# Classroom Changemakers

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nesta

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## Acknowledgements

Thank you to the brilliant teachers and teaching assistants across the UK, who have made this programme possible and done such remarkable work during the COVID-19 pandemic to keep our young people learning.

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# Classroom Changemakers

# 1. Executive summary

**We all remember an inspirational teacher: whether it was someone who helped instil confidence in a subject where we lacked it, someone who enabled us to achieve things we once felt were impossible, or someone who went above and beyond to make lessons exciting and accessible to all. The Classroom Changemakers award programme recognises 15 of these inspirational teachers who have developed new ways to give young people the chance to get creative and solve problems in Maths and Computer Science lessons.**

With these two vital subjects still suffering from a perception by many students of being difficult and dull (according to recent research by Wellcome Trust[1]), the ideas put forward by our Classroom Changemakers show that this need not be the case. From a James Bond themed Maths day to a project on harnessing technology to solve problems in the local community, there are new and interesting ways to deliver these key subjects and allow creativity and problem-solving to flourish.

Uncovering these flashes of innovation and sharing them more widely was the original aim of the Classroom Changemakers programme, and one that we hope you agree we have achieved. However, as is often the case, events have overtaken original plans. In the context of the global Coronavirus pandemic, where teachers have gone to extraordinary lengths to keep our children learning as schools have closed their doors, the need to uncover and cultivate innovative teaching practice is greater than ever before.

Lessons uploaded onto social media platforms, novel new homework tasks and an explosion of online resources are just some of the ways that the education profession has responded to the challenge. It would be a travesty if we were to lose this creativity from teachers, as we collectively search for a 'new normal' in education. While awards such as Classroom Changemakers have a big role to play in encouraging teachers to share this creativity, we sincerely hope the past few months show the need to find more permanent ways of tapping into their ideas and knowledge.

There are always anxieties when you launch a first time programme at Nesta or anywhere else – especially one that relies on the time and commitment of a group you have not worked directly with in the past. These anxieties have proven to be entirely unfounded. It has been an unmitigated delight working with our 15 successful applicants, seeing their obvious passion for their subjects, their profession and the students they work with.

We hope that this report provokes others to adopt and adapt these ideas in their classrooms. We hope that it goes some way to showing that Maths and Computer Science can be far from 'boring' subjects. Most of all, we hope that Classroom Changemakers both illustrates how teachers are at the heart of building a better education system and offers a model for how we might go about finding and sharing their ideas on how to do so.

# Summary of recommendations that have emerged from this project

## Continuing Professional Development

To increase opportunities for learning and sharing innovative teaching practice, the government and relevant academic institutions should fund the creation of additional quality CPD networks in other subjects, based on already successful models such as Maths Hubs and the National Centre for Computing Education (NCCE).

## Teacher independence

An apparent lack of trust in teachers' expertise and capabilities stifles their ability to innovate and hampers job retention in the teaching profession.[2] While engendering this trust is a wider cultural issue, there are concrete steps that can be taken to move in the right direction which we have elaborated on in the extended recommendations section at the end of the report.

## Permanent avenues to share innovative ideas

Education charities, in conjunction with the government, should make available a rolling programme of funding to ensure that teachers can develop and scale high-potential ideas on how to improve Maths and Computer Science.

## Giving young people the tools to benefit from innovation

The government's current commitment to giving disadvantaged students internet connectivity during the COVID-19 pandemic should be made permanent in collaboration with industry and delivery partners. In a world that is increasingly digitally connected, all young people ought to be able to take advantage of innovation in education, much of which requires an internet-connected device. However, this must not be seen as an end in itself, and is complementary to other actions, such as CPD.

## Involving teachers in making a better education system

Organisations working on improving the UK's education system, including government, charities and industry, should recognise the unique role that teachers play in innovating education and improving the life outcomes of young people, and build consultation with teachers into programme creation as standard, not as an extra.

The report begins with a review of teacher innovations in Maths and Computer Science from elsewhere, and then considers how the Classroom Changemakers programme fits in. This is followed by the methodology that we used to select our 15 awardees, and profiles of their ideas, their inspiration, and how they intend to keep pushing the boundaries of their subjects. Finally, we summarise the lessons that we learned from the programme, and detail the recommendations that have emerged.

# 2. Review of research relevant to the Classroom Changemakers programme

**In this section of the report, we discuss the outcomes of a review of research into creativity and problem-solving in Mathematics and Computer Science (this is a summary of the full publication, which is available on request). The review of research, which was undertaken in late 2019 by Nesta's Research and Policy team, involved:**

- A literature review (which, after a comprehensive search, identified and then analysed more than 70 research papers and reports).
- A survey of more than 3,000 teachers (conducted by TeacherTapp).[3]
- Four in-depth teacher interviews.

After defining some key terms, here we look at the approaches to creativity and problem-solving used by Maths and Computer Science teachers, before summarising teacher views and looking at some of the barriers to adoption.

## Definition of key terms

The OECD's work[4] on creativity and critical thinking provides a useful definition of creativity. Creativity involves 'fluency (having many relevant ideas), flexibility (having many different types of relevant ideas), originality (having statistically novel ideas), and elaboration (being able to elaborate one's ideas)'. The OECD also identifies four components of the 'creative process': inquiring, imagining, doing and reflecting.

In Mathematics, creativity involves a *"process that results in unusual (novel) and/or insightful solution(s) to a given problem..., and/or the formulation of new questions and/or possibilities that allow an old problem to be regarded from a new angle."*[5] In other words, enabling students to be creative in Mathematics broadly involves the use of divergence from routine methods of problem-solving applied to familiar forms of problems.

The dominant approach to problem-solving in computing, known as computational thinking, clearly also involves creativity and divergent thinking but does not explicitly mention them. In fact, digital technologies do provide many opportunities for creative applications in education. Tools such as Arduino kits and Raspberry Pis, platforms such as BBC Mixital, and other digital making technologies (e.g. for animation, video, or games development) are associated with the development of digital creativity.

## Approaches to creativity and problem-solving in Maths and Computer Science

Across the literature, teaching for creativity and problem-solving consists mainly of student-centred approaches associated with constructivist and constructionist theories of learning. Both theories hold that children learn through interaction with the world around them, with constructionism placing emphasis on the creation of artefacts as a result of this learning. Students' active role is emphasised, and associated teaching methods are characterised by collaboration, communication, real-world problems, and a facilitating role for the teacher.[6]

Specific pedagogical methods include problem- and project-based learning, research-based learning, and expeditionary learning. These approaches are strongly linked with the development of so-called '21st-century skills' such as creativity and problem-solving.

**Maths key approaches**: There is a broad consensus in the literature as to the features of Maths learning environments that are conducive to creativity and problem-solving skills development. In particular, the research suggests that it is important for teachers to cultivate environments that are interactive, facilitating engagement and collaboration amongst students. Teaching for creativity and problem-solving in Maths is characterised by the use of rich tasks, open-ended questions, multiple-solution tasks, and complex, unfamiliar and non-routine tasks.[7]

One example is the Millennium Maths Project,[8] a Maths education and outreach initiative by the University of Cambridge, which provides resources for rich Maths education. Their NRICH[9] website provides detailed guidance on promoting rich mathematical thinking in the classroom, and the Wild Maths resource suggests lesson ideas for developing creativity in Maths.[10] Featured strategies are gamification, design challenges, and the use of simple craft materials to visualise problems.

**Computer science key approaches**: The literature on Computer Science advises achieving a balance between computer-based and 'unplugged' activities for developing creativity and computational thinking. Nesta[11] and others have argued that teaching should emphasise the thinking skills entailed in Computer Science ahead of their application.

One example involves playing and creating computer games, which can be tools for learning both creativity and problem-solving. Games such as CodeMonkey and LightBot challenge students to use programming skills to solve problems within games. Coding their own games using software such as MissionMaker[12] allows students to be creative and independent in applying their coding skills and knowledge, and to solve problems iteratively.[13] For example, UCL's Knowledge Lab led a programme for 14-year-olds in London to link the English and Computer Science curricula, with students creating games based on their reading of the poem *Beowulf*.[14]

## Teacher views

The evidence shows that teachers are broadly supportive of the idea of developing creativity and problem-solving skills in Maths and Computer Science, but that they use teaching methods associated with these skills at low rates.

In particular, 89 per cent of Maths teachers thought it was important for students to learn creativity and problem-solving in lessons, with 52 per cent saying that it was 'highly important'. Ninety-two per cent of Computer Science teachers thought that it was important, with 62 per cent saying it was 'highly important'.

There are differences according to role and context, however. Classroom teachers were more likely than headteachers to believe that learning these skills was important. Teachers in fee-paying and more affluent schools perceive their school as being more committed to emphasising creativity and problem-solving skills.

There is also a stark contrast in the types of methods and techniques used across different secondary classrooms by subject. For example, real-world problems were the most popular method among Maths teachers, with 56 per cent of teachers reporting using the method, while just 8 per cent use project-based learning (as opposed to 52 per cent of arts teachers). Computer Science teachers also use real-world problems (43 per cent), but use project-based learning much more than Maths teachers (40 per cent) Meanwhile, across all subjects, brainstorming was the most popular method used to encourage creativity and problem-solving, at an average of 50 per cent of teachers.

## Barriers to adoption

The results of the survey emphasised 'lack of time' as the greatest barrier to teaching creativity and problem-solving skills across subjects. In addition, just under a third of Maths (31 per cent) and Computer Science (32 per cent) teachers believe that there is a lack of emphasis on these skills in the curriculum, while just over a third (37 per cent) are unsure of how to teach these skills (a view that was also supported by the literature). In particular, teachers often have a lack of confidence and knowledge of how to implement more student-centred pedagogies, such as inquiry-based, project-based and discovery learning. They are also averse to dealing with uncertainty during lessons, underconfident about managing a less regimented classroom environment, and unsure about how to facilitate greater student autonomy.

Other issues raised included a lack of the time needed to make better use of project-based, interdisciplinary and makerspace approaches, and a lack of emphasis in the curriculum. In particular, research has observed that there can be a conflict between curriculum and assessment goals and the type of teaching that might lead to creativity and problem-solving skill development.[15] For example, following student propositions within a lesson presents a trade-off for classroom teachers, who are accountable for what their students learn. It was also noted that the current knowledge-based curriculum and high-stakes testing environment in England favours teacher-centred approaches such as direct instruction (especially for children with lower socioeconomic status), with more constructivist approaches seen as risky and counterproductive to curriculum and assessment goals.[16] OECD research has also found that the UK has the highest rates of learning by rote memorisation across the OECD.[17]

# 3. Methodology

**The Classroom Changemakers award programme was opened in January 2020, with an application period that ran for six weeks. We invited applications to be made via Submittable, a submission and evaluation platform.[18] The award was open to secondary school Maths and/or Computer Science teachers and teaching assistants from across the UK. Applications could be made in groups of up to four teachers. In addition to basic details on the applicant(s), we asked them to respond to the following:**

- A detailed explanation of how their idea works.
- How their idea aimed to give young people aged 11–18 the opportunity to be creative and/or solve problems in Maths and/or Computer Science.
- In what ways had their idea shown potential, and what successes have they had to date with students?
- What inspired them to design and implement their idea? Was there a need they identified which the idea was designed to address?

From over 100 teachers who submitted their ideas, a shortlist of 30 was made based on those who scored highest (out of a maximum possible score of 40) in answering the questions above. This stage of the shortlisting was completed by members of Nesta staff working in the Education team. A number of those shortlisted were asked to clarify specific details within their application via phone interview.

We then convened Maths and Computer Science panels to reduce the shortlist. Both panels contained two experts from external organisations with a deep knowledge of both education and their chosen subject. We provided these panellists with our initial scoring and comments and asked them to evaluate the ideas and provide their comments. After a discussion, we asked for their opinion on whether each idea ought to be one of the 15 finalists or not, or if they were unable to come to a definite conclusion.

At the end of the panel stage, we were left with 18 applications still in contention for only 15 awards. Consequently, we convened a further meeting involving Nesta staff in the Education team to decide upon the 15 most promising, based on the initial scoring, the comments of our panellists and our own personal evaluation.

# 4. Our 15 Classroom Changemakers

## Clarissa Grandi: Artful Maths

### Thurston Community College, Bury Saint Edmunds

Clarissa Grandi is the creator of a set of fully resourced Maths lessons that seek to combine mathematical and artistic elements. The lessons involve creating 'mathematical art' or geometric patterns using pencils, pens, rulers and sometimes compasses. Initially devised for her students at Thurston Community College in Suffolk, the classes are now publicly available online at www.artfulMaths.com[19] (which Clarissa set up in 2016, using her own resources).

The lessons provide accessible mathematical art activities for all students: *"You don't need to be able to draw, or be "good at art" to be able to produce stunning geometric patterns. You simply need to be able to count, to follow instructions carefully and use a pencil and ruler accurately"*, says Clarissa.

*"The aesthetic considerations involved in drawing the patterns entail a particular form of visual problem-solving that is essentially mathematical in nature"*, she says. The drawing of snowflakes, for instance, requires students to use basic construction skills and reflective symmetry using tracing paper, while the drawing of impossible objects reinforces the need for accurate measuring and attention to detail. This is particularly important given that questions involving geometry or measurement are those most often left unattempted in GCSE Mathematics exams.

A lot of creative thinking also comes into play with decisions about how to arrange, repeat or tile patterns, and how to use colour to enhance the symmetry and tessellation of completed designs. *"That mathematics can be visual and colourful and beautiful is a revelation to many"*, says Clarissa. Designs include mandalas, Celtic knotwork, cardioids and patchwork paper patterns.

The lessons have been a huge success. Clarissa doesn't know the exact number of students who have benefited from her classes online, but speculates that it must be in the many thousands, judging *"from the photographs of students"* work that have been shared on Twitter, and the *"feedback I have had from teachers across the world"*, she says.

Clarissa hopes that through the Classroom Changemakers programme and her award, she can promote Artful Maths further and expand its impact to other children all around the UK. We would again encourage you to take a look at her brilliant work online at www.artfulMaths.com

# Tina Götschi: Collaborating with Industry

## Ada, the National College for Digital Skills, London

Tina Götschi is Vice Principal and Head of Computing at Ada, the National College for Digital Skills. Three times a year, she and a cohort of 15 other staff members run a series of team-based projects for later year students in Maths, Computing and Graphic Design classes. Each project is led by an industry partner who provides guidance and training. So far, the school has worked with volunteers from companies such as Salesforce, Deloitte and Bank of America. The programme is particularly innovative in that it involves close collaboration between the industry partner, the students, and the school.


A recent project gave students the opportunity to use data about their home city of London to identify a pressing social, health or environmental problem. Students then supported their findings with rigorous analysis of the data using programs such as Excel and Python in Jupyter notebooks. *"We use these projects to develop the creative problem-solving skills that our students will need to be work-ready and to give them opportunities to network with industry experts who may be their future boss"*, says Tina.

The programme's aim is to redress the disconnect between education and industry. Currently, many students leave school without a clear understanding of what the world of work is like and what jobs in the digital sector are available to them. This reflects a wider problem of students not realising the exciting roles on offer if they take computing courses, as well as a general underestimation of how creative and collaborative these jobs generally are.[20]

Tina's programme gives students opportunities to develop soft skills like communication and collaboration, and to use technology to solve problems in creative ways. So far the results have been promising. *"Our students use these experiences when writing personal statements for university applications or when being interviewed for apprenticeships"*, she says. Ada is now working with Deloitte to bring the programme online due to the school closures made necessary by the pandemic, which will help to spread its benefits further.

Once schools reopen fully, Tina hopes to continue working with Nesta to expose students to the world of innovation and beyond. If any teachers are considering sharing a new idea further, Tina says, *"Just do it. Don't be scared of doing it and don't worry if it is rubbish at first!"*

# Domingo Garcia: Maths in Real-Life Situations

## Shaftesbury High School, Harrow

Domingo Garcia is a Maths teacher at a special needs school who runs curriculum enrichment mini-projects that incorporate real-life situations alongside more traditional Maths modules. Every half term, Domingo runs workshops for students in years 8 to 11 in which the students use and apply Maths to real-life situations such as running a cafe, budgeting, and shopping for items in supermarkets and department stores. These classes *"enable our students to gain an appreciation of money and its value"*, says Domingo.

The programme is particularly innovative in that it involves using multiple scenarios that are cross-curriculum – involving subjects as diverse as PE, ICT and Geography, and activities such as completing online forms and participating in interviews – all to teach Maths.

Domingo is pleased his work is being recognised. The Classroom Changemakers award *"validates the promising progress we have seen in student achievement, attendance and behaviour"*, he says.

Because Shaftesbury High is a school for students with additional needs, which caters for over 150 pupils, classes are planned thoroughly to ensure inclusion of the range of learning difficulties and needs. In a class about personal finance, for instance, some students might engage in the simple recognition of coins and use money in class-based shopping activities.

Others might apply and use their knowledge to set up and run a 'Shaftesbury Starbucks'. *"Our ideas are based on developing the skills and aptitudes that will help our young people become independent and valued members of the community and carve a pathway to employment"*, says Domingo. This is particularly relevant given the rate of employment for young people with special needs, which is currently only 6 per cent.

The classes also help students develop 21st-century skills like creativity, critical thinking, communication, and collaboration. The overall goal is to provide students with the confidence to engage and actively participate in their community and wider society.

The award will be used to extend the programme, such as buying some Raspberry Pi micro-computers. Domingo is also keen to embed the programme more widely across the school, and to develop other scenarios that involve other real-world situations. Above all, it's important that students are given opportunities to learn things for which they can see a real personal benefit; the classes are for this reason aimed at pushing students into the 21st century and into the world of work: *"Our idea is to incorporate enterprise-focused learning', says Domingo. On encouraging other teachers with bright ideas to share them,"* he says, *"Be brave. Everything is new and strange but just try it and you conquer the fear. Ultimately, the students will benefit from it."*

# Peter Dring: KPRIDE (Keywords, Predict, Run, Investigate and Debug)

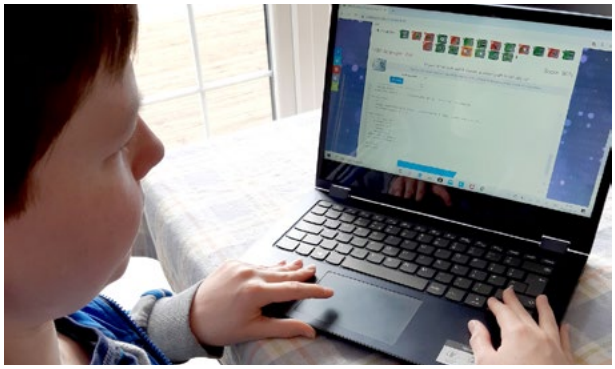
## Fulford School, York

Having been a teacher for 11 years, Pete Dring is currently Head of Computing at Fulford School. He developed a programming pedagogical framework aimed at mixed ability students in years 7–11 called KPRIDE (Keywords, Predict, Run, Investigate, Debug, Extend). He believes that using creativity and problem-solving in computing breaks down stereotypes because it enables individuals to realise that they can use a concept to make something that is their own.

Pete became inspired to innovate how he taught programming to young people when he volunteered to run a Python training course for teachers as part of the National Centre for Computing Education. Subsequently, he critiqued and adapted the course's coursework and scoured the latest research into programming pedagogy and how it could be harnessed to boost the confidence and competence of students learning to code.

York has a relatively low percentage of pupils disadvantaged by the system but it does have pockets of significant deprivation. Many students can access home learning resources but that doesn't mean that they have the time, support or equipment to be able to print those resources, complete them, or submit them. Almost all students will say they have access to the internet in some form but students who are disadvantaged by the system are more likely to suffer from slow or unreliable broadband speeds or data limits or they will have to share a device with parents or siblings. As a result, Pete has made a concerted effort to ensure that resources for KPRIDE are easily accessible.

The KPRIDE framework that Pete devised enables students to unleash their creativity in a structured way. It involves students predicting what a piece of code might do, extending the code with their own ideas, investigating intriguing lines, and debugging. This gives students the confidence and competencies to solve problems with code, without worrying too early about the details, and then to tackle open-ended programming challenges.



Perhaps the best evidence of the success of Pete's idea is the testament of his students, who said about using the KPRIDE Framework: *"It is fun and educational, making coding easy for everyone. It gives me something to do in my free time and I enjoy it. The lessons are fun and you also learn at the same time."*

Pete intends to use the Classroom Changemakers award to create tools to allow students to compete in coding contests with a weekly prize on offer. He hopes this will bring a sense of community and excitement among students and teachers. He has also conducted further research into the ways that students have accessed home learning resources since schools closed, with a view to using some of the prize money to purchase Raspberry Pi desktop kits or laptops for families that would benefit from them the most.[21]

# Andy Jones: Creative Project Work in Computing With Girls

## Sacred Heart High School, London

Andy Jones is a new Head of Department at an all-girls state school in central London. Teaching in this environment motivated him to better promote the idea that computing can be a subject for all, despite the fact that it often suffers from some of the most gender imbalanced classes in the UK. As a result, his idea, 'Creative Project Work in Computing With Girls' aims to widen access to computing as a subject and to encourage students to share their views, generate new ideas and enjoy the myriad creative aspects of the subject.

Computing With Girls engages students in real-world issues and uses insights from other subjects often perceived as more exciting such as the creative arts and drama to help students better understand that computing is not a dry subject.

Andy has been redeveloping the department curriculum, since he became an NQT in 2018, to make it more varied. He says that *"It is very important to think outside the box and creatively in the classroom"*, with *"the curriculum not always encouraging creativity as it could do."* The success of this approach is shown by the fact that within the first year of his redevelopment of the curriculum, uptake of computing at GCSE increased by 60 per cent, to the school's biggest ever cohort. In total, the new curriculum is reaching over 400 students aged 11–16 and involves new units of work such as programming and creative design.

Examples of projects Andy has delivered through his idea are using the story of Bletchley Park and the cracking of the German Enigma code during World War Two as a way to teach about encryption and data. Another is getting students to create a Christmas karaoke machine using JavaScript to help teach coding.

He had not anticipated receiving one of the Classroom Changemaker awards, so was hugely excited, saying that it was a nice feeling to be recognised *"especially for the students because they have been so creative, engaging, and have worked so hard."*

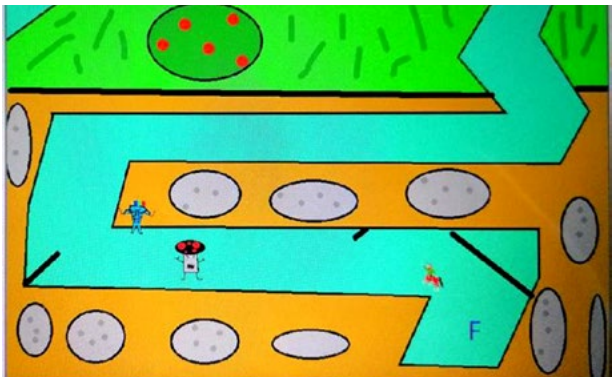
Andy says that 'young people love to be creative and always find ways to be creative The more creative you are, the more learning naturally happens'. He hopes that his example shows that letting students get creative can encourage a greater and more diverse number of students to take computing in the future.

He hopes to use some of the award to get some space to teach BTEC in IT, or to purchase equipment for disadvantaged students so that they can have the necessary tools to learn. Have a look at an app created by some of his students at: www.year10computing.co.uk

# Bryan Irvine: Games Development

## Biggar High School, Lanarkshire, Scotland

Bryan Irvine is a Computer Science teacher at Biggar High School who has created an idea called 'Games Development'. This is *"a project that was originally developed by me to teach software development to first-year students"*, he says. The goal of this project is to engage learners in creative problem-solving, along with giving learners at all ability levels the chance to engage with the creative development process and achieve success through ownership of their own projects and challenges.




This idea taps into the enormous interest in games development among young people. As opposed to some career options within computing, games development is seen as an exciting industry where creativity and technical problem-solving skills are used. Consequently, Bryan believes it is an ideal way to teach these vital skills in an engaging way.

One of Bryan's favourite aspects of his 'Game Development' idea is that it has helped to engage more girls in taking a subject that is disappointingly male dominated. *"Creativity and problem-solving are essential 21st-century skills for all learners,"* he says, *"but these sorts of skills certainly seem to attract a more diverse range of students and are worth encouraging as a result."*

Bryan believes that there are thousands of amazing teachers around the UK who are delivering innovative work like this, and that we need to do more to encourage them to share their ideas. He hopes that one positive thing to come out of the school closures, caused by the COVID-19 pandemic, will be that schools will use more digital technologies, which will also help spread the innovative projects.

The response to 'Games Development' has been overwhelmingly positive.

'[Through "Games Development"]. I learned that to solve my problems I have to take them one step at a time, and we learned to overcome the difficult challenges of coding and debugging games.'

**Biggar High School student**

# Jessica Barnecutt: The Mathematics of Migration

## Oaklands School, Bethnal Green, London

Jessica Barnecutt, Assistant Headteacher and Mathematics teacher at Oaklands School, has developed an idea she calls 'The Mathematics of Migration'. It is a five-hour unit of work that uses a real data set from one of Europe's largest academic research projects, MEDMIG, along with a powerful visual story, to help pupils critically engage with the realities of migration — through Maths.

When she started to teach the new A-level statistics course, Jessica and her team discovered that their students often couldn't use spreadsheets like Microsoft Excel. She therefore decided to challenge students to learn how to use Excel through big data on migration, which would also encourage them to critically interpret data.

The project allows students to develop their own line of inquiry from the data. Jessica encourages students to identify questions they are interested in (questions like 'what were the education levels of the people who migrated?') and then to find answers in the data, which are then presented in a poster.

The project has had some real successes, with evaluations showing that students' understanding of statistical techniques and use of spreadsheets has improved dramatically. In addition, student engagement in the lessons has been high.

Jessica is delighted to have received a Classroom Changemaker award and believes that it is a great way to promote the brilliant work that teachers are doing behind the scenes. She intends to use the award to promote and share her idea further, possibly by producing a video about its success. Since school closures began, she has run multiple webinars with other teachers to show them her idea. The aim is to turn it into a multi-subject project which will foster a smoother transition for students from primary into secondary school.

# Mari Chikvaidze: Maths to Make Biological Molecules Come Alive

## Claremont High School, Harrow

Dr Mari Chikvaidze was selected as one of the Classroom Changemakers Award finalists for developing 'Using Computing and Mathematics to Make Biological Molecules Come Alive'. This idea is an innovative combination of Maths, computing and biology.

Mari, who teaches Maths at Claremont High School Academy, has developed an innovative way to teach the complexities of biological molecules through a 3D, computer generated, world – and without having to conduct the physical experiments that are impossible in a classroom setting. She based the idea on her PhD research, and has previously used a similar approach, employing real-world problems and technology, to teach the natural sciences.

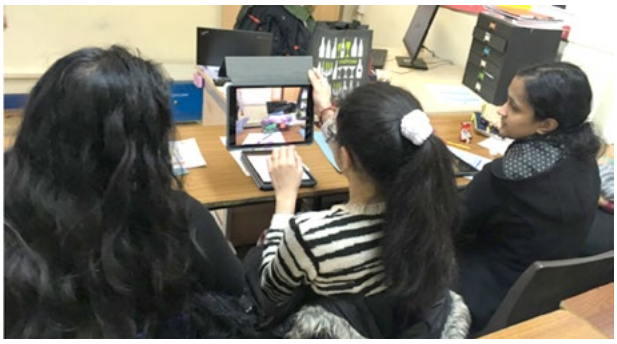
One example of her idea in practice is the use of Augmented Reality to move and rotate molecules 'in the air' until their 3D structures fit together. The task of matching the virtual 3D models helps students uncover the main concepts of computational drug design, which are otherwise very difficult to grasp. The aim is to 'help students understand the relationship of a biological molecule and its biological function'. In addition, there is a lot of overlap with A-level applied Mathematics, due to the equations that are necessary to run molecular dynamics computer simulations.

Much of the inspiration behind Mari's work is the need to break down subject boundaries within STEM. 'The curriculum does not explain the link between Maths, Biology and Computer Science, which creates a gap in the education system', she says. *"This separation does not reflect life in the 21st century."*

Originally from Georgia, Mari was a teacher in her home country before moving to the UK. She is planning to use the award to buy some iPads that students who are disadvantaged by the system can borrow to keep up with their homework.

'Computing and Mathematics to Make Biological Molecules Come Alive' has received a positive response from many students: *"[It] has exposed me to the importance and intricacy of drug design using computational methods. We had the opportunity to use iPads in order to easily manipulate biological molecules. I've loved using new software and equipment to develop my understanding of drugs and molecules and put into perspective – with the iPads – the complexity of their structures."*

Claremont High School Academy students using the Augmented Reality app on iPads to make penicillin-binding protein 'come alive'.



# Subashini Suganthakumaran: Problems Set by Professionals

## Hammersmith Academy, London

Subashini Suganthakumaran, a Key Stage 3 Coordinator and teacher of Mathematics at Hammersmith Academy, developed an idea she calls 'Problems Set by Professionals' which encourages problem-solving in real-world work situations.

She works with professionals to identify Maths problems that they have come across in their work, and then encourages students to tackle the problems using skills that they have learned in lessons, while applying general problem-solving skills. The students are then given the opportunity to feed back to the professional who set the problem. Through these tasks, students are able to see how relevant the topics they are studying are to the real world, by using seemingly abstract skills in a concrete way.

Subashini says that the *"creativity comes from the fact that students realise that they already have skills that are needed in the workplace"* and that this helps build confidence. A consistent theme in the response of students has been enjoying being able to see how what they learn translates into reality.

Following her award, Subashini intends to set up a platform for students to communicate and share their ideas online. It is hoped that it will be an impactful way to communicate, engage and allow students to share their ideas. She believes that teachers clubbing together, both in the context of COVID-19 and when developing new ideas, is really important. Having a cheerleader who supports you as a teacher and an avenue to test ideas and get advice will allow the idea to flourish.

'Some people find it difficult to close the gap between what they learn in school and skills that will help them after finishing school. They are left with a mass of background knowledge but no way to apply it. They also are really good for motivating and intriguing students. Often in the classroom you hear the phrase; "but miss [or sir] how is this going to help me in real life?" These types of questions are a direct answer and allow students to understand how important Maths is in our modern world.'

**Hammersmith Academy student.**

# Michael Jones: If a Machine Can Think, What Should it Think For Us?

## Northfleet Technology College, Kent

Michael Jones, who currently teaches Computer Science, developed an approach he calls 'If a Machine Can Think, What Should it Think For us?' The idea aims to provide students with the opportunity to develop applied Computer Science skills, using affordable hardware and a range of industry-standard machine learning algorithms. In particular, young people are tasked with solving a range of societal problems by using Artificial Intelligence techniques.

As part of this project, students have used image and text recognition tools, to create systems that are able to recognise strangers from known individuals, identify medication, and interpret advanced instructions and inputs. Students have been able to train systems to recognise facial expressions, shapes and gestures. This success has spurred the students on, in the knowledge that they are able to influence what technology does.

Michael started his idea with a group of 20 Year 8, mixed ability students, when he introduced them to artificial intelligence and machine learning. For one lesson per week, students have been exploring machine learning, programming simple systems using the Scratch[22] programming environment and Jetson Nano[23] development hardware. This has enabled the students to experience what it is like to be a creator of artificial intelligence, rather than to just act as passive recipients of the technology.

Michael says that a key reason to highlight the links between Computer Science and AI is that he is *"worried because Computer Science is already a subject that has a male-centred bias."* However, the current way that jobs are recruited in Computer Science is not likely to lead to a diverse workforce. He says, *"we are in danger of making Computer Science a male-centred and nerdy subject"*, and that we consequently *"must make the subject interesting enough to attract all young people."* Key to doing this is highlighting creativity within Computer Science.

The Classroom Changemakers Award has encouraged Michael to develop more ideas. He also mentioned that the incentive has given his students a lot of confidence because, if they had not put such effort into the idea, their school wouldn't have been recognised in this way.

# Amy Large: Whole School Maths Days

## Millgate School, Leicester

Amy Large, a Maths teacher, developed 'Whole School Maths Days', which, as the name suggests, gives students across the entire school the chance to see Maths in new and exciting ways through themed events.

The days are designed to enable students to see real-life applications of Maths, such as the mathematics principles used in the James Bond film *Casino Royale*, or in the work of Martin Krzywinski in 'Art on 'Pi' day. Each class is timetabled to visit in turn all of the school departments, which each offer a cross-curricular workshop aligned to the theme.

In the *Casino Royale* day, for example, subject leads in English and Catering together offered a workshop that integrated their subject with Maths and James Bond. In one workshop, students explored probabilities using poker and blackjack!

Amy says *"the levels of engagement and enjoyment of all students across all the workshops was astounding, resulting in no behavioural incidents at all on the day. As a SEMH special needs school, this is a rare and key marker of success."*

Amy hopes to build on the whole school event theme to raise the profile of Maths, targeting all students and helping them enjoy it as a subject. An opportunity to see Maths in a creative, different and applied context enables students to engage in a way that they had not done previously. *"Now that the framework is in place for these themed days and the model shown to be a good one, Maths themed days at Millgate have the potential to expand and continue throughout the years"*, she says.

Plans were already in place for a Maths Olympics in the summer of 2020, but this was postponed because of the pandemic. Amy is eagerly awaiting the opportunity to get back in the classroom as her students, many of whom have additional needs, have been disproportionately affected by the school closures. The past months without face-to-face lessons have been a huge barrier for her students, especially as many are not from families who are digitally literate. She hopes that, once the crisis is over, she will be able to spend the Classroom Changemakers award on taking her students to Germany, to visit an interactive Maths museum.

'It was awesome. The casino was great – I won lots of pretend money and it has helped me when I go to the shops to work out how much change I should get. It made my adding quicker when we played cards. I like doing learning like this.'

**Millgate School student.**

# Edward Vine: Integrated STEaMplus

## Hockerill Anglo-European College, Hertfordshire

Edward Vine, STEaMplus Coordinator at Hockerill Anglo-European College, and his colleagues created 'Project-based integrated STEaMplus, Flight, Space Mission X', which they have now been running since 2012.

The project is based on three themes: flight, space and polar exploration. It works on the basis that students work both individually and in teams across the STEAM subject boundaries. Each project incorporates an element where students consider the impact of the technology on humankind. Projects are delivered as both lessons within the normal timetabled curriculum and on special enrichment days.

The project also links with the science and DT departments at the school and gives an opportunity for students to work with others in different year groups. This allows older students to develop their leadership skills as they themselves learn. The project also enables students to work in a competition setting and to learn how to iteratively modify their designs in the light of testing in a virtual environment. They gather data and do experimental work and analysis which inform design decisions. This also encourages creative problem-solving behaviour. The success of this approach can be measured both by the results and by the enthusiasm and positive feedback from the students.

Edward says about his work that *"students are more committed when they have invested in a project and have ownership: they are more dedicated and are more prepared to tackle the Maths and work to support their own project and that of their team."*

Thanks to the award, the school will be buying some additional equipment to enrich student learning. Edward also intends to expand the model further by setting up hubs across the country that would promote this interdisciplinary approach to learning and creativity.

# Janice Osbourne: Computer Science Mentorship

## The Charter School, North Dulwich

Janice Osbourne runs a mentoring programme at her school in North Dulwich that seeks to empower and support students studying Computer Science.

Mentors are selected based on their performance in class and on results from tests such as the Bebras Computing Challenge.[24] Over the course of six weeks, mentors meet with mentees for one-hour sessions in which they work through a set of programming challenges.

In order to become a mentor, students must attend a 45-minute training session in which they learn about power imbalances and skills for listening and questioning effectively. The programme is beneficial to both mentors and mentees: mentors say that they have increased their own problem-solving and communication skills, as they need to find creative ways to make their ideas clear, while mentees have reported that they feel more confident in applying programming knowledge to different tasks.

Janice says: *"Most computer programmers do not work in isolation and many students panic when they are unable to solve a problem so become less willing to explore or make mistakes. This programme allows them to be vulnerable within a supportive setting with someone in their age group who they are confident with."*

This dedication to building confidence is a theme that runs across Janice's mentorship programme. One of the inspirations behind her idea was the realisation that many of the more confident students in her classes were becoming better and better, while those with less confidence were going in the opposite direction. Setting up a programme where students at the top of the class shared their knowledge and helped build the confidence of others as a result benefited everyone. Janice is particularly proud of the success of her work in helping SEND students to develop leadership skills.

Janice is particularly keen to use the Classroom Changemaker award to help disadvantaged students at her school. She is hoping to introduce additional courses on digital literacy aimed at those who might not be taking Computer Science as an optional subject but who would really benefit from gaining the sort of basic digital skills that are so important for today's jobs.

# Marc Matthews: How Can Technology Improve Your Local Community?

## West Exe School, Exeter

Marc Matthews, Computer Science teacher at West Exe School, developed an idea called 'How Can Technology Improve Your Local Community?' This aims to use Computer Science to help solve problems in the local community, at the same time allowing students to develop soft skills like project management and public speaking.

The idea involves students identifying everyday problems in the local community that could be solved by a mobile app. This then involves a rich range of activities, including brainstorming a real-life problem that could be solved by using an app, agreeing on an idea as a team, identifying the app features that would be most beneficial to potential users, designing and prototyping an app, and pitching an idea.

The programme fills a gap in Computer Science teaching. *"I identified that there is no scope for project-based research in the Computer Science curriculum"*, says Marc. *"It has shown great potential to build student teamwork, communication, presentation, research and design thinking skills."*

Some of the student app ideas have already shown great promise, with winning projects ranging from assisting tourists to reducing knife crime. Marc says, *"it is important to show students what kind of technology is accessible out there and how we can be creative with it. Computer science has a lot of content but can be quite boring as a subject. Therefore, making it creative enables the students to engage and develop their creativity skills."*

This combination of creativity, problem-solving and illustrating how Computer Science and Maths skills can tackle problems on a local or national scale goes to the heart of the Classroom Changemakers programme. Marc hopes to spend his award on resources for Year 9 and Year 10 to support GCSE revision. He would also like to introduce virtual reality equipment to students as well as artificial intelligence to make the learning experience in his classroom even richer.

# John Healy: Income Support in a Micro Society

## Oakland School, Bethnal Green

John Healey, a Mathematics teacher at Oakland School, developed 'Income Support in a Micro Society', a project designed to help students employ their problem-solving skills in the environment of a created society.

John's idea involves students creating a virtual micro-society of 24 families, each with complete profiles detailing family structure, living conditions, incomes and expenditures. Students are then tasked with creating a policy to distribute income support benefits. They must create a clear, precise mathematical model for distributing benefits, and engage with issues of fairness, inequality and efficiency to solve the problem.

'The project is informed by research demonstrating the significant impact that project-based learning has on students' attitudes towards mathematics, their mathematical literacy and their long-term retention of knowledge. Perhaps most importantly, projects such as these develop students' problem-solving skills.'

**John Healy**

In addition, 'Income Support in a Micro Society' encourages creativity and helps address subject matter that is partially missed in the curriculum. Students must be creative in their design of the problem and in their solution. Additionally, the project allows students to handle and create data in critical ways, the opportunities for which are often sparse.

On what made him want to develop his idea, John says, *"I was inspired to create this project by an article I read. The article promoted the view that a Mathematics education should teach students how to engage with the world with a critical and creative perspective. Students are faced with a large amount of raw data lacking any context, for instance annual incomes and tax rates. In order for this data to inform, they need to contextualise it by comparing it with data on median incomes and essential expenditures, for example."*

To encourage teachers to share their ideas, John says, *"Look around, find examples, there is so much great stuff out there to learn from, work with people in your school or other organisation and especially be collaborative."*

# 5. Reflections on the Classroom Changemakers programmes

**The quality of ideas from our 15 finalists and the high number of excellent applications that we were unable to award has shown that there is a great pool of knowledge, expertise and creativity to draw on within the teaching profession. Despite specifically focusing narrowly on Maths and Computer Science at a secondary level, we received over 100 applicants over a short period of time, which also highlights the appetite there is for teachers to share their innovations if given the chance to.**

For the Nesta team, the most rewarding part of the Classroom Changemakers programme has undoubtedly been speaking directly with the successful applicants: in particular, having in-depth conversations with them about their ideas, and a more general chat about what motivated and still motivates them to teach. The fact that most of these interviews took place in a context of school closures due to COVID-19 also allowed us an opportunity to see up close how teachers were responding to a difficult and often ambiguous situation, which required teacher resourcefulness and novel ideas to ensure their students kept learning.

Amy Large: Whole School Maths Days. Millgate School, Leicester

Tina Götschi: Collaborating with Industry. Ada, the National College for Digital Skills, London

Below we identify a number of conclusions from the conversations with the 15 successful applicants, in addition to other conversations with teachers during the application period.

- All 15 finalists said they would develop their idea further as a result of their award.
- All of the finalists believed that additional incentives to sharing teacher innovation, whether that be through awards programmes such as Classroom Changemakers or wider structural change in perception of the role of teachers, was important.
- All agreed that awards like these helped to motivate them to develop additional new ideas in the future.
- Several mentioned that they did not feel the UK education system offered a culture which encouraged teachers innovating.
- Many felt that much of the innovation in education is now predicated on technology and that more work needed to be done to ensure all students, particularly those from disadvantaged backgrounds, were able to take advantage of these innovations. The effect of homeschooling during school closures only magnified this issue.
- Almost all the teachers we spoke to went into teaching with the desire to share knowledge and empower students as key motivators. While retaining this desire, a number have felt disappointed by their inability to do this in practice due to the regimentation of the way in which they have to teach.

# 6. Recommendations from the Classroom Changemakers programmes

## CPD available for all

Certain subjects have excellent CPD networks where good practice and new ideas can be shared, critiqued and improved. However, this is not uniform across the UK's education system, either in terms of subject or geographic location. For example, the Computing at Schools (CAS) Network for IT and Computer Science teachers managed to successfully create communities across the UK with minimal resources and, at its core, a small number of highly enthusiastic teachers.[25, 26] Its success is illustrated by the fact that the government based much of the model of the NCCE on it.[27] A somewhat similar CPD network for Maths is available through nationwide Maths Hubs.[28]

These sorts of networks are not, however, ubiquitous. Other STEM subjects such as Physics do not have an obvious equivalent, and even within existing structures like CAS and Maths Hubs, there is a definite regional disparity, with the most active hubs mainly in the South-East and other more populous areas.[29]

We recommend that support is made available through government funding to create CPD networks for a wider range of subjects, with priority being given to those like Physics that suffer from a shortage of teachers. This would have the dual effect of providing support and learning opportunities for teachers in the mould of the NCCE, while giving a designated avenue to diffuse ideas and innovative practice with other members of the profession.

## More independence for teachers

The high-stakes nature of the UK's education system, with a focus on preparing children for exams and imparting core knowledge, does not leave a great deal of room for teachers to experiment in how they teach.[30] The spectre of Ofsted inspections in the background fuels this problem further. Andreas Schleicher (Director for Education and Skills at the OECD) described the UK as having a cultural 'mistrust of teachers' and their skills.[31]

While, from the perspective of policymakers, such a system is understandable, it is not one which incentivises teachers to be creative in how they deliver learning or to share their ideas. High teacher workload, in part caused by the administration necessary to uphold such a system, only compounds the problem, with 84 per cent of teachers saying in a National Education Union survey[32] that their workload was 'sometimes' or 'never' manageable.

To get the best from teachers and consequently get the best results for students, there needs to be a stronger sense of trust that teachers know

what they are doing and allowing them to do it. While this will only fully happen i if there is a cultural shift away from the existing system, there are a number of immediate steps that could be taken including:

- Scrapping of no-notice Ofsted inspections championed by the government before the last election.[33]
- The Education Select Committee should launch an inquiry into teacher workload, its causes and how to address it.
- The Department for Education should act upon the findings of their 2018 study into teacher retention with reference to the sections looking at teacher independence and creativity.[34]

## Permanent structures to share innovation

One of the issues mentioned repeatedly in discussions with our Classroom Changemakers was the lack of avenues to promote, develop and share their innovations. The avenues that are available tend to be regional or time-limited, though potentially good models to grow. The London Teacher Innovation Fund,[35] a competition rewarding exceptional teachers with up to £10,000 to develop their ideas, is one such example managed by the SHINE Trust[36] and funded by the Mayor of London's Office.[37]

To better tap into teacher innovations, we recommend that a rolling system of funding be made available to develop their ideas, as opposed to standalone competitions. Furthermore, this should be UK-wide, or at least England-wide. This would enable new ideas to be developed year-round and more equitably across the country.

## Giving students the tools to benefit from innovation

Most of the ideas put forward by our Classroom Changemakers required the use of computer technology and the internet. Several were explicitly designed so that young people could access resources online away from the classroom should they wish. Given the prevailing increase of technology in education, it is fair to predict that the number of innovations requiring online connectivity and computers will continue to increase.[38] The recent spate of school closures has put into sharp focus the continuing inequities between students when it comes to being able to access computer devices.

Previously, Nesta has also found that schools in better-off areas are significantly more likely to take part in schemes that promote innovation, with there being a striking north/south divide in particular.[39] The recent closure of schools has resulted in a raft of new evidence showing that there remains a sizable gap between the digitally enabled and the digitally disenfranchised.[40] The fact that more than one of our award winners plans to spend their £5,000 on purchasing internet-connected devices for disadvantaged students speaks volumes about the continuing problem.

The government's financial commitment to helping those without suitable devices to obtain them during the crisis is a welcome first step,[41] as is its partnership with BT to give low-income families internet for up to three devices for six months.[42] However, to make the most of innovation in education, we not only need to give teachers an avenue to share their ideas, but also give children the capability to benefit from them. Consequently, we recommend that the government expands its commitment

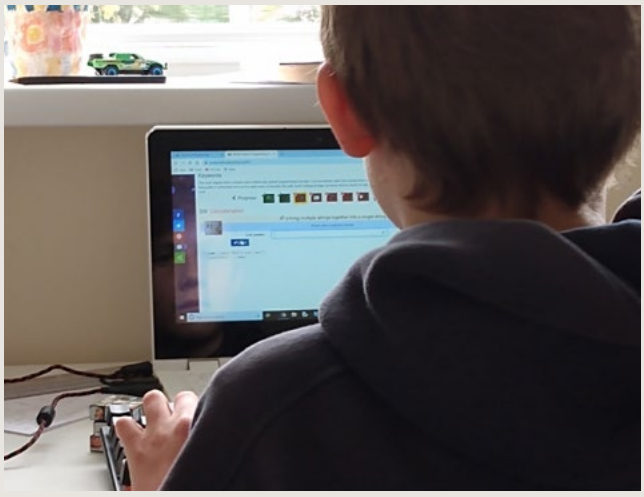
beyond the present crisis and ensures that all children have access to an internet-connected device in the future. However, we are also well aware that computers and internet connections only provide the necessary foundation, and that greater emphasis needs to be placed on high-quality online pedagogy and CPD for teachers to help them make better use of online learning.

## Harnessing the lived experience of teachers

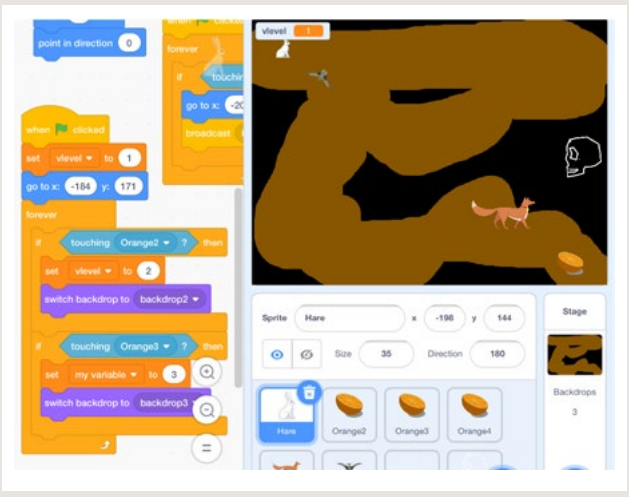
At a time when the world is attempting to come to terms with the injustice that still exists, through the Black Lives Matter movement and more widely, the importance of lived experience is rightly coming to the fore. These lessons ring especially true in education. In spite of the fact that the quality of teachers is the single biggest controllable factor over student outcomes, their role in advancing teaching practice is all too often effectively marginalised.[43]

While several of our recommendations would help to increase the prominence of teachers in the process of advancing teaching practice, there also needs to be a wider cultural shift towards a system which not only values teachers, but recognises the unique role they have in educating young people and improving their life outcomes.

What this means in practice will vary between organisations. At its heart, it means involving teachers and listening to their voices, whether that means a foundation such as Nesta tapping into their knowledge before launching an education programme, or the government going out of their way to listen to what teachers really need to deliver the best learning possible. Accordingly, we conclude by calling on all organisations, state and independent, working on improving education, to commit to prioritising the genuine involvement of teachers when making decisions that will impact them, their students, and wider society.



Peter Dring: KPRIDE (Keywords, Predict, Run, Investigate and Debug). Fulford School, York

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