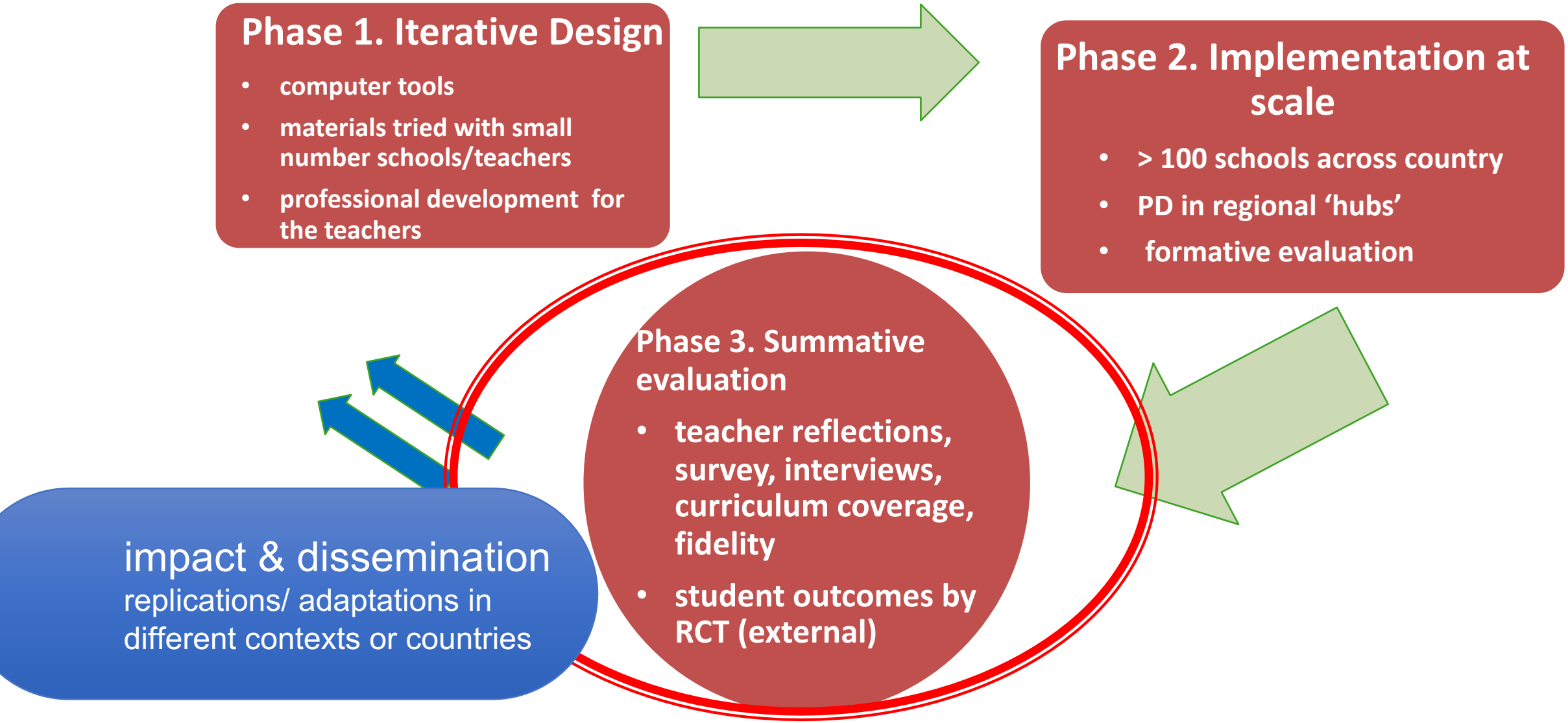
- teacher reflections, survey, interviews, curriculum coverage, fidelity
- student outcomes by RCT (external)

impact & dissemination
replications/ adaptations in different contexts or countries

Phase 2: Implementation at scale

- 7 regional hubs and local coordinators (**maths and/or computing PD leads**)
- **110** English primary schools with **2,986** students
- **PD in each region** by UCL team along with hub lead and ongoing support
- **Independent evaluator** appointed in April 2015 for Phase 3

Three Phases of UCL ScratchMaths



Phase 3: Summative evaluation

Teacher reflections

survey, interviews

fidelity: professional development, technology access, coverage, curriculum time, curriculum progression

Students outcomes (independent evaluator)

- randomised control trial methodology (RCT)

treatment and **control** groups with schools matched according to 2 standard measures

  - socio-economic status using proxy measure of eligibility for free schools meals
  - prior attainment as measured by national standardised mathematics assessment at age 8 years

- **Computational thinking test scores** for Year 5 students, test designed, administered & scores analysed by evaluator
- **National Key Stage 2 Maths test** for Year 6 students

Findings from RCT evaluation of impact of ScratchMaths

- **Positive & significant impact** on Computational Thinking skills in Yr 5
- **Particularly evident among disadvantaged pupils** ..those who had or currently have free school meals
- **No difference between girls and boys**
- **No evidence of impact on the national Key Stage 2 Maths test**

"ScratchMaths is an affordable way to cover aspects of the primary computing curriculum in maths lessons without any adverse effect on core maths outcomes"

The evaluation report can be found at

- https://educationendowmentfoundation.org.uk/projects-and-evaluation/projects/scratch-maths/

- The student and teacher materials are freely available from the UCL website http://www.ucl.ac.uk/scratchmaths (creative commons license)

Why these findings?

- **Positive & significant impact** on Y5 Computational Thinking skills
- **Particularly evident among disadvantaged pupils**
  ..those who had or currently have free school meals
- **No difference between girls and boys**
- **No evidence of impact on the national Key Stage 2 Maths test**

Fidelity

very high in Year 5 ..dramatic drop in Year 6

- ? negative impact of the high-stakes testing in mathematics at the end of Year 6

–

- Huge variation in pedagogy

  computing was new; maths is scary.
- Lethal mutations ☹
- Need to return later: 3 to 4 years …..

Three Phases of UCL ScratchMaths

UCL ScratchMaths materials upgraded to Scratch 3

number schools/teachers

- professional development for the teachers

ation at

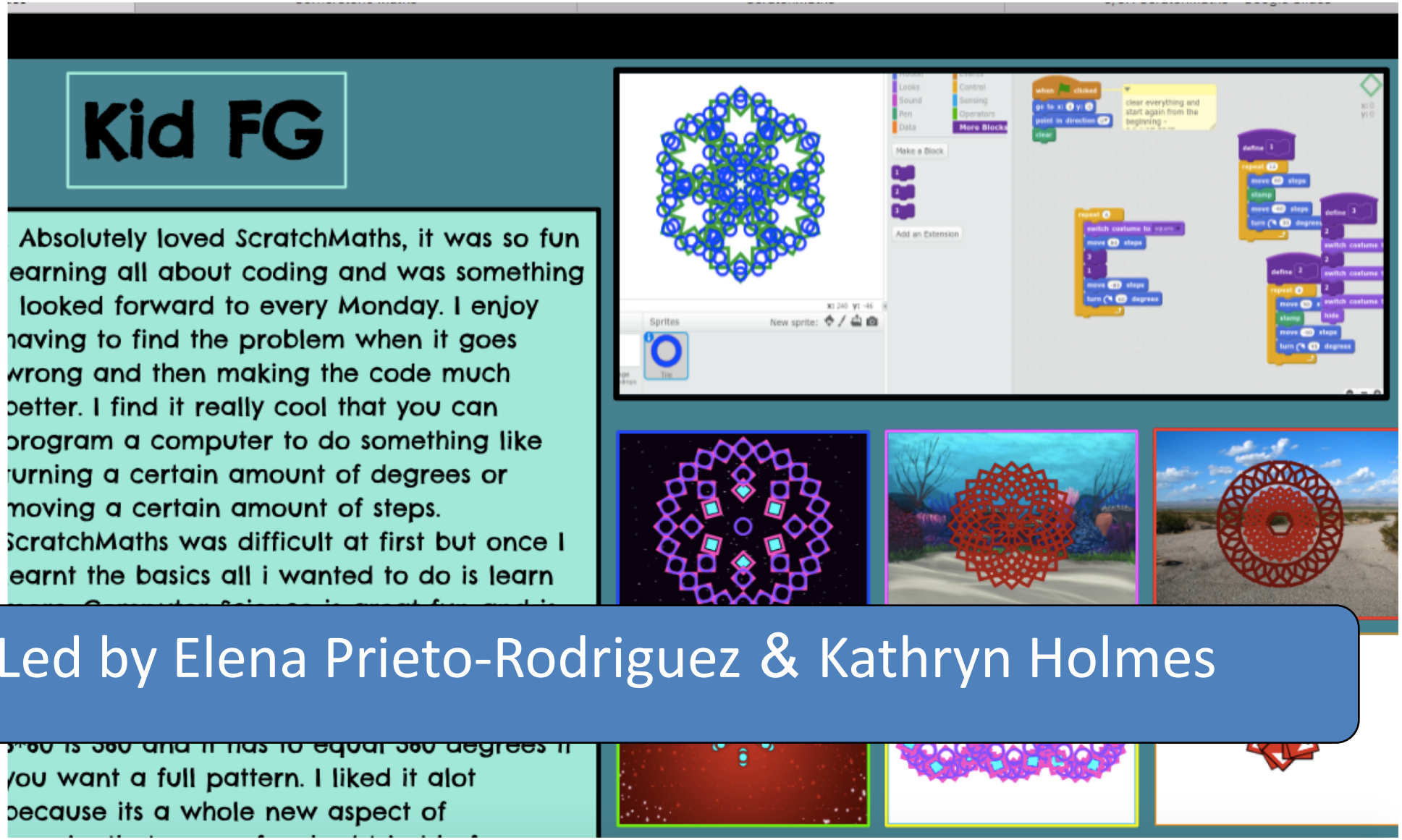
- **> 100 schools across country**
- **PD in regional 'hubs'**
- **formative evaluation**

Phase 3. Summative evaluation

- **teacher reflections, survey, interviews, curriculum coverage, fidelity**
- **student outcomes by RCT (external)**

impact & dissemination
replications/ adaptations in different contexts or countries

UCL Scratchmaths in Australia



Led by Elena Prieto-Rodriguez & Kathryn Holmes

UCL Scratchmaths in China

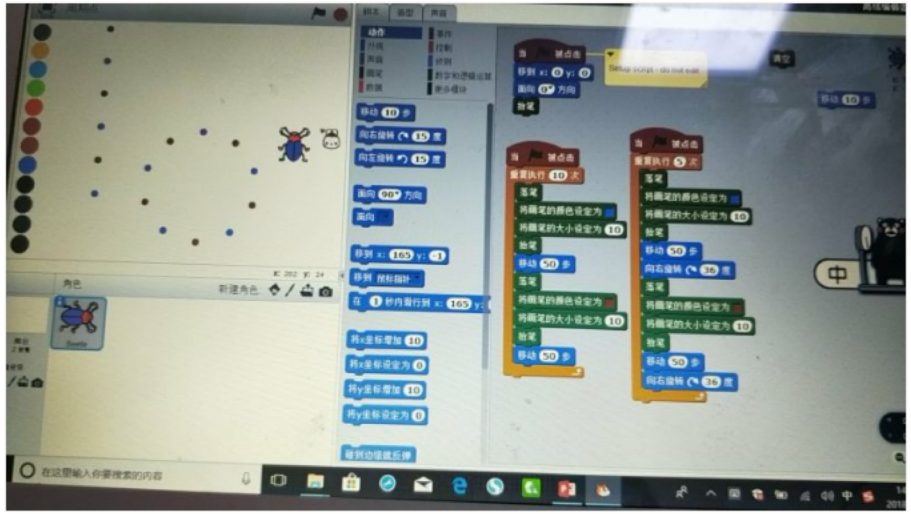
我们的小朋友们在课上都十分认真并积极地举手，想回答老师的问题哦。

现场同学们的积极参与如同炎炎夏日一样热情炽烈，给我们在场的小先生和志愿者们以最大的欣慰与满足！

Dr. Hongliang Ma, Professor in Educational Technology, Shaanxi Normal University

- designed ScratchMaths learning materials aligned to the Chinese Math Curriculum Standard for grade four students

首先呢，小先生罗沁媛先简单在计算机上画了两个图案，一个是直线，一个是圆形。



UCL Scratchmaths in Spain

- The Spanish Ministry of Education translated ScratchMaths curriculum into Spanish *and* updated the materials to Scratch 3.0.
- Implemented an online teacher training course using the SM curriculum (Dec 2018-Jan 2019) with 310 teachers across Spain taking part (about 4000 students)
- From February-May 2019 the teachers implemented the activities with their students
- Evaluated the impact computational thinking and maths skills through pre/post tests.

Final report of "Escuela de Pensamiento Computacional" (School for computational thinking) part of which concerned the impact of the Scratch maths was published in Dec 2020

Google translate says:

....

the results show that it is possible to include programming activities in 5th grade in the area of mathematics, so that students not only learn to program and engage in computational thinking, but also improve the development of their mathematical competence greater than their colleagues who have worked in this same area using other types of activities and resources not related to programming."

personal thoughts on limitations of our project

- **Assessment** of student outcomes: mathematics & computing
- **Assessment** of teacher outcomes
  - understanding of computational concepts; e.g. in Scratch: multiple sprites, parallel processes, sending & receiving messages, sensing collisions…….
  - competence & confidence in teaching them (self-efficacy)
  - **and another subject focus …?**
- **Assessment** of **actual** practices in classroom? fidelity measures, gender interactions?
- Commitment to **professional development** for teachers

Need more fine-tuned and nuanced quantitative student outcomes?

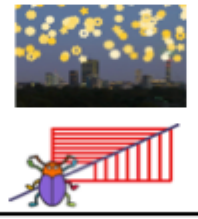
Module 1: Tiling Patterns

Module 2: Beetle Geometry

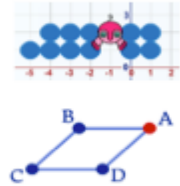
Module 3: Collaborating Sprites

Module 4: Building with Numbers

Module 5: Exploring Mathematical Relationships



Module 6: Coordinates and Geometry



All those teaching UCL ScratchMaths have engaged with the PD……
Impossible…….☹

More general reflections…

- On **pedagogy**: multiple representations
- Other **subject domains**: is there anything special about maths and computing/programming?
- **Transitions**: upwards and downwards?
- **Teacher confidence**
- **Affective** component
- **School component**…Support of senior management?
- ……

A great chance for mathematics *and* computing

"Magic in front of my eyes"

Glimpse of the classroom

case studies

Thank you