THE MAGAZINE FOR COMPUTING & DIGITAL MAKING EDUCATORS

(Hello World)

Issue 18 | Mar 2022 | helloworld.cc

INTERVIEW: CYBERSAFE FOUNDATION
Raising awareness of cybersecurity threats

MUCH ADO ABOUT...
Computational methods and Shakespeare

KYOKUSHIN
Japanese logic puzzles for computational thinking

CYBERSECURITY

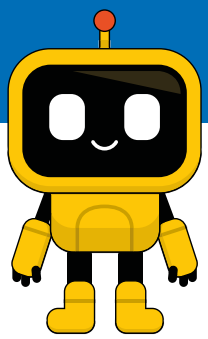


PLUS ISAAC CS GCSE • VR FOR COLLABORATION • CYBERSECURITY ETHICS • RASPBERRY PI PICO OPEN DAYS • CAPTURE THE FLAG • INCREMENTAL WINS • SCRATCH ACCOUNT MANAGEMENT AGILE METHODOLOGY • E-SAFETY TIPS • ANNUAL SURVEY RESULTS • QUANTUM COMPUTING

code club world

Introducing Code Club World

This free online platform is a new way for children to learn to code.



It's a great resource for beginners to enjoy and get started independently at home, or as a complementary activity to enhance their learning at Code Club.

Young people can:

- Create their personal robot avatar
- Make music, design a t-shirt, and teach their robot to dance!
- Learn to code on islands with structured activities
- Discover block-based and text-based coding in Scratch and Python
- Earn badges for their progress
- Share their coding creations

> **"I've not coded before, but found this really fun! ...I LOVED making the robot dance."**
> Learner, aged 11

Code Club World supports learners to get started on their coding journey, providing activities that are meaningful, fun, and flexible.

Encourage young learners in your school and community to get involved at **codeclubworld.org**

Code Club World is part of the Raspberry Pi Foundation (registered charity no. 1129409)

HELLO, WORLD!



On the surface of things, emulating the bad guys doesn't sound like the best advice to give schoolchildren. Cybersecurity threats, though, are increasing and changing all the time; as Zach Huffman argues on page 26, understanding the bad guys' motives and methods can help us to become better good guys.

This issue focuses on all things cybersecurity: the good, the bad, and the cryptographic. We have a huge range of articles (in fact, Hello World's biggest collection of themed articles yet!), spanning the ethics and legalities of hacking, advice about teaching cybersecurity to primary schoolchildren, and an introduction to quantum cryptography (which isn't as scary as it sounds). We also share some fantastic ideas for making this topic as hands-on as possible, including by using networked robots (on page 32), using tools and techniques used by real-life penetration testers (on page 18), and taking part in a Capture the Flag competition (on page 30).

We're also delighted to have celebrated Hello World's fifth birthday last month — doesn't time fly when you're sharing teaching ideas about such a fast-moving subject? To kick the celebrations off, we held our first Twitter Spaces event and had the pleasure of chatting with members of the Hello World community about how they have made the most of the magazine over the years. Thank you to all who participated, especially our guests Catherine Elliott and Alan O'Donohoe. You can find the recording on our Twitter page (**@HelloWorld_Edu**) and we will soon be making it available on our podcast.



Gemma Coleman
Editor

FEATURED THIS ISSUE



BABAK EBRAHIM

Babak is a computing teacher at Bishop Challoner Catholic College Secondary in the UK. On **page 28**, he shares how he set up a cybersecurity club to engage female students.



ZAHRA AMIN SHELKE

On **page 60**, Zahra, head of the primary ICT department at GEMS Westminster School in the UAE, shares her top tips for ensuring your school is e-safe.



TOM LIAM LYNCH

Tom is policy director at The New School, New York, USA. On **page 61**, he explores integrating computer science into the study of literature and humanities.

(HW)

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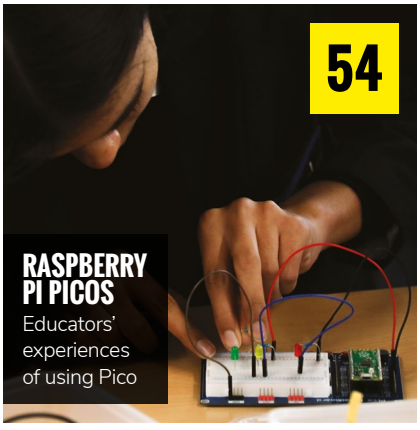
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ISAAC PLATFORM EXTENDED TO GCSE

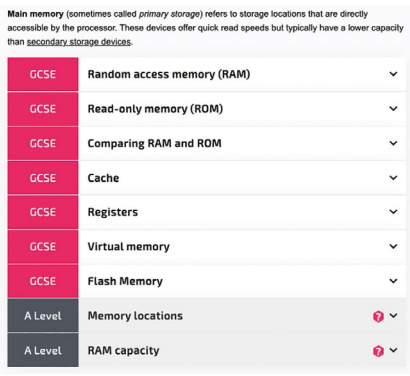
The first batch of GCSE content for all England exam boards has been released on the newly designed Isaac Computer Science site

Allen Heard

As an ex-teacher and head of department, I know how difficult it can be for learners to access quality materials at home that reinforce the content taught in the classroom. I also know how time-consuming it can be for a teacher to set meaningful, challenging homework that is truly valuable to a learner and tests their understanding of computer science concepts. All this is made harder by the fact that there are five different GCSE computer science specifications in England (for students aged 14–16), each of which takes subtly different approaches to some content, and often includes different topics. For educators and learners, finding free, high-quality resources specific to an examination board can be a difficult and sometimes fruitless task.

Developing Isaac CS GCSE

Isaac Computer Science (**helloworld.cc/isaac**) is a free online platform with concept-led exam board content and a large number of questions to test students' knowledge and understanding. It previously catered solely for A-level students, but the Raspberry Pi Foundation and the University of Cambridge have been working hard to bring GCSE content to the platform, with the initial launch in January 2022. The good news is that all the features that were previously available to A-level learners will now be available to GCSE learners too, plus some other exciting developments for everyone, including teachers! Content creators have been busy curating material that meets the needs of all learners, regardless of which examination board's specification they are following. It is packed with explainer videos, walk-through demonstrations, animations, and questions to support learners on their computer science journey. Learners can really develop their understanding and get a sense of their progress, tackling relevant problems of a similar level of difficulty to those they will face in an examination.



Isaac Computer Science offers different views depending on the user type and examination board chosen

New features for all

There is a large overlap in the concepts covered at A level and GCSE, which the platform is using to its advantage with the integration of stage and board views. In the board view option, users will only see content that is applicable to the examination board they have indicated they are studying. This is to ensure that topics are tailored to the subtle nuances of each examination board. The stage view option is useful for both GCSE and A-level students: if a GCSE learner wants to see what is coming up at AS, or how a topic is different at an advanced level, they



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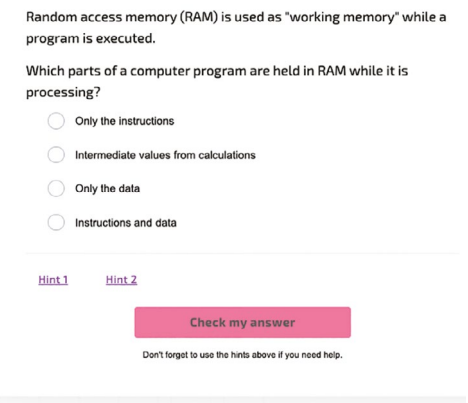
Educators teaching multiple exam boards can easily toggle between content rather than digging out different specifications with subtly different content

can choose to see content relevant to that stage. Likewise, an A-level student could go back and look at the fundamentals of a topic by viewing the GCSE content. Teachers will benefit from these different views too, as they are able to select more than one examination board in their profile. This will be useful if a teacher is teaching OCR at GCSE and AQA at A level, for example. They can easily toggle between content that is relevant to their current class, without having to dig out specifications or individual schemes of work to surface that subtly different content.

> CONTENT CREATORS HAVE BEEN BUSY CREATING MATERIAL THAT MEETS THE NEEDS OF ALL LEARNERS

Personalised learning experiences

Question leveling is another brand-new feature that has been introduced. There are hundreds of A-level questions, with hundreds of GCSE questions in the pipeline. Just like content, questions can be useful for all users at differing levels of ability. There will be three levels of practice (P) questions, and three levels of challenge (C) questions. The content team has spent a considerable amount of time tagging all the questions. For instance, a question tagged C2 at GCSE could also be tagged as a P1 question at A level. Using this system, learners effectively have access to a huge bank of questions in which they can select the level of difficulty and topic. As before, the feedback supplied to learners when they submit a wrong answer is specific to the wrong answer they gave, offering some advice on why that answer is wrong, or providing a hint on how they should proceed.



Example question from a memory and storage topic

Currently, 20 percent of the platform's new GCSE content is live, and this should increase to 50 percent by the end of March 2022. By August 2022, Isaac Computer Science will be a wealth of interlinked content to help GCSE and A-level learners alike develop their subject knowledge and computer science problem-solving skills, and help teachers to directly access related lesson content and professional development opportunities. (HW)

COOLEST PROJECTS RETURNS!

To mark its tenth year, the event will go even further to showcase inspirational projects and recognise the achievements of their creators

Matt Richardson

Coolest Projects Global, the world-leading showcase for young digital makers, is returning in 2022 as an exclusively online event starting in February and closing in mid-May. Individuals or teams of creators can submit their projects whether they were created at school, at their club, or on their own. All creators will be recognised in a massive online showcase gallery and a live-streamed celebration in June.

Creators aged up to 18 can submit their projects in one of six technology categories: Scratch, games, web, mobile apps, hardware, or advanced programming. Judges will evaluate projects based on their coolness, complexity, design, usability, and presentation. Beginners and advanced coders alike are encouraged to share their creations for consideration.

What's new in 2022

After a successful online event in 2021, the organisers received a lot of valuable feedback from creators, with tons of ideas about how to make Coolest Projects even cooler.

For example, creators often make projects related to topics that they care about. It could be solving a problem in their community, educating their peers about health issues, or expressing something about their own cultural identity. The improved registration system will allow creators to select from a series of topics when registering, and project gallery visitors will be able to explore projects related to these topics.

Something that creators value about in-person Coolest Projects showcase events is the ability to engage face to face with the judges and get direct feedback from them. Feedback will now be shared for the online event, too: all creators will receive feedback from the judges who reviewed their projects.

The creators of the judges' favourite projects will receive a Coolest Projects medal to display proudly around their necks or along with their other artefacts of accomplishment. Of course, everyone deserves a reward for participating, so every creator will be eligible to receive a limited-edition Coolest Projects poster created by artist Joey Rex and inspired by past projects.

Get inspired, get involved

The main ambition of Coolest Projects is to inspire and celebrate young people who create with technology. While the Coolest Projects Global online event may happen only once a year, creating with technology happens year-round. So throughout the year, the Coolest Projects team will be sharing a dynamic line-up of inspiring projects, creators, how-to guides, and new technology via email, social media, and on the refreshed **coolestprojects.org** home page.

There are two ways to get involved right now. One is to go to **coolestprojects.org** to sign up for email updates from the Coolest Projects team. The other is to encourage your students to submit their digital projects to the Coolest Projects Global showcase. Resources for mentors are available on the site to help you get started.

Whether online or in person, it's important to give young creators the opportunity to show off what they've made and be recognised for their accomplishments. (HW)



Young creators at Coolest Projects USA 2020 share their hardware project with the world

FREE COURSEWARE AND HARDWARE

With the support of Infosys Foundation USA, the Raspberry Pi Foundation has created two new courses for US-based educators, with free kit available

Matt Richardson

In September 2021, the Raspberry Pi Foundation launched two new free online courses for educators in the USA, with the support of Infosys Foundation USA, who are committed to expanding access to computer science and maker education in public schools across the United States.

To kick-start their learning journey, we gave qualified US-based educators the chance to receive a free Raspberry Pi Pico microcontroller hardware kit. We still have kits available to give away, so read on to find out more. You can find both new courses on the Pathfinders Online Institute (**helloworld.cc/pathfinders**), a platform which supports US classroom educators in bringing high-quality computer science and maker education content to their kindergarten through 12th-grade (K–12) students.



Teachers will discover how to inspire their students through programming and physical computing

The courses

The first free course is *Programming Essentials in Scratch* (**helloworld.cc/infosys1** — login required). It supports teachers in introducing the essentials of programming to fourth- to eighth-grade students. The course covers the key concepts of programming, such as variables, selection, and iteration. Teachers will also discover how to inspire their students and help them create music, interactive quizzes, dance animations, and more.

The second free course is *Design, Build, and Code a Rover with Raspberry Pi Pico* (**helloworld.cc/infosys2** — login required). It gives teachers of fourth- to eighth-grade students everything they need to start teaching physical computing in their classrooms. Teachers will develop their students' knowledge of the subject by using basic circuits, coding a Raspberry Pi Pico microcontroller to work with motors and LEDs, and designing algorithms to navigate a rover through a maze. By the end of the course, teachers will have all the resources they need to inspire students and help them explore practical programming, system design, and prototyping. Some teachers have told us what they're hoping to get from the courses and kits, and we've been encouraged to hear comments such as, "My students love learning how to code using blocks and Python, and would absolutely love to see their code in action with physical computing DIY projects!"

Free kit

Thanks to the generous support of Infosys Foundation USA, the Raspberry Pi Foundation is able to provide qualified educators with a free kit of materials to participate in this second course. This is particularly exciting because the kit includes Raspberry Pi's first-ever microcontroller, Raspberry Pi Pico (**helloworld.cc/pico**).

This offer is available to 1000 US-based K–12 public or charter teachers on a first come, first served basis. To claim your kit, just create a free account at **helloworld.cc/pathfinders** and start the course. On the first page of the course, you'll receive instructions for how to apply for a free kit. If you're not a qualified educator, if you've missed out on the opportunity to receive the free hardware, or even if you're not based in the USA you are still welcome to join the course. You can find the materials yourself, or purchase the kit from our partners at PiShop.us (**helloworld.cc/shoppico**). (HW)

COLUMN

DEVELOPING STRENGTHS IN THE INCLUSIVE CLASSROOM

Young people with special educational needs and disabilities can excel in computing when their strengths are developed and supported

When I found out the theme for this issue of Hello World, I started thinking about how to incorporate that into my column. How do we support our learners with special educational needs and disabilities (SEND) to undertake cybersecurity activities in the classroom? Then I remembered a number of articles I had read about organisations actively recruiting neurodiverse people to cybersecurity roles. Neurodiversity is often used to describe autistic people, together with those with attention deficit hyperactivity disorder (ADHD), dyslexia, dyspraxia, and other developmental and cognitive disabilities.

These prospective employees often demonstrate a number of key qualities that are sought after in this sector, including:

- Attention to detail
- Pattern recognition
- Reliability and integrity
- Out-of-the-box thinking
- Clear focus on the task in hand

Combine these with an interest in technology and you have an ideal candidate for a cybersecurity role — notwithstanding some workplace adjustments that might need to be made to accommodate specific needs.

Celebrating strengths

I often start any training on computing and SEND by asking teachers to consider the strengths of the young people they teach, rather than focusing solely on weaknesses and barriers to learning. One student may love working as part of a team, while another excels at independent learning. Where one learner can see the whole problem and come up with creative solutions, another learner may be better suited to the detail and structure of a specific task.

Obviously, we still need to address weaknesses and reduce the barriers faced by all the young people in our lessons. However, by acknowledging and celebrating their strengths, we can help develop confidence and ensure everyone has a sense of belonging in a class; this is at the heart of inclusion.



Catherine is the SEND lead for the Sheffield eLearning Service (**sheffieldclc.net**), and since the announcement of the computing curriculum in 2013 she has been working on ways to make the subject accessible for all learners. She is a member of the CAS Include working group, and leads the SEND Virtual and the Sheffield and South Yorkshire Secondary CAS Communities (**@catherinelliott**).

Universal Design for Learning

Identifying, celebrating, and developing each individual's strengths isn't easy, but this is where the Universal Design for Learning (UDL) framework can help. It is a "framework to improve and optimize teaching and learning for all people based on scientific insights into how humans learn" (**helloworld.cc/udlcast**). Essentially, if we consider and provide multiple means of *engagement*, *representation*, *action*, and *expression* in lessons, this can provide learners with a range of ways in which to engage with lessons, learn about content, participate in activities, and express what they know. In doing this, we can address potential barriers before they arise, and allow the diverse strengths and interests of our young people to be developed in different ways (see **helloworld.cc/hwudl** for a Hello World article about this).



Many cybersecurity firms actively recruit neurodiverse people because of their strengths and skills

For example, you could present content in different formats — video, audio, text, and image — and make the most of learning platforms to provide learners with a place to revisit lesson content in a time, place, and format that suits them. Try to provide a range of options for lesson activities — so in terms of learning about cybersecurity, students might watch a video and answer questions, role play a specific scenario, devise their own cipher to encrypt a message, or design a poster to make young people aware of cybercrime. Where students are learning about how computer programs can be written to decipher messages, they can investigate and modify working programs, complete Parson's Problems, or debug existing code.

Physical computing devices can be more engaging for some learners, and their tactile, sensory nature can help students make connections with the code in a way that can be harder with a text-based language on a screen. Consider ways to incorporate this into a cybersecurity lesson, such as the networked robots introduced on page 32. The more opportunities we provide for learners, the more we can recognise and celebrate individual strengths.

Project-based learning

Project-based learning can also enable more choice in how learners learn and express themselves. Provide some choice in context to appeal to varied interests, and if students are working in groups, allow them to assign tasks according to the strengths of each member. Furthermore, not all students enjoy working in teams, and this can be a barrier in itself. One way to help mitigate this is by providing learners with a specific task within a group that can be undertaken independently, but will still contribute to the final project. For example, in cybersecurity teaching, a capture-the-flag competition is a team effort, but tasks can be allocated to individuals (see page 30 for more on this).

I remember working with some secondary-age students on an enrichment project around technology. One girl was completely switched off during the 'Robotics' unit, and seemed uninterested when we began the app development project. Once we had outlined all the different elements of making an app, from the design of the app, to content writing, coding, and testing, she became much more animated. She was a keen artist, and took on the design side of the project while her friends coded the app and wrote the content. The app they developed was excellent, benefitting from a well-rounded group of collaborators.

We are all individuals, with different skills and experiences that influence how we perceive and interact with the world. The more inclusive we can make our computing lessons by providing a range of ways to participate, the more students will enjoy lessons and the more they will achieve. This in turn should encourage a more diverse set of students taking computing-related qualifications, finally leading to a more diverse workforce in tech-related jobs. This is essential to ensure that diverse experiences and ways of thinking frame the development of future services and technologies. It will also benefit companies in the future, as they will be better equipped to solve complex problems by drawing on the wide range of strengths displayed by their employees. (HW)

#INSIGHTS

ADDRESSING THE CYBERSECURITY SKILLS GAP

STORY BY Hammad Kazi

Over the last two years, the shift towards remote working and schooling has forced people to adopt new ways of living and working. The use of internet-based applications has increased, including use by new and often unskilled users such as older people and children. Unfortunately, and perhaps predictably, hackers have taken advantage of these gaps in knowledge. A 2021 survey by the UK's Department for Digital, Culture, Media & Sport, for example, demonstrated the threat that cybersecurity breaches pose to businesses and charities (helloworld.cc/breaches2021). It outlined that 39 percent of businesses and 26 percent of charities in the UK reported having breaches in the preceding twelve months, and that the most common type of breach was a phishing attack.

There are opportunities for the IT industry, computer science academia, and educational institutes to help address this threat by developing cybersecurity skills in more students, especially by treating cybersecurity as a metadiscipline (incorporating ideas and theories from multiple disciplines) rather than as a single discipline. Some academics argue that cybersecurity education should begin at high school, before being integrated into computer science, engineering, and other IT-related degree programme curricula, to ensure that cybersecurity knowledge isn't just concentrated in specialists (**helloworld.cc/crick2019**).

Opportunities

There are several ways in which educational institutes are increasing opportunities for undergraduates to develop cybersecurity knowledge and skills (**helloworld.cc/parrish2018**). For example, traditional computing programmes are incorporating security-based topics into their content. Some institutes are also offering separate cybersecurity courses in their continuing education, undergraduate-, and postgraduate-level programmes. There are also crossovers on this topic in subjects such as criminal justice, business law, and social science subjects that deal with the societal impact of internet-based breaches.

For us to get to the level of treating cybersecurity as a metadiscipline, it is important that it is introduced at high school, for example through the angle of providing a secure ecosystem in which programming activities can take place. There is evidence that students receiving a computing education in high school are eight times more likely to major in a computing degree (**helloworld.cc/jin2018**). Even if high-school students do not end up studying computer science later on, they will be better placed to have a basic understanding of cybersecurity, which can prove useful both in their careers and personal lives. Since there is a high prevalence of early-years usage of internet-based applications, in more industrialised countries at least, it makes sense to plug the cybersecurity knowledge gap during secondary school.



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A 2021 survey of UK businesses concluded that phishing attacks were the most common type of security breach



Guest lectures by industry experts can be an effective method of teaching cybersecurity

Challenges

This is still a work in progress, however, and a conscious effort is required to develop the course infrastructure in a way that enables students to work in a proactive cybersecurity environment, rather than in a reactive one. A review of the top 100 UK computer science university courses revealed that 6 percent of security curriculum content has no references to cybersecurity, privacy, secure programming, or other cybersecurity content during the course (**helloworld.cc/ruiz2019**). Furthermore, 39 percent of these courses do not offer mandatory cybersecurity content and instead push it to the end of the course as a low-priority add-on. Finally, only 17 percent of courses offer cybersecurity content in the first year.

These numbers make a strong case for the need for cybersecurity content in the UK to be baked into the course syllabus, starting from the high-school level, and continuing with priority into computer science degree programmes. In this way, students are taught how to develop their approach and thinking from the systematic perspective of a safe and secure platform.

Ways forward

Several factors should be considered to help overcome the challenges of integrating cybersecurity into course curricula as a metadiscipline (**helloworld.cc/crick2019**). Firstly, it is important that all the skills that a competent head of information security or chief information security officer should have, for example, are taught at the academic level. These skills include psychology, management and organisational behaviour, and technical knowledge, as well as soft skills such as communication, analytical thinking, and collaboration.

Cybersecurity should be taught in an effective manner using real-life case studies and guest lectures by industry experts in the field, and should include appropriate cybersecurity standards within the curricula (for example, the Payment Card Industry Data Security Standard — see **helloworld.cc/pcidss**). Course content can also be taught from the point of view of a hacker, thereby fostering a more experimental and creative approach to understanding how a network can be made safer and more secure. Institutions should prioritise the recruitment, retention, and development of the faculty, ensuring that they are kept abreast of all key developments in the field from around the world. Finally, it is critical that there is ample investment in educational resources, ranging from laboratories and equipment to course content and pedagogical innovations. A very pertinent example of this is the series of game-based camps run for high-school students by Purdue University Northwest in the USA to increase their awareness and interest in the field of cybersecurity (**helloworld.cc/jin2018**).

> “ CYBERSECURITY CONTENT NEEDS TO BE BAKED INTO THE COURSE SYLLABUS FROM THE HIGH-SCHOOL LEVEL

Addressing the cybersecurity skills gap is vital. It is clear that a concerted effort involving the IT industry, academia, and educational institutes is necessary to move cybersecurity from an optional add-on to a prioritised metadiscipline. (HW)

FURTHER READING

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LESSONS FROM THE CYBERSECURITY INDUSTRY

STORY BY Katharine Childs

Cybersecurity topics in school computer science curricula often focus on defending against cybersecurity attacks and on understanding the ethical and societal implications of data privacy. In programming topics, however, a proactive approach to writing secure code is also important. A research project called Motivating Jenny (motivatingjenny.org), supported by the UK's National Cyber Security Centre, has created a number of tools to help developers consider the security of their code and embed a workplace culture in which software security is seen as a fundamental value. Although this research has been conducted in industry, there are many ways in which educators can translate the findings into good classroom practice.



Using prompt cards and values cards can help to stimulate positive conversations about cybersecurity issues

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Real-world industry perspectives

In a 2019 study by the Motivating Jenny project, researchers took an ethnographic perspective. An ethnographic research study aims to find out more about the behaviours and routines of a group through direct observation, and researchers conducting this study met with professional developers in their workplaces to find out more about their beliefs, attitudes, and experiences with writing secure code. The write-up of the study provides a real-world example of a computing career and is useful for both teachers and pupils.

The researchers ran a series of workshops with groups of professional developers, with the aim of finding out more about how social interactions and a culture of software development contributed to supporting developers in writing secure code. In the first part of the workshop, participants read various examples of a security compromise that had taken place, each with a different focus or perspective. They then all read a first-person account of the impact of the security breach. Finally, the workshop concluded with a discussion of participants' own experiences. Prompt cards and values cards kept the group conversations focused on attitudes, beliefs, and behaviours, to create discussions that were "refreshingly different" and "participatory".

Applying findings to the classroom

The findings from the workshops were designed to be applied to professional settings. However, the themes that emerged could be equally relevant to the computing classroom:

Personal stories resonate: Cybersecurity can often seem like an abstract or intimidating topic. However, all software and systems are designed and implemented by people. Consider how to use examples of real-life security compromises, such as the first-person account that was used in the research, in teaching and learning (**helloworld.cc/firstperson**).

Values can support positive discussions: In the research, using values helped to create positive, non-confrontational conversations. Your school community is likely to have a set of values to help each pupil shape their understanding of the world. For example, a classroom wall display that links cybersecurity considerations to the school's values is a powerful way of modelling this and providing discussion prompts.

Group discussion through play is effective: The researchers gamified group discussions by using a timer and prompt cards. This provided a valuable structure to conversations and helped to give each participant a chance to speak. Consider how this approach could work when you are leading classroom discussions with your pupils. (HW)

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MULTIPLE-CHOICE QUESTION CONSTRUCTION

STORY BY Oliver Quinlan

While multiple-choice questions (MCQs) are often considered to be a tool for assessing learning, the process of answering them can be a valuable learning experience in itself. There is extensive literature on the use of such questions in these two different ways, and researcher Andrew C. Butler compared the best practices for both scenarios. He found that whichever way you are using MCQs, there are some key things to get right.

Avoid using complex questions or answers

The traditional MCQ is a single question with a single correct answer and several wrong answers (or distractors). Some question writers make this more complex by providing answers such as 'none of the above' or 'option A and B but not C'. Research suggests that these questions are more difficult to write well and that they can be particularly susceptible to learners guessing, or engaging with cognitive processes that are focused on test-taking strategies rather than the content the question is concerned with.

Simpler questions mean that different learners are more likely to be engaging in the same cognitive processes when answering them. Butler argues that for both assessment and learning, you want learners to be using the cognitive processes you intend them to.

Create questions that require engaging with specific cognitive processes

It is important to consider how a question addresses both specific content and specific ways of thinking about that content. One way to achieve this is by using resources that provide template questions, or shells, based around different cognitive processes. For example, questions such as 'Which best defines X?' or 'Which distinguishes X from Y?' Frameworks such as Bloom's taxonomy can also be used to consider how questions can address different types of thinking.

Use three plausible possible answers

The literature finds that a question with three answers is the format that strikes the best balance between beneficial engagement with the question and the amount of time it takes a student to answer. However, the more important aspect of this is that all the possible answers must be plausible — and if this means only having two options, this is preferable. Plausible answers are often common errors or misconceptions. Some MCQ platforms allow educators to analyse incorrect answers, which can help them to identify the misconceptions or errors learners are making. When using MCQs for learning, it can help to use correct answers to later questions as distractors in earlier questions, but only if they could plausibly be possible answers.

> "ANSWERING MULTIPLE-CHOICE QUESTIONS CAN BE A LEARNING EXPERIENCE IN ITSELF

Sets of questions should be challenging, but not too difficult

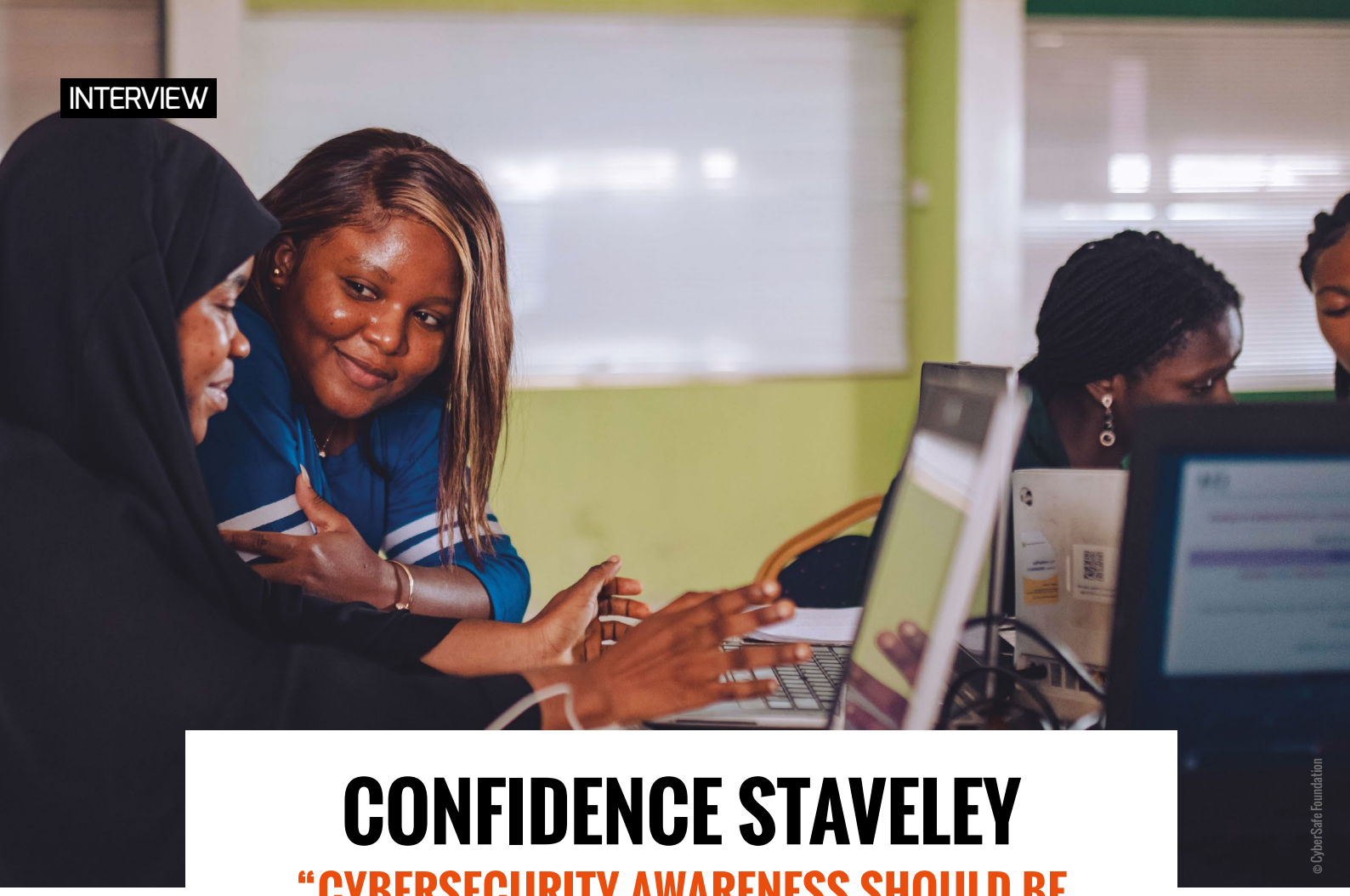
For assessment, questions should be able to determine whether a student has understood a concept or not. Educators should therefore pitch MCQs at a level at which students get some answers right and some wrong. This allows the educator to assess the level across the group. The same applies in a learning situation, as questions can be used to identify which learners may need additional support in learning the material.

Across all of these key considerations, Butler emphasises that it is important to provide feedback to help learners understand where they are at and continue to learn. This feedback can be effective whether it is immediate or after a delay.

Whether you are using multiple-choice questions to assess students or support their learning, considering these key points will help you to make the most of this powerful tool. (HW)

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- Butler, A. C. (2018). Multiple-choice testing in education: Are the best practices for assessment also good for learning? *Journal of Applied Research in Memory and Cognition, 7*(3), 323-331. **helloworld.cc/issue18insights5**



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CONFIDENCE STAVELEY

"CYBERSECURITY AWARENESS SHOULD BE EMBEDDED IN EVERY AREA OF YOUR LIFE"

Gemma Coleman speaks to Confidence Staveley, founder of the CyberSafe Foundation, about its fun and relatable approach to building cybersecurity skills and awareness

Confidence Staveley and her Nigeria-based NGO the CyberSafe Foundation are on a mission. "Cybersecurity is very much like Covid," she explains. "We are not safe until we're all safe. Through relatable awareness campaigns, art, and training, we aim to facilitate changes that ensure online safety across Africa. The biggest thing we're trying to do is address the skills shortage and close gaps in awareness, and our work can serve the rest of the world. Africa can become the next cybertalent hub to feed shortages, and fill those jobs to reduce attacks locally and abroad."

Confidence founded the CyberSafe Foundation (**cybersafefoundation.org**) three years ago, after her mother became a victim of cybercrime. "It hit very close to home. I was enraged — in a good way — and I wanted to stop this, to educate people." She states forcefully, "The number one preventative measure is not a software tool. It's awareness." Although the Foundation is relatively young, Confidence's interest in tech stretches back to her childhood: "When I realised how much I loved coding and creating, there was fire in my eyes. I came home and told my parents I didn't want to be a doctor like they wanted me to be. Instead, I did a presentation to show them why I wanted to build a career in tech." She laughs, "That was the beginning … But I soon realised I was called to do more than just helping to keep different companies' IT infrastructure safe."

Guided by Confidence's passion and steely determination, the Foundation has grown to about 40 staff, a network of 500 volunteers, and a host of unique initiatives. "What really makes us stand out is our approach to awareness," says Confidence. "Cybersafety can be very boring, but we leverage storytelling a lot, and this very human-centric approach makes cybersecurity lessons much more interesting for people to consume." Confidence points to their 'NoGoFallMaga' ('Don't fall victim') campaign, including radio dramas focusing on cybercrime, a music video billed "possibly Africa's first afrobeat cybersecurity awareness song," and market tours in which staff and volunteers approach shoppers with cybersafety information and resources.



Staff and volunteers visit markets to spread cybersecurity awareness



CyberGirls aims to close the digital gender gap in Nigeria

Not only does this style of approach insert some much-needed fun into cybersecurity, it also ensures that the Foundation is reaching the less privileged and non-digital natives, who are spending less time online.

"I want to give people more avenues to learn about cybersafety, an opportunity to change their habits. When I founded the CyberSafe Foundation, that kind of information was lacking in Nigeria for end users who weren't tech-savvy," Confidence explains with her signature gusto. "We like to think about cybersecurity awareness as something that you experience all around you. It shouldn't be something you have to go to separately. It should be something embedded in every area of your life and consumed in the way you consume other content."

> "WE ARE NOT SAFE UNTIL WE ARE ALL SAFE

There are specific programmes targeting those who are particularly vulnerable to attacks, including older people and children. Shine your Eye, for example, is a cybersecurity initiative for seniors that has reached 5000 people so far. The Foundation started this programme recognising that older people are generally not digital natives. "They have the twin struggle of learning how to use new technologies, and also keeping that technology safe," Confidence explains. "People get called up or emailed by scammers all the time in Nigeria — 'I'm calling from Facebook and I need your password for this and that' — and seniors hand over their password very easily, because they don't realise it's not Facebook calling! They're more vulnerable because of this lack of awareness, and because they also have so much more to lose: pensions, savings … They are always in scammers' crosshairs."

Staying true to form, the programme leverages video content and stories to simplify the message. "We've found that giving seniors actionable tips has been key. For example, we think we've created the first pan-African cyberawareness handbook for seniors. It's available in seven languages and the information is contextualised for each region. This means that there's hardly [any] part of Africa that will not be able to access this. Literacy is one of the barriers to awareness in Nigeria. That is bridged by having this guidebook in multiple languages spoken in Africa."

The programmes that are perhaps closest to Confidence's heart, though, are CyberGirls and DigiGirls: "The younger age group that we're targeting [15–21 and 15–40 years respectively] is about the age I was when I got involved in tech. They are very pivotal ages for girls in Africa," Confidence explains. "A lot of girls aren't in tech in Nigeria and in Africa because they don't even know that it's an option for them." CyberGirls focuses on giving girls cybersecurity skills to use in future tech careers, while DigiGirls, which the UK government funds, aims to build broader digital skills such as UX, graphic design, digital marketing, and cybersecurity.

"A lot of cybercrime in this country is driven by poverty. If we can give people the skills that will lift them out of poverty, we are reducing the rate of people going into cybercrime," Confidence proudly explains. "What we're hoping to achieve is to close the digital gender gap in Nigeria. Women here don't have as much access to technology as men. But if women do not have tech skills, they are automatically cut off or disadvantaged in the workplace. This plays out in lots of ways, including increasing the chance of girls being victims of domestic violence. We are arming girls with the skills to fend for themselves, to fit into the new world of work."

In a world in which cybersecurity threats are constantly evolving, it can be hard to know if your message is having an impact. Confidence takes this one day at a time. "At the end of one session with young children, we wanted to test them, and we asked them to give us their address so we could send them a package to summarise what they'd learnt. One of the children unmuted their mic and said, 'Auntie, you said we should not give our address to strangers! I have to tell my Mummy before I can give it to you!' That's when we knew we'd done our job well that day." (HW)

ACTIVITIES AND TOOLS TO BRING CYBERSECURITY TO LIFE

Rob Parker shares how his school teaches cybersecurity skills using real-life tools and projects, increasing engagement and excitement in the classroom

Teaching cybersecurity can be dull without hands-on practical experiences and exercises. Fortunately, my passion for cybersecurity and my more than 20 years of experience as a data security engineer have helped me to understand how to motivate my students to acquire the real-world skills needed for success in industry. In this article, I'm going to present activities and tools you can use to link cybersecurity to the world outside the classroom.

Projects with real-life consequences

I recently gave my students a taste of industry experience through a data security project about our internal IT infrastructure. Working alongside a team of remote penetration testers, I identified weaknesses in our own school system that could allow a data breach. We then set up various machines mimicking commonly known vulnerabilities, to demonstrate how a penetration tester could identify weaknesses and show how they could be fixed. Running an activity such as this not only has the advantage of keeping our school network as secure as possible, but also helps students to understand the types of threat schools face and how to put their learning into action.

This project particularly stressed the importance of keeping all operating systems up to date and using suitable security software, and the real-life consequences of not doing so. Students absolutely thrived during this project, as it allowed them to develop some basic skills that ethical hackers and penetration testers use in industry, as well as practical skills they can use in their everyday lives. It also allowed for topical classroom discussions in which students debated the advantages, disadvantages, difficulties, and ethics of such a project. Students are always interested to learn more from real-life case studies that help them relate personally to the importance of cybersecurity. Khanteepop Thaipradith, one of my students at Steam Labs, shared, "I learn ethical hacking to keep myself updated with the news and security. By going through the process of ethical hacking, I'm able to gain knowledge in order to use it to secure myself, as well as people around me, from being hacked."



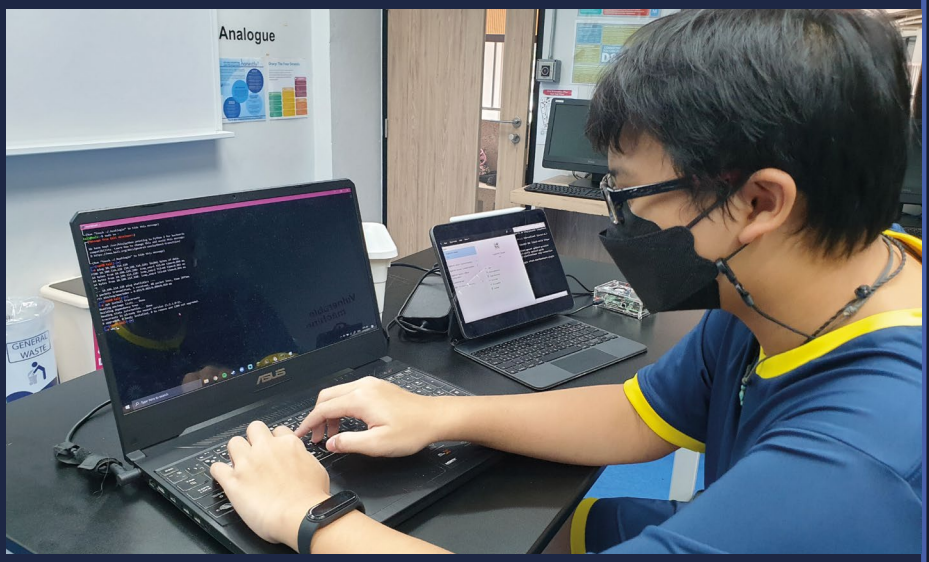
Keep students engaged with cybersecurity by using real-life tools and projects

Professional real-world tools

Another way of increasing engagement in cybersecurity teaching is through using tools that are actually used in industry. We use Raspberry Pis preloaded with Kali Linux, a system commonly used by industry specialists, to teach students about evolving threats in cybersecurity (**helloworld.cc/kalilinux**). Students learn the fundamental skills and steps needed to protect themselves against these threats, and the importance of ensuring that any data that is transmitted is encrypted. Using Kali Linux, students explore how to scan devices and sniff packets of data that are being transmitted. They learn how penetration testers identify whether particular ports are open on network devices using a TCP half-open port scan, and then look at what action a pen tester would take if there were ports open that could be dangerous (you can learn more about how to do this at **helloworld.cc/sniffpacket**).

FURTHER RESOURCES

- **helloworld.cc/steamblog**: Blog at Steam Labs (an online school that teaches robotics and ethical hacking), where I post free cybersecurity content for schools at the request of other global educators
- **helloworld.cc/robparker**: My LinkedIn profile; here, you can contact me for help with designing lessons, and raise queries about how to integrate cybersecurity into the classroom



Another great way of putting cybersecurity into practice is by using Secure Shell. Using Raspberry Pi's command line, students learn how to access a device remotely by analysing the weaknesses in its security. The students take the perspective of the hacker, and search for areas of weakness. From there, we challenge them to think of ways of fixing the issues in the system. Any skilled ethical hacker or penetration tester has to be able to understand offensive security and think like a black-hat hacker. Students are taught the ethics behind cybersecurity, and they thrive when learning about the skills that white-hat (ethical) hackers develop and use in higher education.

Similarly, we use Shodan (**shodan.io**), which can index every device connected to the internet, to demonstrate the importance of keeping devices that are connected to the internet up to date. We use it to explore how a hacker could potentially take advantage of a device using an outdated operating system. Wireshark (**wireshark.org**) is another powerful real-life tool you can use in cybersecurity lessons. It analyses network traffic and explores how encryption works, underlining the importance of having a strong password. Our students quickly discover how easy it is to crack a user's password using tools such as John the Ripper (**helloworld.cc/john**), and why systems block multiple password attempts when individuals use brute-force tools such as Hydra. Through these activities, we're developing their analytical and problem-solving skills, which they can transfer into everyday life and other parts of their education. Importantly, students finish these lessons with the know-how they need to help protect themselves and their families' devices from this type of hacking.

VirtualBox (**virtualbox.org**) is another great tool, particularly if you're low on time and budget. It is a well-rounded, free, open-source piece of virtualisation software. This type of software allows you to install and use applications and operating systems other than the one running on your computer. This means you can look at malicious files safely without infecting your computer, which can be a great starting point for applying cybersecurity knowledge and skills in the classroom. Raspberry Pi OS Lite is another good place to start. You can download a headless image and teach students how to access devices without a keyboard, mouse, or monitor.

> "ANY SKILLED ETHICAL HACKER HAS TO UNDERSTAND OFFENSIVE SECURITY AND THINK LIKE A BLACK-HAT HACKER

If educators develop fun and exciting projects in cybersecurity, we will start to unlock our students' ability to excel, and help them to keep their own data and devices secure, as well as those of the organisations they work for in the future. (HW)



ROB PARKER

Rob is a computer science educator and the data protection officer at St Andrews International School, Bangkok. He is also a robotics and technology coach at Steam Labs (**steamlabs.co.th**), a specialist online school that teaches robotics, computer science, and ethical hacking. Rob is a certified Ethical Hacker with EC-Council.

(HW)

HEAR FROM THE WRITERS!

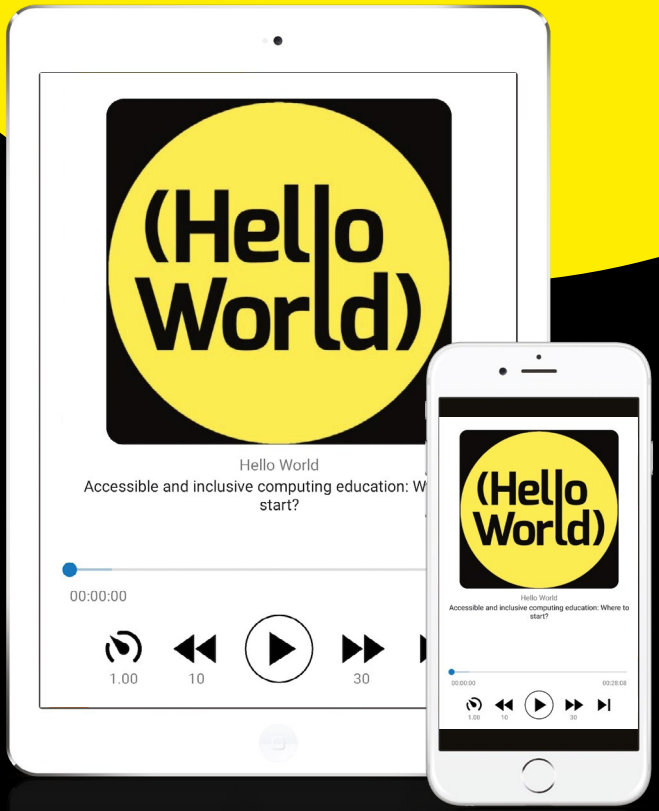
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OUR MOST POPULAR EPISODES

How moral is your machine? Ethics in computing education

Accessible and inclusive computing education: where to start?

How can we get everyone excited about code?

THE THIN BLUE PIXELATED LINE

Jon Chippindall and **Alan Merrett** discuss what the law says about hacking and the resources you can use to educate your learners

Mention 'hacking' or 'hackers' to your class and you might spot a few smiles or exchanged glances. There might even be confessions of "I managed to hack so-and-so's Roblox account once." Pupils' eagerness to identify as a hacker might be somewhat explained by the romanticisation of hacking in popular culture. But let's be absolutely clear: without express permission, unauthorised access to any computer system is illegal, and our pupils need to know this so they don't find themselves on the wrong side of the law. In this article, we'll unpick a little about what the law says around hacking and other cybercrimes, and share some resources you can use to educate your pupils. Although this article focuses on UK law, its learnings should still be relevant for all.

"It's OK, I only teach primary"

You might question whether we need to be covering the legalities of hacking in primary schools, as surely pupils are too young to be at risk of offending, but you'd be surprised. The *Pathways Into Cyber Crime* report from the UK's National Crime Agency (NCA) highlighted that 61 percent of hackers start hacking before the age of 16, and many can trace their pathways back to discussions in game-modding forums at the top end of primary-school age (**helloworld.cc/ncareport**). Looking at the make-up of many digital literacy curricula, perhaps we've spent too much time on teaching how to protect against cybercriminals at the expense of reminding pupils not to become the cybercriminals themselves! What's more, the advent of new off-the-shelf hacking tools has lowered the bar of technical knowledge required to undertake cyberattacks, so it's more important than ever that we educate pupils from a young age on what is and isn't OK to do with computers.

There is also a real positive opportunity here to promote cybersecurity career choices and strike an appropriate balance of stick and carrot. Pupils need to know what is illegal, but also that if they have an interest in the computer science behind hacking, there is an ever-growing world of jobs available to them when they're a bit older. Indeed, many offenders interviewed by the NCA and police officers were motivated not through malicious intent, but by genuine curiosity, and by the satisfaction to be gained from solving the complex technical challenge of the hack. If we can get these pupils on the right track, they'll be a huge asset to any organisation that employs them to defend their digital interests. So, what does the law actually say?



Figure 1 Child-friendly translations of the laws constituting the UK's Computer Misuse Act 1990

What the law says

In the UK, the Computer Misuse Act 1990 (**helloworld.cc/cma1990**) sets out what constitutes illegal activity with a computer. There are five elements of the law, which were

FURTHER RESOURCES

barefootcomputing.org/cyber: All the activities mentioned in the article and more can be downloaded here.

cyberchoices@nca.gov.uk or **NCCUprevent@nca.gov.uk**: Email addresses for additional cybercrime-related support in the UK.

translated into child-friendly explanations as part of Barefoot's Be Cyber Smart resources, and are shown in **Figure 1**. This figure also shows details of the sentences that people can receive if convicted of each element, including imprisonment and fines.

To bring the Computer Misuse Act to life, let's look at a selection of real prosecutions to illustrate the elements that make up the law. The following case information was taken from a record of convictions maintained at **helloworld.cc/cmacases**. This record could be explored with older pupils to deepen their understanding of when and how the law is broken, but please be aware that some cases include crimes of a sexual nature inappropriate for students.

Case 1

A 22-year-old student created software capable of harvesting names and passwords for various online services. They deployed the software to gather these credentials so that they could then access the services for free. They were imprisoned for six months after they were found guilty of creating the software to harvest login credentials (**breaking law 5**) and accessing the services without permission (**breaking law 1**).

Case 2

A disgruntled Jet2 employee launched a revenge attack that shut down Jet2's booking system and accessed the CEO's email. Recovery from the attack cost the company £165,000 (approximately $225,000). The person was convicted of accessing Jet2's files without permission and subsequently damaging them (**breaking laws 1 and 3**). They were sentenced to ten months in prison and their laptop was destroyed.

Case 3

A student hacked into social media and gaming accounts using a program they had created, and then they sold the personal information from within them (**breaking laws 1 and 4**). They were sentenced to four months imprisonment, suspended for one year.

From these three cases alone, we can see the far-reaching impact of cybercrimes. Here, the victims include those whose online services were being used without their permission, and social media users whose personal information was sold without their knowledge — potentially leading to further crimes such as identity theft. In their interviews, the NCA learnt that cybercriminals often see their crimes as victimless. With large-scale hacks, though, the sheer number of victims can vastly surpass traditional crimes, as demonstrated in these case studies. Most large businesses now employ cybersecurity teams to prevent hacks by regularly testing their organisation's defences. These penetration



> MANY CYBERCRIMINALS INTERVIEWED WERE MOTIVATED NOT BY MALICE, BUT BY GENUINE INTEREST AND CURIOSITY



testers are just one example of the careers available in cybersecurity.

By introducing pupils to the Computer Misuse Act 1990 (or your country's equivalent) and case studies such as these, we can lead discussions to educate pupils on what constitutes the illegal use of computers, the impact of these crimes, and the sentences perpetrators can receive. Here is a selection of questions to lead a discussion with pupils:

- How was the law broken?
- What specific part of the law was broken?
- Who are the victims? How are they affected?
- What might the punishment be?

Taking this one step further, the free Barefoot You're the Jury resources, which can be downloaded for free at **barefootcomputing.org/cyber** after a quick registration, suggest turning classrooms into courtrooms and putting pupils in the roles of defendant, barrister, and jury members. Pupils then hear a number of cybercrime cases and for each, consider whether the law has been broken, who the victims are, and what the punishment might be. The resources even include templates to create a barrister's wig for pupils and a judge's wig for the teacher!

From the same set of resources, You're the Cyber Security Expert brings us back to the positive opportunities of the topic, namely raising awareness of cybersecurity careers. It does this by giving pupils a taste of life in this field as they learn what a brute-force hack is and, importantly, what strategies we could deploy to guard against it. So, for those pupils who exchanged a knowing glance at the mention of hacking, let's harness that curiosity and raise their awareness of rewarding careers that pursue this interest legally. (HW)



JON CHIPPINDALL & ALAN MERRETT

Jon (pictured) is the Barefoot director and the computing lead at Crumpsall Lane Primary School in Manchester, UK. He also leads the computing PGCE at The University of Manchester. Alan is a senior officer in the Cyber Prevent Team at the UK's National Crime Agency. He has 34 years of law enforcement experience, including overt and covert roles with HM Customs and a team leader role at the UK's Interpol Desk and Fugitives Unit.

ROBIN HOOD VS THE SHERIFF OF NOTTINGHAM

Matthew Hewlett shares his thoughts on the importance of developing students' understanding of ethics through the lens of cybersecurity

Consider the following: in 2015, the dating website Ashley Madison was hacked and its users' data was stolen. Names, addresses, and credit card numbers of the people using the site were subsequently leaked. If this wasn't bad enough, Ashley Madison was no ordinary dating site: it specialised in matching people who wanted to have affairs. The consequence of this leak was, among other things, numerous divorces, and at least one person taking their life. Ethically speaking, who should shoulder responsibility for these outcomes? The hacker, for leaking the material? The owners of Ashley Madison, for not securing or encrypting their users' data? Or the users themselves? We will all have a gut response to this, but it is important to be able to develop a considered ethical response.

Robin Hood vs the Sheriff

It is fair to assume, as computer science educators, that we are more comfortable with cybersecurity content knowledge than we are with ethics. If that is the case, how can you help students to approach an ethical quandary in a cybersecurity context? Firstly, remember that you are applying ethics to a context, and that as such, there are developed ethical systems to draw upon. Of the many approaches to ethics, there are two well-used approaches that we can apply to help our students make sense of an ethical question and therefore begin to formulate a response.

A consequentialist approach considers the outcomes or consequences, rather than the underlying motivation of the agent. The tale of Robin Hood is probably one of the most famous examples in history: he stole from the rich to give to the poor, and the theft of private property can be justified by the happiness that his redistribution of an individual's wealth entailed.

By contrast, a deontological approach considers the intentions rather than the consequences of an event when judging a person's behaviour. Actions that adhere to ethical rules are right, regardless of the outcome. Theft, as the Sheriff of Nottingham in the tale of Robin Hood would point out, is theft, and theft is always wrong.

KEY TERMINOLOGY

Ethics: The discipline of studying what is good and bad, right and wrong.

Deontological: An ethical philosophy that believes that morally right actions can be determined by asking whether they adhere to a set of agreed rules.

Consequentialism: An opposing theory that holds that the outcomes of someone's actions define whether they are behaving morally.

Practical applications

If pupils are required to consciously refer to one of these ethical branches in their responses to cybersecurity issues, they will be able to structure their thoughts on the issues more confidently. Having stated an initial position, students are able to develop their opinions more articulately when the inevitable nuances of an ethical argument present themselves.

For the following cybersecurity ethical scenarios, ask students how they would approach these issues and whether they consider themselves to be consequentialist or deontological thinkers. Is there an agreed moral principle that should be adhered to? Can it be broken for the sake of the outcomes?

1. You are an ethical hacker and have uncovered a security flaw in a globally used operating system. This flaw can allow unethical agents to inject malicious code onto people's computers. Before you can take action, a friend who works for a rival company offers to employ you on a lucrative contract as long as you stay quiet about your discovery.
2. You work for a social media company and have access to the 'big data' that is generated by the millions of users of the platform. A general election is underway and the party



In cybersecurity ethical dilemmas, students must ask themselves, are they Robin Hood or the Sheriff of Nottingham?

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that is almost certainly going to win is, in your opinion, opposed to your nation's values. Providing the data to another political party could successfully swing the election to one that is better for society. Do you share it?

3. You have developed a messaging platform with secure end-to-end encryption. The majority of your users are using your platform to engage in illegal activity. Should you maintain the platform?
4. You run a new PR firm that has secured its first major contract. Your firm uses software that has security flaws, but you can't currently afford the cost of resolving the issues. What should you do?

Can you think of extra context that would challenge your students' initial response? Having identified their initial ethical stance, it should be easier for them to respond further.

Why is it important?

Exposure to these ethical concepts is vital, despite the fact that many computing curricula dedicate little time to them. Admittedly, it can be hard to fit these concepts into lessons with less teaching time than many comparable subjects — lessons which are also under pressure to deliver programming skills and digital literacy. However, we have to play our part in helping our students understand their own actions and, as much as possible, the actions of others (for example, dealing with questions around why people may hack, rather than just focusing on how to hack).

> "IS THERE AN AGREED MORAL PRINCIPLE TO ADHERE TO? CAN THAT PRINCIPLE BE BROKEN FOR THE SAKE OF THE OUTCOMES?

It's often said that we are preparing students for a world they can't imagine. I disagree. In computer science we are teaching students to shape a world we can't imagine. It is incumbent upon us to develop young people with not just the skills, but also the ethical grounding to make them responsible, empathetic, and considerate overseers of the ongoing technological revolution. Did the owner of Ashley Madison consider his deontological duty to do no harm? Did the people using the website, presumably all consequentialists, apply a reasoned ethical argument to their actions? Whenever your students are presented with an ethical dilemma, cyber or otherwise, get them to start by picking a side. Are they Robin Hood or the Sheriff of Nottingham? (HW)



MATTHEW HEWLETT

Matthew is the computing development lead at Fairfields Primary School in Basingstoke, UK. He is a facilitator for the UK's National Centre for Computing Education and a facilitator for Isaac Computer Science. Matthew is also a resource author and a keen Raspberry Pi tinkerer.

KNOW THY ENEMY

Pretending to be the bad guys adds depth, understanding, and fun to cybersecurity classes, and helps us to become better good guys

Know thy enemy. This is one of the most famous tenets of warfare, according to the legendary Chinese general Sun Tzu. It's great advice on the battlefield, and its utility extends to the teaching of cybersecurity. In a way, cybersecurity is war: an ever-evolving conflict between those who want information and those who have that information. By the time I start teaching phishing, most students have already been phished. If you want to beat the bad guys, I teach them, you have to walk a mile in their shoes to understand them.

Walk a mile

When I introduce cybersecurity, I use as many real-world examples as possible. I keep every single phishing email I get in a folder, so that when we study phishing, we are studying primary sources. I pick out a few and, as a class, we study each one. We ask ourselves, what is this person trying to accomplish? How are they trying to accomplish it? What is their motivation? Understanding the offence improves our defence. Understanding the techniques phishers use helps us to identify them more quickly and accurately.

After studying these emails, it's time for students to show me what they've learnt, by phishing me. In doing so, they have to ask themselves the same question as the bad guys: what am I trying to accomplish, and how? Some students' emails are more convincing than others, but they all make it clear that they know what a phishing attempt looks like. Most of them are funny, and occasionally, one of them actually fools me. Any student that does this gets extra credit and provides the entire class with another learning opportunity: it's a win-win situation.

By studying and then creating real-life artefacts, we deepen our understanding of them. Being the bad guys makes us better good guys. So, the next time you study a threat, have your students emulate it. Have them write a clickbait title for a fake news article, or equate a spurious correlation with causation. In doing so, they gain a level of understanding that does not come with simply studying the subject. They understand their foe, and as Sun Tzu said, "If you know the enemy and know yourself, you need not fear the result of a hundred battles." (HW)

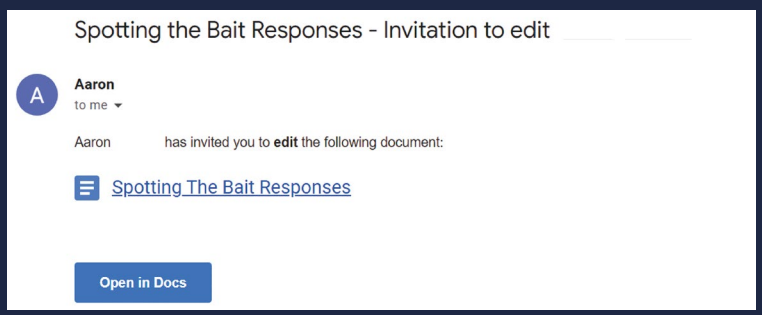


ZACH HUFFMAN

Zach is an upper-school computer science teacher at the Hun School of Princeton in New Jersey, USA. He is an avid gamer and has spent the last five years teaching computer science, from kindergarten all the way up to 12th grade (**@ltwheat**).

PHISHING CONTEST: THE WINNING ENTRY

Most real-life phishing emails try to alarm you into acting quickly and irrationally. Aaron, last year's winner, appealed to my lack of attention. I primarily use Google Docs for grading, and receive about 50 emails every week that all say "[Student] has invited you to edit the following document," with the little blue Google Docs icon. I click these without a second thought. Aaron knew that, and exploited it. This provided a meaningful teaching moment in class.



KEEP CURIOUS AND CARRY ON HACKING

Ben Garside explores the meaning behind the word 'hacking' and argues why we should teach students to hack

Over time, the meaning of the word 'hacking' has changed. Today, it often has pejorative connotations around the bad things that bad people do on their computers. However, the term has much more positive origins, with its first recorded use coming from MIT's Tech Model Railroad Club in the 1950s.

> WE DECIDED TO GO BEYOND THE THEORY AND GIVE STUDENTS THE CHANCE TO EXPLORE THE CODE BEHIND THESE ATTACKS

Members of this club enjoyed taking apart model trains to discover how they worked, with the aim of enhancing them; they were 'hacking' the technology they were working with. In this article, I argue that hacking shouldn't be used as a dirty word, and that teaching students how to hack isn't necessarily a bad thing.

When I was a teacher, I often asked classes to open up old computers over a series of lessons about hardware. We would look at their components, see how they fit together, and discuss what we could do to improve the machines. This method of teaching students about hardware had more benefits than just visualising the abstract: without realising it, I'd been teaching my students how to hack. Just as Grace Hopper famously enjoyed dismantling clocks as a child to figure out how they worked, my students were learning how to be problem-solvers and how to fill the gaps in their knowledge. They were learning to hack, in the spirit of the original meaning of the term.

Developing students' problem-solving skills is no bad thing, but what if we were to take this a step further and also teach students how to hack in the more common, malicious sense of the word? When writing cybersecurity units for the Teach Computing Curriculum (**helloworld.cc/tcccyber1** and **helloworld.cc/tcccyber2**), this is exactly what we did. We made the conscious decision, in places, to go beyond the theory of how these attacks work and give students the opportunity to explore the code that makes them happen. We created activities in which learners use very unsophisticated code that could be used for a brute-force attack, as well as an activity in which students perform an SQL injection on a fake website.

We're not encouraging students to become criminals, of course, and we contextualise these activities with the ethics and legalities of these types of action. As Zach argues in the previous article, I believe that we're encouraging students to get a deeper understanding so that they can better protect themselves against real threats. I relate this approach to the karate principle. Although martial arts teach people how to do harmful things to other human beings, a sensei is there to guide students in self-control and discipline. Relating this to hacking, students can easily go online and follow hacking tutorials, but at home, there is no sensei there to guide them about the rights and wrongs of their choices. As educators, we need to remember our role as sensei.

Let's keep teaching our students to be curious about technology, to want to know how something works, to be problem-solvers, and, therefore, to be hackers — just like the good people of MIT's Tech Model Railroad Club. (HW)



BEN GARSIDE

Ben is a learning manager for the Raspberry Pi Foundation. He has worked on the production of the Teach Computing Curriculum, and on online courses including the recently released *Introduction to Machine Learning and AI* (**@BenberryPi**).

CYBERSECURITY FOR GIRLS

Babak Ebrahim explains how his school used a cybersecurity club to increase interest in computing among girls

It is impossible to walk into an upper-secondary computer science lesson and not notice the number of boys compared to girls. This is a common issue across the world; it is clear from reading community forums and news headlines that there is a big gap in female representation in computing. To combat this problem in my school, I started organising trips to local universities and arranging assembly talks for my Year 9 students (aged 13–14). Although this was helpful, it didn't have as much impact as I expected on improving female representation. This led me to alter our approach and target younger female students with an extracurricular club.

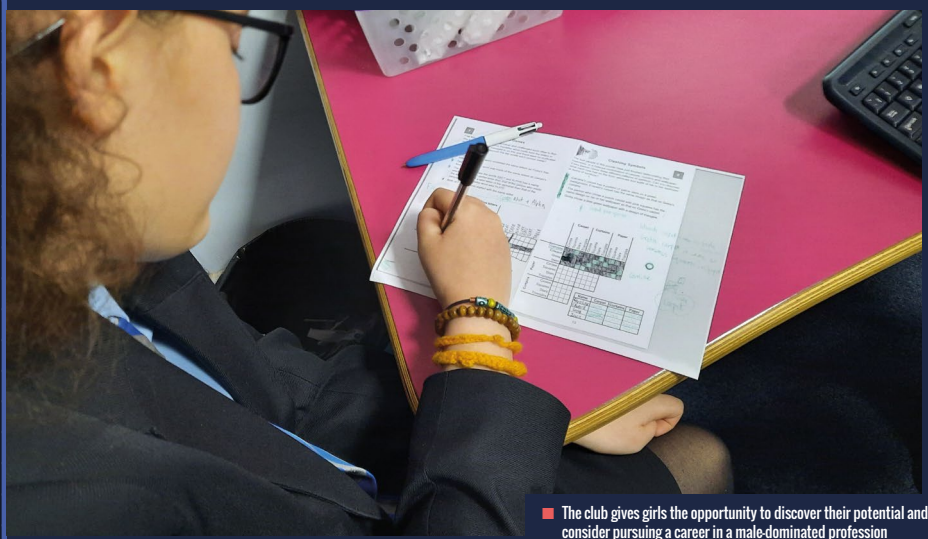
As part of our lower-secondary curriculum, all pupils study encryption and cryptography, and we were keen to extend this interest beyond lesson time. I discovered the CyberFirst Girls Competition (**helloworld.cc/cyberfirst**), aimed at Year 8 girls in England (aged 12–13) with the aim of influencing girls when choosing their GCSE subjects (qualifications pupils take aged 14–16). Each school can enter as many teams as they like, with a maximum of four girls in each team. I advertised the event by showing a video of the previous year's attendees and the winning team. To our delight, 19 girls, in five teams, entered the competition.

Club activities

To make sure that this wasn't a one-off event, we started an after-school cybersecurity club for girls. All computing teachers encouraged their female students to attend. We had a number of female teachers who were teaching maths and computing as their second subjects, and I found it more effective when these teachers encouraged the girls to join. They would also help with running the club. We found it to be most popular with Year 7 students (aged 11–12), with 15 girls regularly attending.

We often do cryptography tasks in the club, including activities from established competitions. For example, I recently challenged the club to complete tasks from the most recent Alan Turing Cryptography Competition (**helloworld.cc/alanturing**). A huge benefit of completing these tasks in the club, rather than in the classroom, was that students could work more informally and were not under pressure to succeed. I found this year's tasks quite challenging for younger students, and I was worried that this could put them off returning to the club. To avoid this, I first taught the students the skills that they would need for one of the challenges, followed by small tasks that I made myself over two or three sessions.

For example, one task required students to use the Playfair cipher to break a long piece of code. In order to prepare students for decoding this text, I showed them how the cipher works, then created empty grids (5 x 5 tables) and modelled the technique with simple examples. The girls then worked in teams of two to encrypt a short quote. I gave each group a different quotation, and they weren't allowed to let other groups know what it was. Once they applied the cipher, they handed the encrypted message to another group, whose job was to decrypt it. At this stage, some would identify that the other group had made mistakes using the



The club gives girls the opportunity to discover their potential and consider pursuing a career in a male-dominated profession

TRY IT FOR YOURSELF!

- Dedicate a school display board to celebrating the work students do at your cybersecurity club. This may encourage others to come along, and help to retain current members.
- Invest in a long-term plan by focusing on early-year groups. We find that Year 7 students (aged 11–12) are generally keener to attend after-school clubs than older pupils, and will then continue attending as they get older.
- Work with other teachers to promote and encourage more students to join the club.
- As women are underrepresented in computing, encourage female members of staff to help run your club.

techniques, and they would go through the text together to identify them. Once students were confident and competent in using this cipher, I presented them with the competition task, and they then applied the same process. Of course, some students would still make mistakes, but they would realise this and be able to work through them, rather than being overwhelmed by them.



Students feel under less pressure and can work more informally in a club-based setting

> "EVERY EFFORT THAT WE PUT INTO OUR STUDENTS' LEARNING JOURNEYS WILL HELP SHAPE WHO THEY BECOME IN THE FUTURE

Trips

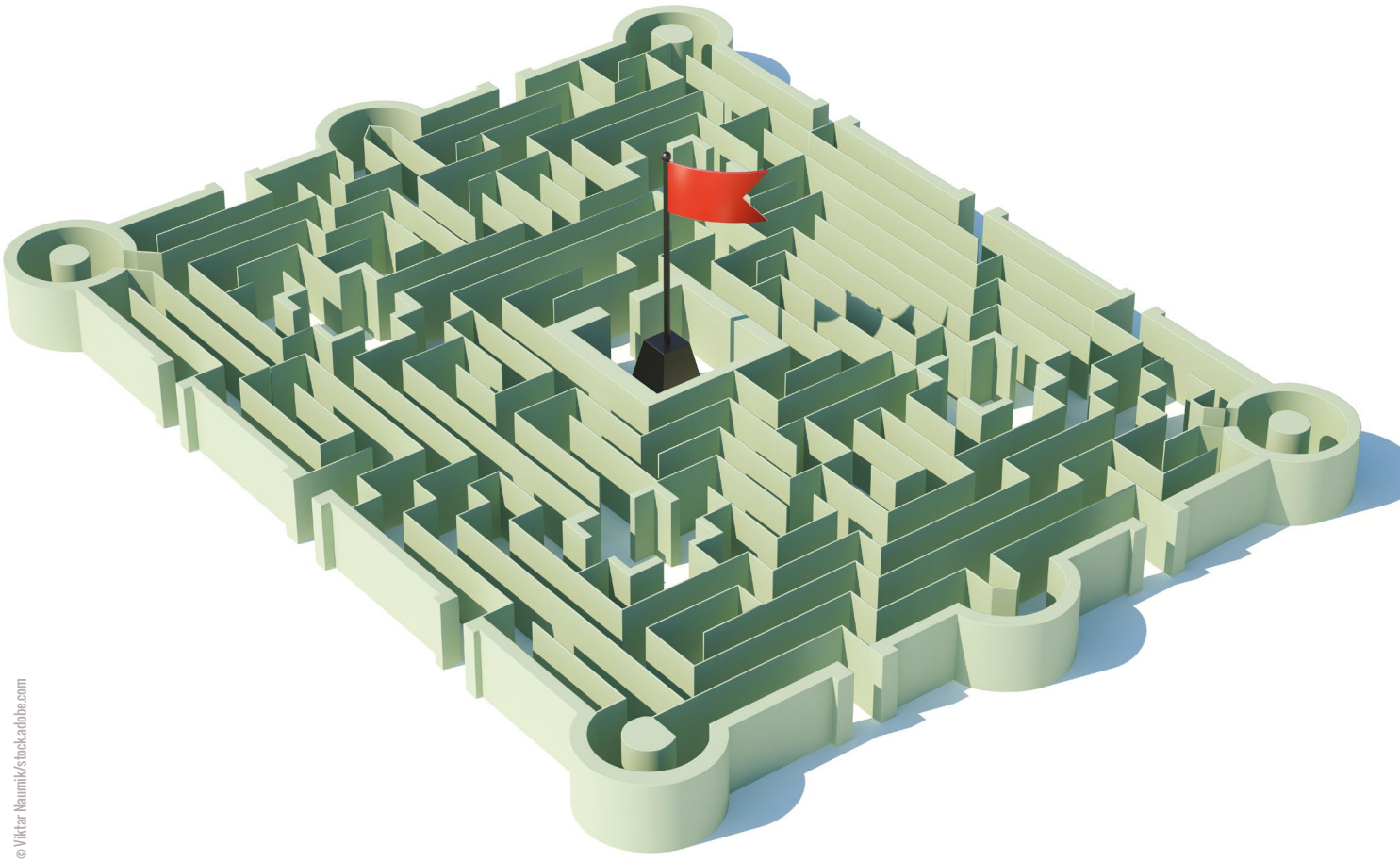
Other club activities have included a trip to Bletchley Park. As a part of the package, students took part in a codebreaking workshop in which they used the Enigma machine to crack encrypted messages. This inspirational trip was a great experience for the girls, as they discovered the pivotal roles women had in breaking codes during the Second World War. If you're not based in the UK, Bletchley Park also runs a virtual tour and workshops (**helloworld.cc/bletchley**). Another worthwhile activity in the club has been for older pupils, who are in their second year of attending, to mentor and support girls in the years below them, especially in preparation for participating in competitions. You could also organise a day trip to a local university where students could attend different workshops run by female lecturers or university students; this could involve a mixture of maths, science, and computer science activities.

We are thrilled to learn that one of our teams won this year's CyberFirst Girls Competition! More importantly, the knowledge gained by all the students who attend the club is most heartening, along with the enthusiasm that is clearly evident each week, and the fun that is had. Whether this will have any impact on the number of girls who take GCSE remains to be seen, but it certainly gives the girls the opportunity to discover their potential, learn the importance of cybersecurity, and consider pursuing a career in a male-dominated profession. There are many factors that influence a child's mind as to what they would like to study or do, and every little extra effort that we put into their learning journey will shape who they will become in the future. (HW)



BABAK EBRAHIM

Babak is a computer science and mathematics teacher at Bishop Challoner Catholic College Secondary in Birmingham, UK. He is a CAS Community Leader and works as a CS Champion for England's NCCE (**@BishopChalComp**).



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CAPTURE THE FLAG TO CAPTURE INTEREST

Nancy Stevens shares her classroom experience with using a Capture the Flag competition to engage students with cybersecurity concepts

I had intended to look into a cybersecurity competition for my students for quite some time, but this was getting pretty comfortable at the bottom of my to-do list as competing priorities took over. Pandemic teaching and learning is tough, though, and by the spring of last year, my district had tried virtual schooling, in-person learning in cohorts, and a hybrid plan that was the worst of them all. I was teaching a number of courses and not only was I discouraged by my failure to get to know my students, I'm not sure that I would even recognise them without their masks. The joy of teaching for me is in taking students on a journey: exploring new content, sharing ideas, and developing a better understanding of the technology in our lives. I needed something that would bring the joy back to the classroom.

Capture the Flag

I soon found just the solution at a cybersecurity summit I attended. In one of the sessions, David Raymond of the US Cyber Range introduced a Capture the Flag (CTF) competition that schools could enter. This CTF was temporarily available to teachers with US Cyber Range accounts (a fee-based service). It would last for three days and students had 90-minute class

TRY IT FOR YOURSELF!

uscyberrange.org: Cybersecurity labs, including a web-based CTF platform

teachcyber.org: Organisation that provides cybersecurity resources, training, and support to secondary school educators

cryptologicfoundation.org: Foundation that shares cryptology educational resources

periods where they would work on the tasks, as well as a little homework time. CTFs take different forms, but most educational ones are jeopardy-style: participants must undertake different problem-solving or programming tasks, and for each task that teams or individuals complete, they are given a flag that equates to points. There are different types of task in CTFs, including cryptography challenges (decrypting or encrypting data), steganography challenges (finding information hidden in files or images), and web challenges (exploiting web pages to find specific pieces of text).

> “I NEEDED SOMETHING THAT WOULD BRING THE JOY BACK TO THE CLASSROOM, AND CAPTURE THE FLAG DELIVERED

The competition that I signed some of my students up to was free, very easy to join, and would get students engaged for the next few days. I could do this! My introductory computer science students (aged 14–16) were at various places in the curriculum, so I pitched the CTF to a group of four students who were working ahead. These students were novice Python programmers and did not have CTF experience. As they looked over the tasks, there were initially a few questions (What is steganography? What is a packet tracer?), but I would provide encouragement and check-ins on their progress only, pushing them to research their questions themselves.

Benefits

CTF competitions present numerous benefits to teaching cybersecurity. Within 24 hours of introducing the challenge to my students, they were problem-solving, researching, communicating, and collaborating — and there were even points on the leader board! I felt like Gene Wilder in *Young Frankenstein* when the monster is brought to life by an electrical charge. CTFs provide the perfect opportunity for students to explore and investigate content on their own terms. Instead of me standing at the front of the classroom teaching a lesson on steganography, my students were searching online and discussing how to solve a problem with hidden information. In this way, I also found that I didn't have to be the expert in the room. I took great pride in watching students write code that exceeded my ability as they took control of their learning, and I instead provided them with relevant content, encouragement, and guiding questions.

In addition to working in class, I found out that students were texting each other in the evenings and continuing to work on the tasks at home. Clearly, you should never underestimate the power of a leader board and points! I know colleagues who have gamified their courses, and the CTF reminded me of how points and challenges can be real motivators. The jeopardy-style format and the hints in the CTF created a challenging yet attainable competition, and a fun way to give students a taste of the skills and understanding required for a career in the cybersecurity industry.

Finally, my students were developing soft skills beneficial to their studies and future careers. Since it was a CTF with limited attempts at each task, coordination and collaboration were important. Students were learning to work together as a team; to communicate and delegate clearly; to persevere; and to explore different approaches to solving a problem, as well as the obvious boost to their computational thinking skills and cybersecurity knowledge and understanding. By the end of the week, my students were in fourth place on the leader board, out of 148 teams!

Cybersecurity education can change the future. It gives the opportunity to learn about protecting your personal information, and it can offer a career in protecting your nation. A CTF or a cybersecurity competition will help you be the change in your classroom. (HW)



NANCY STEVENS

Nancy is a cybersecurity education advocate with Teach Cyber (**teachcyber.org**), which provides cybersecurity courses for high-school students, as well as professional development, virtual lounges for teachers to meet, and free guidelines and curriculum access. She is a former computer science teacher at First Flight High School in North Carolina, USA. She is also a Code.org facilitator.

HANDS-ON CYBERSECURITY

Researchers from Vanderbilt University share how they introduced hands-on cybersecurity to high-school students with networked robots

Since 2015, our team at Vanderbilt University has been working on a block-based educational programming environment called NetsBlox (netsblox.org). Similar to Scratch and based on the open-source code base of Snap!, NetsBlox uses networking abstractions including services and message passing to introduce computer networking concepts to students in an accessible manner. It uses these same networking abstractions to allow students to program robot vehicles and interact with cybersecurity issues in a hands-on way. In this article, we will first introduce NetsBlox, before discussing its applications for cybersecurity learning and its use at a cybersecurity summer camp we ran.

NetsBlox

The NetsBlox server hosts a number of services that can be accessed by a single new block called **call** (see **Figure 1**). These services allow students to get various interesting data from the internet, such as weather conditions, Covid-19 numbers, movie ratings, and stock quotes. They can visualise the data on top of Google Maps backgrounds or generate plots using the chart service. The **call** block is self-documenting: selecting a service configures a drop-down menu of the various functions available. Selecting a function shows the required input argument slots.

The other networking abstraction is message passing. A NetsBlox program can send messages with configurable data payload to any other NetsBlox program running on the internet. Just two new blocks are needed: **send message** and **when I receive**. Message passing makes it possible for students to create online multiplayer games and social applications.

Robots and cybersecurity

NetsBlox uses the very same networking abstractions (services and message passing) to allow students to program robot vehicles. A new service, RoboScape (**helloworld.cc/roboscape**), will enable students to send commands to a Wi-Fi–enabled robot (currently limited to the Parallax ActivityBot 360°, **helloworld.cc/activitybot**). The robot, in turn, responds with messages of acknowledgement or sensor values, depending on the command. **Figure 2** shows an example command making a robot spin by turning its left and right wheels in opposite directions, followed by a message header that is triggered every time the robot with the ID 'robot' sends a message with the content provided in the variable 'message'.

This is a new twist on educational robotics. Firstly, the student's program runs in the browser, making it much easier to debug; and no wires are needed, as there is nothing to compile and download. This also enables remote robotics: the student and the robot do not need to be co-located; only a video stream of the robot's location is required. What makes RoboScape truly unique, though, is the ability for students to eavesdrop on the wireless communication between other students and their robots. They can even send commands to any unprotected robot on the network, which it will gladly execute. This provides an eye-opening illustration to students of why cybersecurity is so crucial. Once they realise how vulnerable their robots are, we can introduce them to the various mechanisms included with RoboScape to defend their robots from cyberattacks.



Figure 1 Example calls in NetsBlox

Cybersecurity camp

Using NetsBlox and RoboScape, we created a curriculum for a week-long cybersecurity summer camp for high-school students. The curriculum covers attacks and attack detection; denial of service; encryption; key cracking; insecure key exchange; and replay attack, all using NetsBlox and RoboScape. This curriculum is not intended as a thorough coverage of all important cybersecurity concepts. Rather, our goal is to introduce cybersecurity in an engaging and motivating manner to spark students'



Students use robots to interact with cybersecurity issues

interest in exploring the topic further.

After an introduction to NetsBlox and RoboScape, we first task students to detect whether somebody is trying to attack their robot. This can be done by comparing the number of commands they sent versus the number of commands the robot acknowledged receiving. Next, we illustrate denial of service attacks. We pick one student and ask them to drive around the room while all other students are repeatedly sending short beep commands to the same robot. Soon, the robot becomes unresponsive and starts to drive erratically. To defend against this type of attack, RoboScape includes rate control: the students can set how many commands per second the robot will accept from any one program and also the penalty timeout it enforces when the limit is exceeded. This sets up a fun game we call tug of war: two students share a single robot set in the middle of an arena. They need to drive the robot to their side of the field by using any commands they wish, but especially rate control. This was a very popular activity in our camps. Students came up with many innovative strategies to try to shut out the other student by making them exceed the rate limit.

The rest of the camp curriculum has similar fun activities related to robotics and cybersecurity. We have run six such camps in the last couple of years with over 100 pupils in total. Engagement has been very high, with one teacher remarking, "... their cell phones, I didn't see them out, they were not distracted by them". Our post-camp surveys have indicated that the camps and their hands-on teaching increased many students' interest in computer science and cybersecurity. We truly believe that making learning fun and engaging is the way to increase participation in STEM. To make the curriculum even more widely accessible, we now have a simulated 3D environment where multiple students can join remotely and run the same programs on the virtual robots. You can find an overview of each unit in the curriculum and an introductory video at **helloworld.cc/roboscape**. (HW)

> "OUR ROBOT TUG OF WAR GAME WAS VERY POPULAR

ÁKOS LÉDECZI, GORDON STEIN, MIKLÓS MARÓTI & BRIAN BROLL

The authors all work at Vanderbilt University in Nashville, Tennessee, USA. Ákos is a professor advising his PhD student Gordon working on the NetsBlox system. Miklós is a visiting professor and Brian, after getting his PhD centred on related technologies, is now a research scientist. Their work is sponsored by the NSA and the NSF.

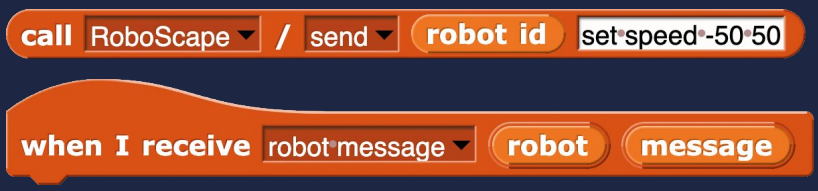


Figure 2 Example robot command and message

QUANTUM CRYPTOGRAPHY

Andreas J. C. Woitzik and **Stefan Seegerer** share an activity for older pupils exploring the fundamentals of quantum cryptography and how to detect eavesdropping

We rely on secure communication for a lot of tasks, from private chat to Covid certificates. Fortunately, we have asymmetric encryption protocols such as RSA (helloworld.cc/rsa), where people do not need to have some kind of secure channel to exchange an asymmetric key. However, the rise of quantum computers means that a lot of cryptography systems are now more prone to deciphering, as these computers can decode some security protocols easily. New protocols therefore need to be invented, and interestingly, quantum information can also be used for encryption itself. These quantum protocols enable secure communication by noting a possible interference by an eavesdropper.

One such protocol is BB84, which is fun to discover with students. Before introducing it, students should already have knowledge of one-time pad and classical ciphers such as Caesar, as the secure cryptography protocol motivates the quantum key exchange. Asymmetric cryptography and potential threats to breaking encryption through Shor's algorithm are also useful prerequisites to introducing this protocol.

The fundamentals

The BB84 protocol (**helloworld.cc/BB84**) is built upon two key features of quantum information, which are strikingly different to classical information:

Invasive measurements: Quantum information, in general, is modified when measured.

No-cloning theorem: Quantum information, in general, cannot be copied.

Before we look at these features, we need to understand how we can describe quantum information. The fundamental bit of quantum information is a qubit, which is visualised here as a straight line crossing the origin on a unit circle (see **Figure 1**). The state of a qubit can be any such line that crosses the origin at any angle (meaning that there are infinitely many different states for a single qubit; you can simply rotate it). Usually, we define the x-axis as a 0° angle (the blue line in **Figure 2**) and this line describes a quantum 0, written $|0\rangle$. The 90° rotated line corresponds to a quantum 1, written $|1\rangle$ (the orange line in **Figure 2**). The final states that we will need for our BB84 protocol later are also shown in **Figure 2**. There is the $|+\rangle$ state, which corresponds to a line with a 45° angle to the x-axis (the green line in **Figure 2**). Finally, there is the $|-\rangle$ state (the orthogonal state of $|+\rangle$), which corresponds to a line with a 135° angle to the x-axis (the red line in **Figure 2**).

Returning to the key features of quantum information, we will deal first with invasive measurements (the principle that quantum information is generally modified when it is measured). To access the value of a qubit, we need to measure it, and this can alter its state. To measure the qubit, we need a measurement basis, which you can visualise as a cross defined by two orthogonal (perpendicular) lines. The two bases we need here are ($|0\rangle$, $|1\rangle$) and ($|+\rangle$, $|-\rangle$) (see **Figure 3**). If we measure in a basis, the current state is changed to one of the two orthogonal lines. The probability to be mapped to any of them depends on the angle between the line that describes the qubit and the two orthogonal lines. In the case of our protocol, we only use the angles 0°, 45°, 90°, and 135°, and here the probabilities of measurement are either 0, 1,

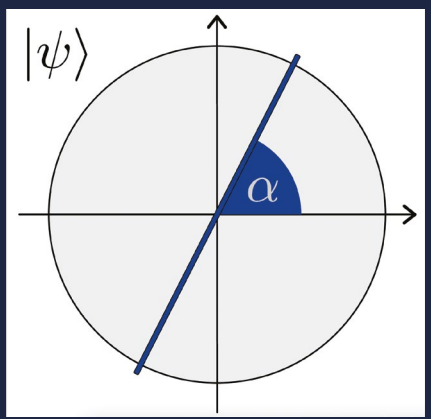


Figure 1 Arbitrary qubit state *Credit: Andreas J. C. Woitzik*

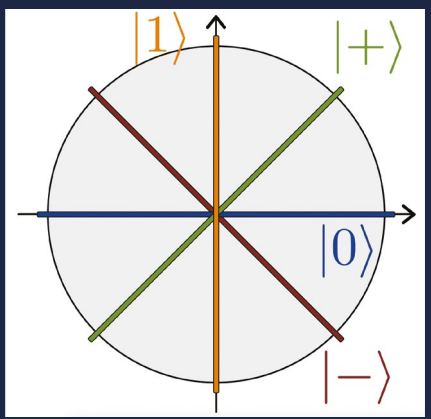


Figure 2 The four qubit states relevant for BB84 *Credit: Andreas J. C. Woitzik*

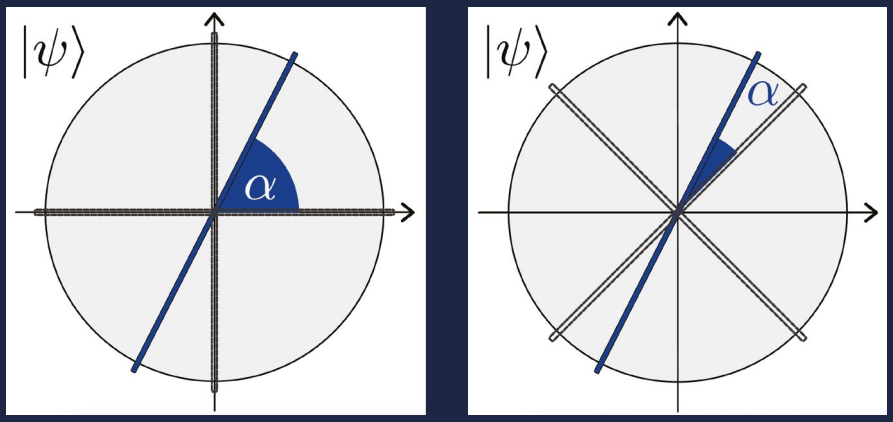


Figure 3 Left: qubit with measurement basis ($|0\rangle$,$|1\rangle$), and right: with ($|+\rangle$,$|-\rangle$) *Credit: Andreas J. C. Woitzik*

or ½. In our game, we will use a coin (with 0 being heads and 1 being tails), rather than trigonometry, to measure with respect to our bases.

The second feature of quantum information is the no-cloning theorem (the principle that quantum information cannot generally be copied). This theorem has a mathematical proof that is outside the scope of this article, but its implication is described by its name. Given an arbitrary quantum state, we cannot simply make a copy of it. This will be important later, as the eavesdropper cannot simply copy the qubits that our two secret-sharers send to each other.

The BB84 protocol

The BB84 protocol is a quantum key exchange protocol, meaning it allows the exchange of a shared secret bitstring between two people, say Alice and Bob. After exchanging the key, it can be used for secure one-time pad communication or other cryptography protocols. We will give a short description of the necessary steps and describe them as a game played by four students. You will need:

- 8 qubits (a template for a circle with specified angles, a paper arrow, a paper cross, and a brass fastener to mimic the images in the table on the next page — see **Figure 4**)
- 4 students (playing the roles of Alice, Bob, Hermes, and Eve)
- 2 coins

Repeat eight times:

1. Alice flips a coin (heads 0, tails 1) to create a random bit. This is the bit intended for the shared key.
2. Alice flips the coin again to randomly decide an encoding basis: ($|0\rangle$, $|1\rangle$) or ($|+\rangle$, $|-\rangle$).
3. If the random bit is a 0, Alice prepares a qubit in $|0\rangle$ or $|+\rangle$. If the random bit is a 1, she prepares a qubit in $|1\rangle$ or $|-\rangle$ (see **Table 1** for possible outcomes).
4. Hermes carries the qubit from Alice to Bob.
5. Bob decides randomly for measurement basis ($|0\rangle$,$|1\rangle$) or ($|+\rangle$,$|-\rangle$) by flipping a coin.
6. Bob then measures the qubit with the basis from step 5 according to the image. If Alice and Bob's bases match, Bob measures the same outcome as Alice did. Otherwise, there is a 50 percent chance for each outcome. Hermes helps in these cases by throwing a coin to decide the outcome (see **Table 2**).
7. Alice and Bob compare which measurement bases they used. If Alice and Bob used the same basis, they include this bit in the key. Otherwise, they discard it.

The resulting key can now be used for a one-time pad or for any other cryptography protocol.

Eavesdroppers

Eve, whose role in the protocol has not yet been introduced, is our potential eavesdropper. Her role is to take over the

> "PLAYING THIS GAME HELPS MAKE ABSTRACT CONCEPTS MORE CONCRETE





ANDREAS J. C. WOITZIK AND STEFAN SEEGERER

Andreas is a PhD student in quantum information science in the Quantum Optics and Statistics group at the University of Freiburg, Germany. He is interested in bringing quantum information to schools.

Stefan is the quantum education manager at IQM Quantum Computers, exploring ways to make quantum computing accessible to everyone (**@StefanSeegerer**).

qubits from Hermes at step 4, then do whatever she wants with them before handing them back to Hermes for him to deliver to Bob. Eve can choose to look at each qubit or not. If she does the latter, she cannot gain any information and hence won't know anything about the qubit's state. The magic happens as soon as she looks at the qubit, which means that she measures it. To measure the qubit without changing its state, though, she needs to get its basis right (remember: simply copying is not allowed in the quantum information world).

As she knows nothing about the basis Alice used to prepare her qubits, Eve only has a 50 percent chance of guessing correctly. If she does, she can observe the state of the qubit without changing it. But if she chooses the wrong basis, she changes the state of the qubit. After Bob

> THE MAGIC HAPPENS WHEN THE QUBIT IS OBSERVED

and Alice exchange the bases used for measurements, they can use parts of their remaining qubits to check whether they both measured the same values. If Bob measured on the same basis as Alice, but observed a different outcome, he knows that an eavesdropper has interfered.

In summary, the activity shows a different spin on cryptography, as quantum information allows for different ways of encoding information. By playing this game, students can get a hands-on impression of the protocol and can more easily keep track of the states of the real-life qubits, making these abstract concepts more concrete. They also get a feel for when randomness kicks into quantum information through the coin toss. In our experience, playing BB84 with students can help to deepen their understanding of the core ideas of cryptography. (HW)

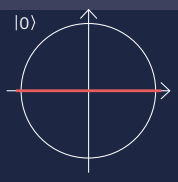
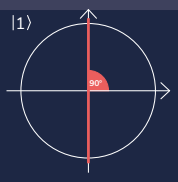
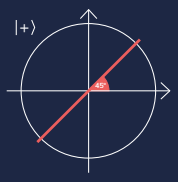
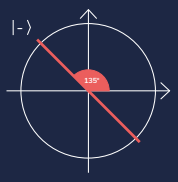
ALICE QUBIT PREPARATION SCHEME	1st coin flip outcome: random bit	
2nd coin flip outcome: encoding basis	0	1
0		
1		

Table 1 The possible outcomes in step 3 of the game

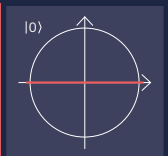
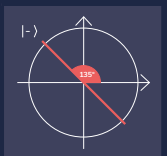
QUBIT RECEIVED FROM ALICE				
Measurement in {|0⟩,|1⟩}	0	1	Hermes tosses a coin for 0 or 1	Hermes tosses a coin for 0 or 1
Measurement in {|+⟩,|-⟩}	Hermes tosses a coin for 0 or 1	Hermes tosses a coin for 0 or 1	0	1

Table 2 The possible outcomes in step 6 of the game



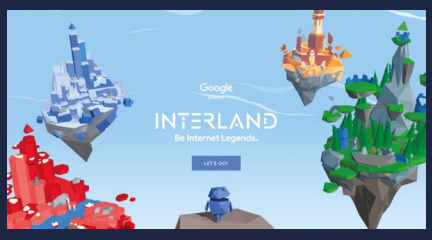
Figure 4 A self-made physical representation of a qubit *Credit: Andreas J. C. Woitzik*

CYBERSECURITY: THERE'S A RESOURCE FOR THAT!

Donna Rawling shares resources to help engage primary students in cybersecurity learning, supporting them in becoming positive digital citizens

Our young learners grow up well versed in rapidly advancing technologies, and there are ever-more sophisticated threats to both their private information and their personal safety. As well as giving them positive experiences of technology, we have a responsibility to make them aware of the potential dangers. Here, I've curated a helpful list of resources that you can use to teach primary-aged pupils about cybersecurity and e-safety. (HW)

RESOURCE	ABOUT
Barefoot Computing (**barefootcomputing.org/cyber**)	This collection of free unplugged activities and interactive games was created together with the UK's National Crime Agency. Topics range from online ownership, to phishing, to the law, to password protection.
Cybergames UK (**cybergamesuk.com**)	Another collaboration with the UK's National Crime Agency, this site features free online games dealing with aspects of cybersecurity, including introductions to malware and firewalls, substitution ciphers, and network ports.
Be Internet Legends (**helloworld.cc/legends**)	This Google program empowers children to use the web safely, and includes lesson plans, codes of conduct, and a fun interactive game, Interland (**helloworld.cc/interland**), in which kids explore issues such as personal privacy, real versus fake info, and thinking before sharing.
Think U Know (**thinkuknow.co.uk**)	This range of resources supports teachers and parents in ensuring children stay safe online, including platform games in which learners answer questions about sharing personal information and pictures, watching videos, and chatting with people online.
iDEA (Inspiring Digital Enterprise Award) badges (**idea.org.uk**)	Billed as the online equivalent to the UK's Duke of Edinburgh awards, these interactive badges have been designed by leaders of industry and can be worked through at a learner's own pace. The 'Citizen' badges include units on cyberspies, code cracking, being safe on social media, and digital ethics. There are three levels of badge (Bronze, Silver, and Gold). They are fun and engaging, and one of the most-requested sites whenever I run a free-choice lesson for children!
Ask an expert!	One of the best resources you have access to is people! Local police authorities usually have dedicated cybersafety teams headed up by expert officers who are often happy to run staff CPD and workshops for parents, and to come and talk to your children. I can highly recommend this as a great way to get your learners thinking about the choices they make and how to get the most out of their digital journey.

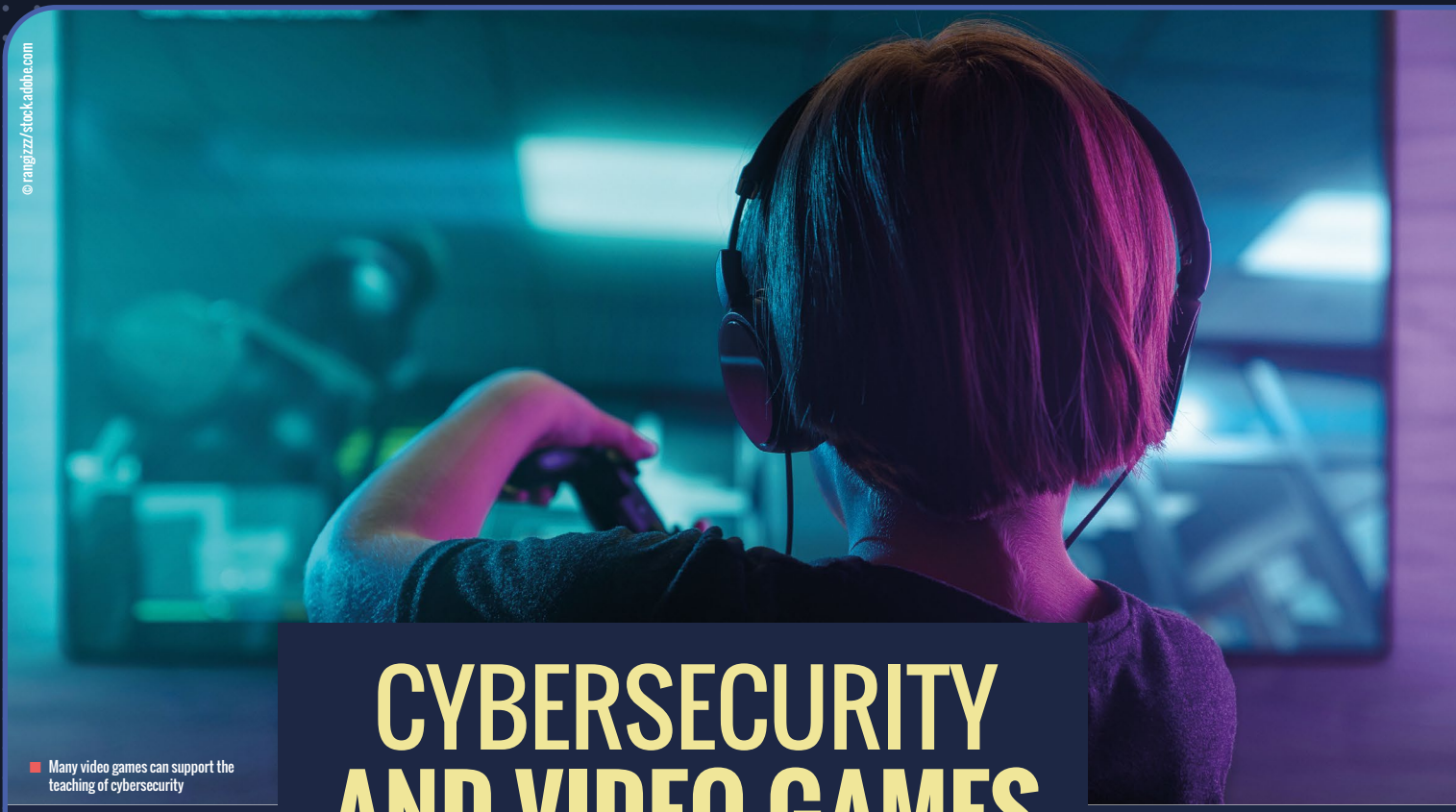


Google's Interland game explores cybersecurity and e-safety in a fun way



DONNA RAWLING

Donna currently works for educational technology solution provider MGL as a computing curriculum consultant, and is a former primary computing coordinator. She is a CAS Master Teacher and a Raspberry Pi Certified Educator (**@DdR333**).



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Many video games can support the teaching of cybersecurity

CYBERSECURITY AND VIDEO GAMES

Neil Rickus and **Andy Robertson** explore how video games can enable pupils to develop their understanding of cybersecurity

In previous issues of Hello World, I [Neil] have examined how retro video games can be used to teach aspects of the computing curriculum, along with discussing how game-based learning can help pupils develop their understanding of computing concepts. Many commercial video games can also support the teaching of computing-related content, including cybersecurity, with a range of benefits often cited, such as developing teamwork, stimulating creativity, promoting critical thinking, and improving decision-making. In this article, we will first introduce how to use video games in the classroom, before Andy introduces using video games to develop cybersecurity understanding. Finally, we will discuss how video games can be used as case studies in the teaching of cybersecurity, and offer up some useful resources.

Using video games in the classroom

A number of factors need to be considered to ensure video games support teaching and learning in the classroom. As with all educational technology, usage needs to be part of a well-planned sequence of learning, with clear objectives and outcomes identified. The use of video games might therefore form only a small part of a lesson, to address a particular issue or concept, rather than being the focus of the whole session. For example, the game Beholder, outlined later in this article, could be used for starting discussions related to consent for taking photographs and videos.

In the classroom, you can use these games like an interactive text. You can play them together as a class and then pause to discuss. However, unlike a text, your experience and decisions in the games are different each time. Students are not only observing what's happening, but are also implicated in the action. This caters to a wide range of different learners, and also opens up new ways for the class to collaborate and investigate issues. For example, the impact of your decisions on others can be clearly seen when making choices within the Headliners game discussed later in the article.

Each game selected should be accessible to all pupils, with appropriate adaptations being made where required. The structure of the session should be carefully considered, too, including the need to promote safe and healthy gaming habits such as regular breaks, exercise, and time away from the screen. It is also beneficial to brief members of the school community on

the use of video games in the classroom, as well as allocating sufficient time to examine a game's technical requirements and resolve any issues.

The range and variety of games available can be daunting, with many titles unsuitable for children or inappropriate for use in schools. It is therefore important to try these games out yourself before using them in a classroom setting. It's also good to stay away from online games, and keep an eye on the age rating. There are resources

> IT IS VITAL TO TRY THE GAMES OUT YOURSELF FIRST

available to support you in selecting appropriate games and facilitating positive experiences for learners (see the 'Useful resources' box for some suggestions). Find the right game and it can become a real highlight of the day for children, and offer a way to engage and evolve learning for a wide range of learning styles.

Cybersecurity games

Last year, I [Andy] wrote one such resource, *Taming Gaming* (**helloworld.cc/taming**). This is aimed at parents and guardians who may be worried about what video games are doing to their children, including the impact of violence, potential addiction, and data security. It addresses these fears by going back to scientific studies (distinguishing between correlation and causation was a common theme) and providing tips and tools to help parents gain the confidence to engage in this area of their children's life. Here are some of my suggestions for appropriate games that can help develop students' understanding of aspects of cybersecurity:

Headliners (**helloworld.cc/headliners**) is a great example for older children. It's a game about controlling a city through the newspaper you publish. It offers a first-hand illustration of what motivates headlines and how important it is to keep your data secure. Bad News (**helloworld.cc/badnews**) is a similar game with a focus on profit rather than control.

Other games on the Family Video Game Database highlight how surveillance and data protection overlap. Orwell (**helloworld.cc/orwell**) is a narrative game in which you play a fictional researcher using a surveillance program called Orwell. Through a series of episodes you are tasked with using Orwell to help solve mysteries such as the bombing of a public plaza. To do this, you trawl websites and documents in the game for clues.

Nuts (**helloworld.cc/nuts**) takes the surveillance theme in a more light-hearted direction, but still paints a fascinating picture of corporate power and responsibility.

USEFUL RESOURCES

Since 2009, European Schoolnet has published the *Games in Schools* handbook, which explores the opportunities and challenges of integrating video games into the classroom. Their 2020 version of the guide explores the educational benefits of commercial video games, along with the most popular lesson plans selected by their MOOC (massive open online course) participants (**helloworld.cc/gameplans**). It also provides additional guidance on commercial video games and the links they provide to other subjects. For example, the popular Just Dance series of games could be linked to both PE and examining algorithms within computing, while Pokémon Go could be used to discuss topics related to geography, citizenship, and critical thinking.

Digital Schoolhouse (**digitalschoolhouse.org.uk**) also has a wide range of resources linking video games to learning in school, including projects related to Mario Kart™ 8 Deluxe on the Nintendo Switch.

Taming Gaming (discussed in the main body of the article) is supported by a freely accessible Family Video Game Database that offers a detailed account of specific games children play (**taminggaming.com**). A parent can look the game up to find out what to be aware of, and also to find suggestions of age-appropriate games if a title is too old for their child. The database covers over 1600 games and is visited by up to 20,000 parents every day. It offers one page on all the popular games, as well as curated lists of games that offer unusual ways to play together as a family. The lists on the database can be filtered by age group and you can also add a filter for which platform the games require.



The Family Video Game Database covers over 1600 games and 20,000 parents use it every day



Some cybersecurity games highlight how surveillance and data protection overlap

Beholder (**helloworld.cc/beholder**) is an interesting game about security for older teenagers. It's a detective game in which you spy on tenants in a building, discover their secrets, and report violations of laws to the authorities. As the game unfolds and you see more of the controlling totalitarian state, an uneasy tension develops between your conscience and your mission. How the game ends depends on your choices.

Video games as case studies

Finally, along with using video games to support learning about cybersecurity in the classroom, I [Neil] recommend using as case studies some of the high-profile cybersecurity-related incidents that have taken place over the past few years involving gaming organisations. For example, in 2011, the PlayStation Network was hacked, which compromised the data of 77 million users (**helloworld.cc/playstation**), while Distributed Denial of Service (DDoS) attacks have been known to take online gaming services offline. Other cybersecurity breaches have seen video game source code and development tools posted on internet discussion forums. For example, the Nintendo Gigaleak (**helloworld.cc/gigaleak**) in 2020 saw a vast amount of data relating to the development of titles for various Nintendo consoles released over the past 30 years. This included unreleased titles, graphical assets, and the source code for a number of releases of popular video games.

By using video game case studies to provide a basis for lesson content, pupils are able to study cybersecurity through examining a topic they are familiar with and often have a detailed understanding of. For students aged 14–16, the case studies could facilitate discussions around methods of preventing cybersecurity-related problems, and for older pupils, opportunities exist to use them to examine the moral, ethical, legal, and cultural issues related to computing.

Have you been using video games in the classroom? What are your favourite cybersecurity-related titles? Get in touch via Twitter with **@computingchamps** (Neil) and **@GeekDadGamer** (Andy). (HW)





NEIL RICKUS & ANDY ROBERTSON

Neil is a senior lecturer in computing education at the University of Hertfordshire in the UK, a primary education consultant for the BCS, and the founder of Computing Champions. He is a CAS community leader, a CEOP Ambassador, and a Raspberry Pi, Google, and Microsoft Certified Educator (**@computingchamps**).

Andy is a journalist and the author of *Taming Gaming*, a book supporting teachers and parents to find appropriate video games for children and understand their benefits (**@GeekDadGamer**).

MEET THE CYBER EXPLORERS

Cyber Explorers is a new platform aiming to help students develop fundamental skills and inspire them to follow a cybersecurity career path

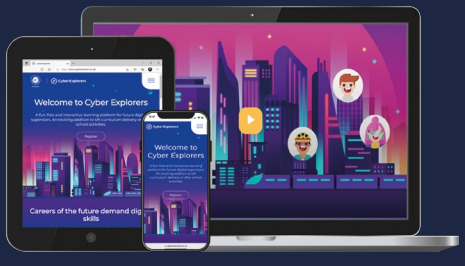
In a rapidly evolving online world, it is imperative that cybersecurity is a pillar of young people's education so that they can access the careers of the future and stay safe online. A new initiative from the UK's Department for Digital, Culture, Media & Sport (DCMS) aims to support this by focusing on improving the diversity and career prospects of students who may want to explore a technical cybersecurity pathway.

Cyber Explorers is a free interactive skills and careers platform that launched in February and will complement the existing CyberFirst programme of activities led by the UK's National Cyber Security Centre. Offering hands-on insights into how digital, computing, and cybersecurity skills are integral to exciting career paths, the platform aims to support teachers of students aged 11–14 by complementing learning objectives for Key Stage 3 in England, Wales, and Northern Ireland, and S2/S3 in Scotland, and to further students' independent learning.

Erika Lewis, director of cybersecurity and digital identity at DCMS, said, "Improving digital and cybersecurity skills is central to the success of the UK's cyber strategy. We want to ensure that there is a sustained supply of diverse and high-quality individuals joining the cyber workforce in the future."

The programme

The platform is set in a virtual city, and learners can select to join one of five characters on a journey through activities, quizzes, and challenges exploring the relevance and excitement of a cybersecurity education and career. Learners head towards the ultimate challenge — to save Cyber City from disaster by putting all the new skills they have learnt to good use.



A new interactive skills platform aims to inspire students to follow a cybersecurity career path

HELEN MARKS

Helen is the marketing communications manager at BCS, the Chartered Institute for IT in the UK.

The programme aims to develop fundamental skills in identifying and understanding threats and risks in digital environments. Equally as important, students also learn about what can be done to mitigate these risks. They will also be introduced to people who work in the industry and explore the strengths you need to be successful. Through interactive episodes, students will discover:

- How to use technology safely
- How to defend against malware
- The principles in protecting the connected world through understanding basic networking concepts, their vulnerabilities, and the security controls used to defend them and the information they contain
- How to secure devices and software by understanding the importance of updates and patches, sourcing safe software, and the secure configuration of applications
- The role of access control from physical security through account types to authentication methods

Teachers can register students at **cyberexplorers.co.uk**. To find out more, email **support@cyberexplorers.co.uk**. (HW)

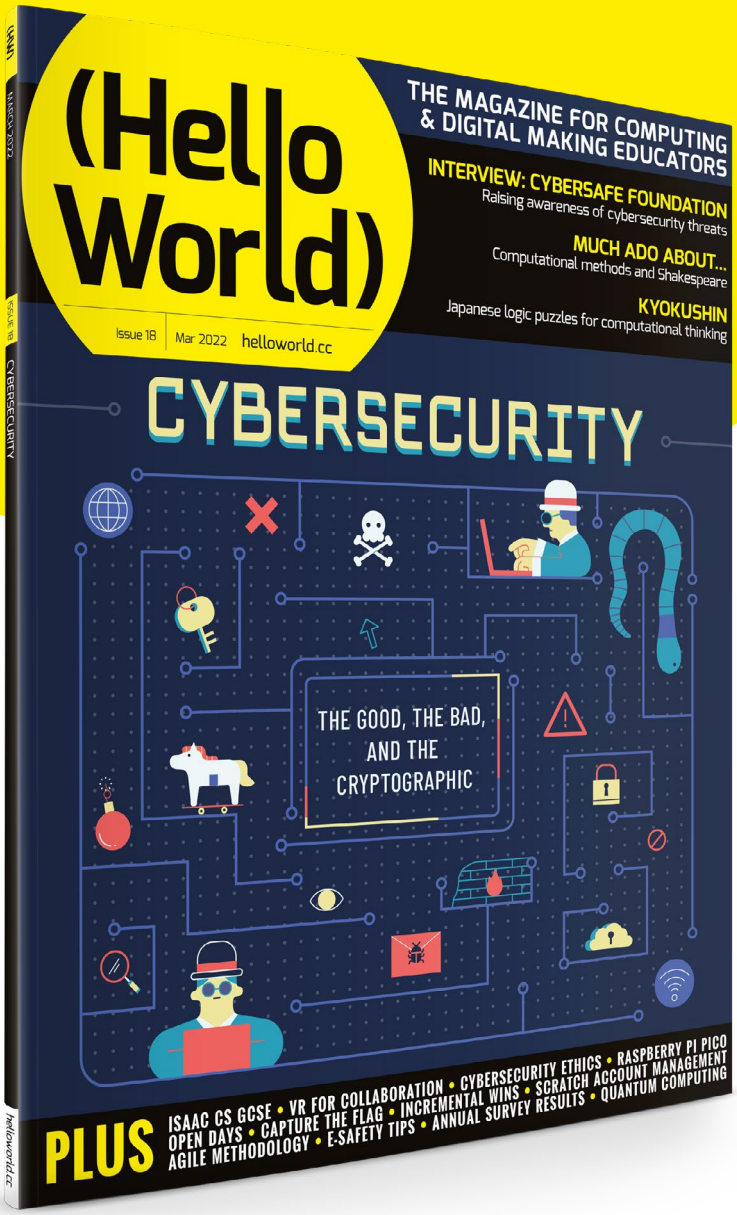
EXAMPLE OF A CYBER EXPLORER ACTIVITY

In Cyber City, learners will meet AJ, a healthcare worker with a keen interest in AI. His team is testing a new robotic knee surgery system. But with all the equipment connected through computer networks and the internet, can AJ really be sure that everything is safe and secure?

During this action-packed episode, learners will learn about networks and how to protect them. They will be introduced to the concept of cryptography, while helping AJ to understand how firewalls work and how they are employed. No industry competitors will be stealing his team's secrets!

(HW)

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LEARNING FROM EACH OTHER

Introducing computational thinking to the very youngest children may sound like a challenge, but pan-European projects are discovering that it can be creative, inclusive, and fun

Heads, shoulders, knees, and toes performed in five languages, arranging gloves in a school playground, weaving ribbons through railings … what on earth have any of these things got to do with computing? Quite a lot, it turns out, when it comes to Co-Make, an Erasmus+ project that brings together schools from the UK, the Netherlands, Finland, Sweden, and Denmark (co-make.eu). We at the Connected Learning Centre (CLC) in London are one of the partners, and we're working with Stockwell, Hitherfield, and Essex primary schools as the UK participants in the project.

This project is looking at how we can build on existing good practice in early years foundation stage or early childhood education, with the aim of supporting the development of computational thinking: patterns, sequencing, instructions, problem-solving, and planning. It's all about enhancing child development through inclusive, collaborative computational thinking, and learning from one another's best approaches.

Heads, shoulders, knees, and toes

And that's where the singing and the gloves come in! The project is based on sharing each country's theoretical approach to computational thinking, before putting the approaches into practice in a learnathon. Learnathons involve children in each of the partner schools tackling a common challenge and sharing their approach to solving it with the other schools, encouraging collaboration and learning from each other.

Our second learnathon had the theme of pattern, and involved children spotting, and then creating, patterns in the world around them. A UK school used tyres and crates in the playground and wove coloured ribbons through the playground railings. A Finnish school had some impromptu fun with gloves, and extended this with a team activity of making patterns that involved checking and debugging. The Swedish settings were influenced by the Reggio Emilia approach (which has an emphasis on quality of environment and aesthetics), which, alongside the shared Scandinavian prevalence of outdoor education, enabled the children to produce patterns using natural objects and art materials.

Heads, shoulders, knees, and toes is a well-known playground song with actions. When viewed from the computational perspective of patterns, sequence, and repeats, action songs such as this are a way of introducing algorithms that fits any early-years approach. Here, bugs have an immediate (and possibly hilarious) effect, and repetition is experienced in a multisensory way by the children, not simply as an abstract idea.

Over Zoom, children across the twelve partner schools performed the Finnish, Swedish, Danish, Dutch, and then English versions of the song. We had fast and slow versions, and some versions with slightly different actions, and the children asked each other questions. They were excited and really curious to see the other classes perform the song live. Teachers reported that this was a very memorable experience for the children to have during lockdown, and it has influenced the subsequent development of the project in terms of creating more opportunities for the children to find out what classes in the other schools are doing.



Our second learnathon had the theme of pattern and involved children spotting, and then creating, patterns in the world around them

Sharing best practice

Co-Make is a follow-on project from Co-Think, which was an Erasmus+ project exploring inclusive practices in teaching computational thinking to slightly older primary school children (**co-think.eu**). As part of the three-year project, children took part in simultaneous learnathons, with their teachers sharing practice and co-delivering computer science lessons across five countries. Before carrying out the learnathons, schools shared their country's general approach to computational thinking, which clearly has different interpretations and definitions in different settings!

Representing the UK, Jane Waite led an initial session in which all the participating educators could explore the concept of computational thinking through her instructional continuum model (**helloworld.cc/continuum**), including differences in the level of scaffolding that various teaching systems offer to children. The most heavily scaffolded way to learn is by rote, through copying code. This can seem like an easy way into programming, but it provides limited design and debugging opportunities. It also often leaves holes in children's understanding, despite allowing them to produce seemingly impressive results. At the other end of the scale, there's tinkering — letting children play with the code freely. The downsides of this approach? The development of bad programming habits; the risk of unfocused or misleading learning experiences, as the teacher cannot assure a sensible progression; and greater divergence in pupil confidence, as those with less experience are likely to encounter greater frustration. Most teachers and education systems mix up these approaches without being aware of it.



Viewed from the computational perspective of patterns, sequence, and repeats, action songs are a great way to introduce algorithms to early-years learners

This underpinning work was further developed through a day of workshops with Linda Liukas, a Finnish computer scientist and creator of the Hello Ruby resources (**helloruby.com**). She helped the participating educators to understand the Finnish take on computer science and how this is deeply rooted in the country's social democratic philosophy, right down to the use of open-source educational resources in schools.

When it comes to computational thinking, Finnish schools focus on problem-solving, and developing logical skills and digital competence within what they call 'transversal competencies' as part of every subject. They have adopted a blended method of teaching computational thinking through both a cross-curricular and a single-subject approach, linking specifically to maths. Schools use an elective approach, and we saw this at one of the partner schools, where students can opt into short computational thinking and programming courses. Teachers are encouraged to use technology, and encourage the development of digital competency across the curriculum.

> "CHILDREN WERE EXCITED AND CURIOUS TO SEE HEAD, SHOULDERS, KNEES, AND TOES PERFORMED IN OTHER LANGUAGES

Exploring different approaches to computational thinking in countries where it is either recently (in the UK, Sweden, and Finland) or not yet (in the Netherlands and Denmark) integrated in primary school curricula was one of the most valuable elements of our Co-Think project. Together, we are crossing the borders of national education systems with the aim of gaining a deeper understanding of how computational thinking can be taught and implemented in new, inclusive ways.

Our latest project, Co-Learn, has recently launched, and will explore blended learning pedagogies used across Europe (**co-learn.eu**). Co-Think, Co-Make, and the new addition of Co-Learn have been incredibly valuable experiences for all the teachers, schools, and partners involved, and we are keen to share the knowledge gained with the wider community. We intend to draw that knowledge together into a set of approaches for computational thinking in early years that will be available to all educators. Watch this space! (HW)

THE CONNECTED LEARNING CENTRE

The CLC is based in London, UK, and supports schools and other settings to use digital technologies creatively and critically. They provide curriculum support, technical services, and professional development (**theclc.co.uk**, **@LdnCLC**).

KYOKUSHIN: PUZZLING THE TRUTH

How can Japanese puzzles help develop logical reasoning skills? **Joanne Lynn** shares her school's unique approach to developing systematic problem-solving skills in young people

Kyokushin is a Japanese concept that centres around finding the nature of one's true character when tried and challenged. It is rooted in discipline, self-improvement, and hard training, qualities we all love to see in our students, right? We decided to use this approach with our students to develop their logical reasoning skills through a range of puzzles also created in Japan.

As pupils work through our curriculum in Years 7 and 8 (aged 11–13), we use a range of logic puzzles as starter activities. At the beginning of each term, we introduce students to a new style of puzzle that develops their logical understanding in a new way. They develop their skills over two years, in a similar manner to the belt system in a Japanese dojo.

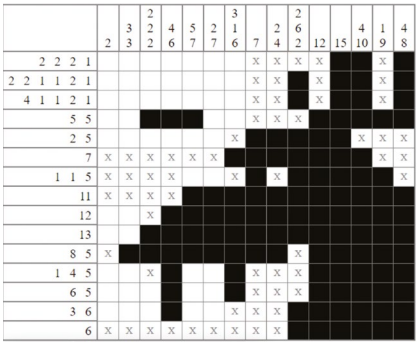
Each logic puzzle has its own kata, or algorithm, for completion. For a pupil to progress to the next level, they must demonstrate that they can follow the algorithm correctly by accumulating evidence of successful puzzle completion in their class notebook. When pupils are introduced to a new style of puzzle, we discuss elements of the kata required to solve it effectively. Pupils then work together as a class to refine the algorithm and become more efficient. The dojo levels (known as kyu) have an associated colour that shows the pupils' proficiency and/or experience in logical reasoning.

Our current kyu system takes pupils through the following logic puzzle types: nonograms, shikaku, KenKen, grid puzzles, sudoku, and kakuro. I will now take a closer look at a couple of these puzzle types.

Nonograms

Nonograms offer a perfect introduction to logical reasoning, so this is where pupils begin their journey. They are easy logic puzzles that involve dealing with true or false statements on a series of cells to discover an encoded image. At the initial level, pupils solve 10 x 10 nonograms. When solving a nonogram, a single clue will not usually be enough to complete a line, but additional information is gained for other columns and rows every time a true or false is found. This extra information sometimes changes a previously impossible line into one that can now be solved. Pupils must follow a systematic approach to moving around the puzzle to complete the picture.

When we introduce these puzzles, we show pupils how to look for the rows and columns with only one possible solution first (that is, any with a clue of 0 or 10 in a 10 x 10 puzzle). As a clue with multiple numbers in it must have a space between each run of colour, pupils look for clues that would sum to 10, including the spaces. After this, we discuss what else we can say must be true, or must be false, with an emphasis on using logic rather than guesswork. If we cannot prove that something is true, we must assume it is false for now.



A part-completed nonogram puzzle. The puzzles are created and completed on **helloworld.cc/nonogramcreator**

TRY IT FOR YOURSELF: TOP TIPS

- Start small: choose one type of puzzle to focus on at first
- Use materials that are already available (try **helloworld.cc/nonograms** or **helloworld.cc/kenken**)
- Practise doing the puzzles yourself first, and make sure you have solutions for (or can solve on the spot) the puzzles you are asking your pupils to complete

At first, this process is carried out as a group, with teacher guidance. After half term, the problems given become harder and larger, and less support is given. Pupils are developing logical reasoning, debugging, resilience, and a systematic approach to problem-solving. Oh, and when we look at run-length encoding, they get that too!

Grid puzzles

In our fourth term, we look at deduction puzzles that can be solved using a grid format to record reasoning. In a deduction puzzle, a scenario is given, followed by a series of statements from which the solver must deduce information about a series of categories. A grid, with sections for each category, is used to match each item to exactly one other item in each category. No two items in a category will ever be matched to the same item in another category.

These puzzles move away from numeric clues and also switch up the type of information that is the focus. Until this point, pupils focused on looking for truths. In a deduction puzzle, it is necessary first to prove what is false, in order to deduce what must be true. Looking at problems from different perspectives is an important skill for problem-solvers to have.

We are looking for pupils to be able to achieve reasoning and a systematic approach, which we do by asking them to talk us through their findings in class discussion. Both the teacher and other students may critique the approach. This allows all pupils, even those who may be less confident, to contribute to the solving of the puzzle and refine their methodology.

The most important aspect of these puzzles is that pupils begin to develop their abstraction skills. They are required to take a statement and look at it from a variety of different perspectives to see what they can deduce. Being able to look at problems in different ways, and to consider varied solutions, as well as critiquing and building on other people's ideas, are undoubtedly skills that are essential to the technological revolution.

We are seeing increased resilience in the students, both with regard to puzzles and in other areas of the curriculum. They are more willing to take risks in order to find solutions to problems. If you would like to find out more about the puzzles we use in our curriculum, head to **helloworld.cc/kyokushin** for more detail, including some of the basic algorithms we use to solve them. (HW)

Four Spies

Four spies are undercover in Europe. Their code names are Crow, Eagle, Falcon, and Raven. One is undercover in Amsterdam, one in Berlin, one in London, and one in Paris. One has been undercover for a week, one for a fortnight, one for a month, and one for six months. The following is also true:

- Eagle has been undercover for longer than the spy in Paris
- Falcon has been undercover for more than a fortnight
- The spy that has been undercover for a week has a name that is earlier in the alphabet than the spy that is in Amsterdam
- The spy in Berlin has been undercover for longer than the spy in London
- The spy in Amsterdam has been undercover for longer than Falcon
- The city Raven is in has the same number of letters as the city of the spy who has been undercover for a week

Based on this information can you deduce the code name and location of each spy, and how long they have been undercover? Use the data structure below to help keep track of your logical reasoning:

	Amsterdam	Berlin	London	Paris	1 week	Fortnight	1 month	6 months
Crow	X	X	O	X	O	X	X	X
Eagle								
Falcon								
Raven	X	O	X	X	X	O	X	X
1 week								
Fortnight								
1 month	X	X	X	O				
6 months								

A part-completed grid puzzle. *Credit: Puzzle text taken from The Turing Trust*

> KYOKUSHIN IS ROOTED IN DISCIPLINE, SELF-IMPROVEMENT, AND HARD TRAINING, QUALITIES WE LOVE TO SEE IN OUR STUDENTS



JOANNE LYNN

Joanne is a computer science teacher at the Royal Grammar School in Newcastle, UK. She is currently studying for an MSc in Artificial Intelligence with the University of Bath (**@jo3784**).



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Using Scratch online allows learners to collaborate and be inspired by others

SCRATCHING BENEATH THE SURFACE

Sway Grantham shares her tips and tricks to help you manage Scratch more efficiently in the classroom

Scratch (scratch.mit.edu) is a wonderful tool for teaching children (and in fact many adults) to program. While you can use Scratch offline via the Scratch app, where learners do not need to have their own accounts, I strongly recommend using it online if it is possible in your setting. Using Scratch online is a much richer experience, allowing learners to collaborate and be inspired by others. However, the logistics of managing 30 children trying to access their accounts, find their saved work, and share that work with you can feel like a big challenge. Here are a few simple tricks for organising your class to make your life easier when using Scratch.

Teacher accounts

Teacher accounts have been a part of the Scratch offering for a while, but they are not easy to find! Although the accounts are called teacher accounts, you can specify whether you're running an after-school club or camp, so volunteers and other educators can also apply. These accounts allow educators to create and manage online accounts for their learners, removing the need for them to have their own email addresses. This gives you the power to reset their passwords, and also allows you to organise them into classes. This can be really helpful when you have younger learners who are still learning to manage their

USERNAME TIP

Using a spreadsheet, put your school's initials in column A, pupils' names in column B, and the year in column C. Then use the 'concatenate' function in column D. It will create a list of the usernames without you having to type them out manually!

own online accounts, while also giving them the opportunity to safely practise the skills of password management.

To get a teacher account, complete the form at **helloworld.cc/scratchteacher**. There are a couple of quirks to note:

- You have to create a new account, as you can't convert your existing Scratch account into a teacher one
- It can take up to 24 hours to be approved, so you need to do it ahead of time
- It asks for a lot of personal information, but you can leave a lot of this blank that they can remember! My suggestion is to use a combination of information, for example, GPSway22. Here, GP is the initials of the school, Sway is my first name and 22 is the year I started Year 3 (the first time we would use Scratch accounts).
- **Class owner:** Will students get a new Scratch account each year, so that they can be managed by their classroom teacher, or are they set up once for the whole time they're at your school? I taught computing to all classes, so it made sense for my learners to have the same account every year. However, this meant I didn't separate learners into classes, and just had a Year 3 class of 60 children. Then, when they were separated into different classes each year, I didn't have to worry about learners being in the wrong group.
- **The first lesson:** Leave yourself some time in your first lesson for getting everyone signed in correctly. For ease, I would recommend setting everyone's password to the same thing when you create their accounts. This means that the first time pupils log in, they will have to create their own password (which you can change later when they inevitably forget it!) and fill in some basic data. After this, the account functions just like any other, and you can start programming!
- **Transferring ownership:** There may come a time when learners leave your school or club, but would still like to access their projects. The simplest way to do this is for them to set up their own account, search for their old username, and remix the projects they want to keep.

> "YOU CAN GIVE YOUR LEARNERS A POSITIVE EXPERIENCE OF BEING A PART OF THEIR FIRST ONLINE COMMUNITY

Thinking ahead

One of the first mistakes I made when using the teacher account was not thinking ahead. I named the first class 'Class 3SG' and started adding pupils (who all need unique usernames that aren't already used on the site). However, you can't move pupils to a different class, or to a different teacher, once their account has been created. This meant that the next year, when all the learners were mixed up into new classes with new teachers, they were stuck in the Scratch class I had originally created for them!

Here are some considerations that will help you use your teacher account more effectively:

- **Username format:** All pupils need a unique username that is not already in use on the Scratch website; doesn't include identifying information; and, ideally, is something

Creating studios

The 'studios' function in Scratch is useful for organising content. As part of your teacher account, you can create studios for each class, and I would recommend creating one per lesson or one per project. At the end of the lesson, pupils share their work on Scratch and add it to the studio. This means that you can view the studio and see all the pupils' work in one place.

I would load the studio onto the board and allow learners to volunteer to share their project. This was a great motivation for them to check that their project was in the correct place, and it made marking their work so much easier. Equally, if any leadership team members or parents want to see what learners have been working on, you can easily provide a URL to the studio.

Once you've got the accounts set up, it really does become a lot easier to use Scratch. Not only that, but you're also giving younger learners a safe space to learn about account management, password responsibility, and thinking about what they share online. You're showcasing to learners the benefits of collaborating online with others who have made Scratch projects, and you can model things such as leaving constructive comments on projects. As with any online tool, there are safety considerations, but Scratch is aimed at children, so it has clear community guidelines and effective reporting procedures.

You can make your life easier and give your learners a positive experience of being a part of their first online community — so get a teacher account and get started! (HW)



SWAY GRANTHAM

Sway is a senior learning manager at the Raspberry Pi Foundation, where she leads a team developing computing resources for primary teachers (**@SwayGrantham**).

VR FOR COLLABORATION: WORKING TOGETHER WHEN APART

Oli Howson shares his experiences of working with young people in Wales to build a virtual reality environment

Virtual reality (VR) is one of the most exciting recent developments in computing. Those of a certain age might remember the blocky vector graphics of Virtua Racing on the Sega Mega Drive, worlds apart from what is now possible with modern — and much more affordable — systems. In this article, I'm going to share my experiences of using VR with a group of young people as a tool for coming together when physically apart.

Youth Shedz (**youthshedz.com**) is a Welsh organisation that aims to bring young people together in a safe and engaging environment, helping them to gain important new skills along the way. With meetings normally taking place in five physical Shedz across North Wales, the pandemic could have had a devastating impact on the young people who could no longer attend due to lockdown. With funding, we purchased ten Oculus Quest headsets, and a project was developed between Youth Shedz, Coleg y Cymoedd further education college, and the Open University to explore opportunities for young people to meet, engage, and overcome the barriers imposed by the coronavirus. The Youth Shedderz wanted to create an online world with continuous open access where they could hang out, chat to people when they needed to, and have a place where they belonged as a group: a 24/7 virtual Youth Shed.

Lost in traditional environments

Youth Shedz members often find that they get lost in traditional youth clubs, or have behaviours that lead them to struggle in more formal settings. The pilot VR project included eight Shedderz who were chosen because of their additional barriers to traditional activities, including substance misuse, prolific offending, significant anxiety, and a lack of digital skills. With the exception of the leader, these additional barriers were not shared with the Youth Shedz volunteers, so as to encourage a safe, open space where individuals could become new people if they so desired.



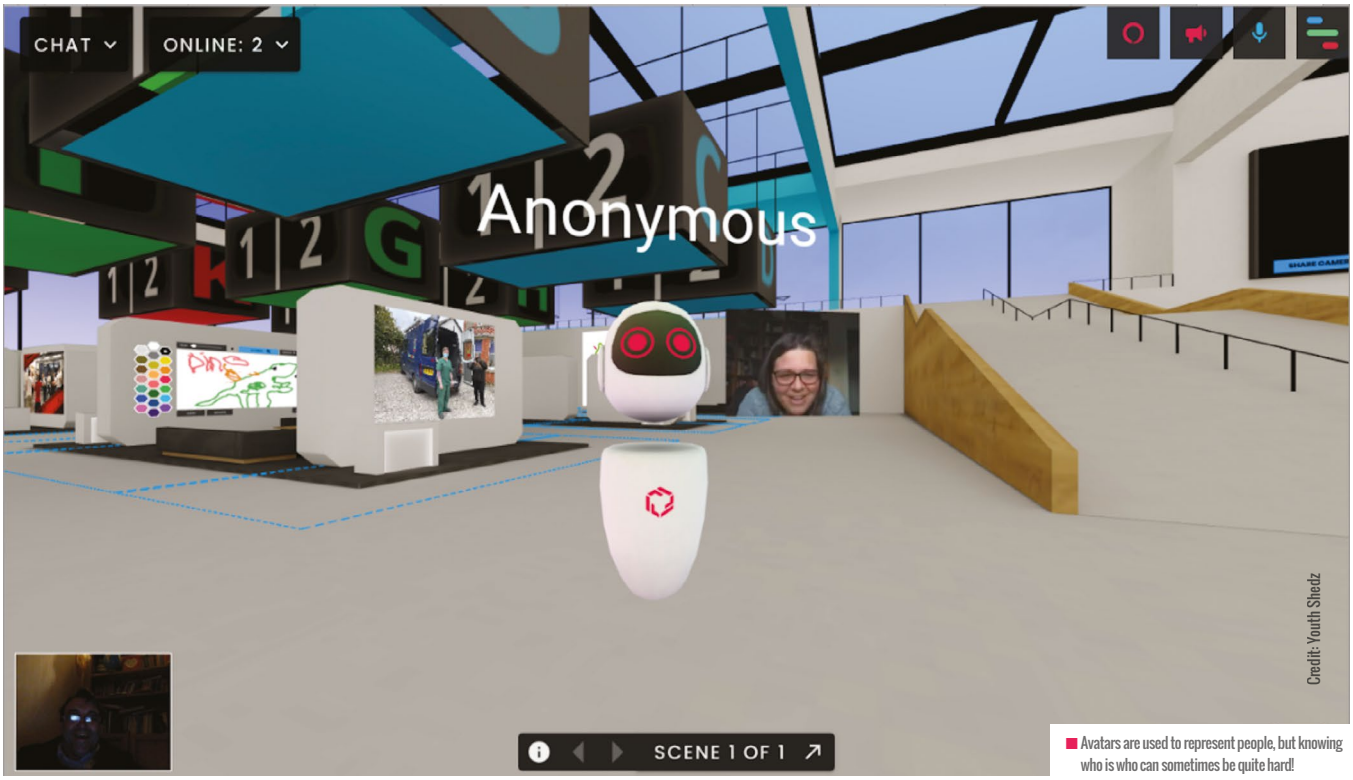
Game time! Collaborative games were a great way to get to know one another and have fun

The group, including Youth Shedz members, staff, and volunteers, met every Thursday evening for group work. Physical Youth Shedz are focused on what the young people want, often with a community focus, or joint learning. We also allow time for the young people to hang out and play video games together. The VR project aimed to mirror this, with the start of each session dedicated to exploring a range of VR applications for meeting and collaborating, followed by collaborative paintballing or bowling.

VR applications

The range of available VR applications was staggering, and all had their own pros and cons. Movement methodology, for example, has a huge impact on user experience. Being limited to teleporting (as in Spatial), for example, feels a lot less natural than being able to move around using a thumb stick. The quality of voice communication could also make or break an environment (something we particularly noticed on Immersed and AltspaceVR). Although the Quest 2 comes with a built-in microphone and speakers, we found that separate earbuds picked up less background noise and greatly improved communication.

It should never be underestimated how easily some people can get lost when exploring the environments! Rec Room (which we used for Real VR Fishing and paintballing) is a tremendous place to explore, but it's enormous, and being able to direct each other to where the group is can really help, as can avatar customisation. Everyone greatly enjoyed creating an avatar that (vaguely!) reflected how they look in real life. The applications



Avatars are used to represent people, but knowing who is who can sometimes be quite hard!

that limited avatar creation, as well as those that didn't show the names of other people clearly, had quite a significant impact on the ease of communication.

The Shedderz finally selected the Frame (**framevr.io**) application to build their virtual shed. This platform had a number of benefits. The environment has huge amounts of customisability, allowing the Shedderz to manipulate the environment into the platform they wanted, much like a real-life shed. They were able to bring in external media, including videos and images, which they used to decorate the environment. Avatars could be customised and walk around freely, and could also enter private zones and talk without being overheard, an important aspect given the needs of the Shedderz. Finally, Frame could also be used cross-platform, meaning that Shedderz could access it through a normal computer or on their phones when headsets weren't available, making it a more inclusive platform.

Technology together

The pilot project was a great success, not only in removing the barriers imposed by the coronavirus, but those imposed by their own physical and psychological needs; all those involved gave very positive feedback. The pilot opened up huge amounts of platform knowledge to the group, and highlighted safeguarding needs and training requirements. But what was really powerful was the ease with which the young people, who came from different backgrounds and areas and in the majority of cases had never met one another, came together along with me (a complete stranger), got along, and worked towards a common aim in a primarily VR environment. The perceived problems of negotiating VR environments, such as motion sickness and communication issues, never really raised their heads.

In computing education, we often look at what new developments can do to support learning in terms of simulation, demonstration, and analysis. We rarely look at new technology, though, in terms of how it can enhance our group work, communication, and shared experiences; how it can break down barriers. VR can really enhance this.

Perhaps the best summary of what came out of the project is this comment from JR, one of the Shedderz, which left me in tears: "VR has helped me over the last few months. I'm in recovery from drugs and alcohol and have struggled with the lockdown, but being able to go in VR and interact and socialise with other people has helped me with my mental health and confidence." (HW)



OLI HOWSON

Oli is a computer science specialist and CAS Master Teacher. He still teaches remotely and has a day job lecturing computing at the Open University. In his spare time, Oli explores microcontrollers, and is currently writing a book on the Raspberry Pi Pico (**@Mr_Howson**).

MAKING THE MOST OF YOUR SKILLS FROM INDUSTRY

Julia Roebuck gives her advice on how those who have switched careers can bring their knowledge and skills from the computing industry to teaching

Moving from a job in industry to teaching computing is a rewarding and fulfilling change. There are a lot of people transferring to teach computer science from other subjects, but there are also many of us who have degrees in the subject and extensive experience from working in the computing industry before we moved to teaching. This article includes my top tips on how you can use your knowledge and skills from industry in the teaching profession.

Inspire and educate with your experience

As an experienced professional, you are in a position to encourage all students to pursue a career in an industry where there is such a shortage. You will be able to give them first-hand knowledge of what it's like working in the industry — both the pros and the cons.

For example, students often feel that they are cheating if they look things up on the internet. But with your work experience, you will be aware that in computing, you don't know all the answers, and you can usually find them out through research. Computing is a fast-changing industry, and you can't be expected to know it all. This is something students don't often think about, and you'll be able to provide the insight that looking things up is actually OK.

You can also bring your own case studies, or those of your friends and colleagues, to class. The ethical dilemmas you experienced, for example, can be used as the basis for class discussions. Providing students with real-life scenarios will give lessons that bit more meaning, as you ask learners what they would have done in your shoes.

Finally, female professionals who have moved to teaching have a unique insight to inspire more girls to study and work in computing. The aim is to have more female computing staff, and you can highlight that working with mainly men isn't something to be avoided. I worked in companies as a programmer for a decade after graduation, and on the whole, I was the only female, or one of a few. I like to point out to the girls I teach that yes, they might still be outnumbered in the computing industry, but that most of my experience working with men was positive, and the imbalance shouldn't put them off. There is obviously a huge disclaimer here: not every workplace is the same. For me, it was always amazing to work with other women, but at the same time, it wasn't the end of the world if I couldn't.



You will be able to give students first-hand knowledge of what it's like working in industry

Harness your specialist skills

It might seem obvious, but having worked in tech probably means you are more ready and open to accept technology as a tool for learning outside of more traditional methods. This will spill over into your teaching approaches, so embrace that and use technology as much as you can in your classroom, and support your teaching colleagues to do the same. The



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You will be able to fill in the industry-relevant gaps in your students' learning

> AS AN EXPERIENCED PROFESSIONAL, YOU CAN GIVE STUDENTS INSIDE KNOWLEDGE OF WHAT THE COMPUTING INDUSTRY IS LIKE

same goes for teaching approaches such as collaboration and pair programming, which you will have used a lot in industry. It's never too early to start students collaborating and talking through coding problems. Contextualising these methods by letting students know that they are used by programmers might help motivate them, and prepares them better for life after school, as they build skills they will use.

If you worked as a programmer, you'll have even more specialist skills that you can harness in your teaching. You'll have extensive programming skills, as well as knowledge of how to develop software. This will be invaluable if you are teaching older pupils. Of course, most of the programming you teach will be much simpler than that you used previously. But you will be able to talk about these more advanced programming and development techniques to your students, and help to whet curious appetites. You might want to introduce additional languages (see my article in Hello World issue 16 for more on this) or go beyond your specification to deepen and broaden your students' learning experience and increase their engagement and interest.

Reading other people's code is a really important aspect of any programmer's job: a lot of work is amending code that someone else has written, rather than writing it yourself! This will, of course, be beneficial when you move to teaching, because you will be fast at reading and debugging student code. But more importantly, you can teach those advanced code-reading skills and techniques to high-achieving students, while also giving them a glimpse into the reality of working in industry.

Find the gaps

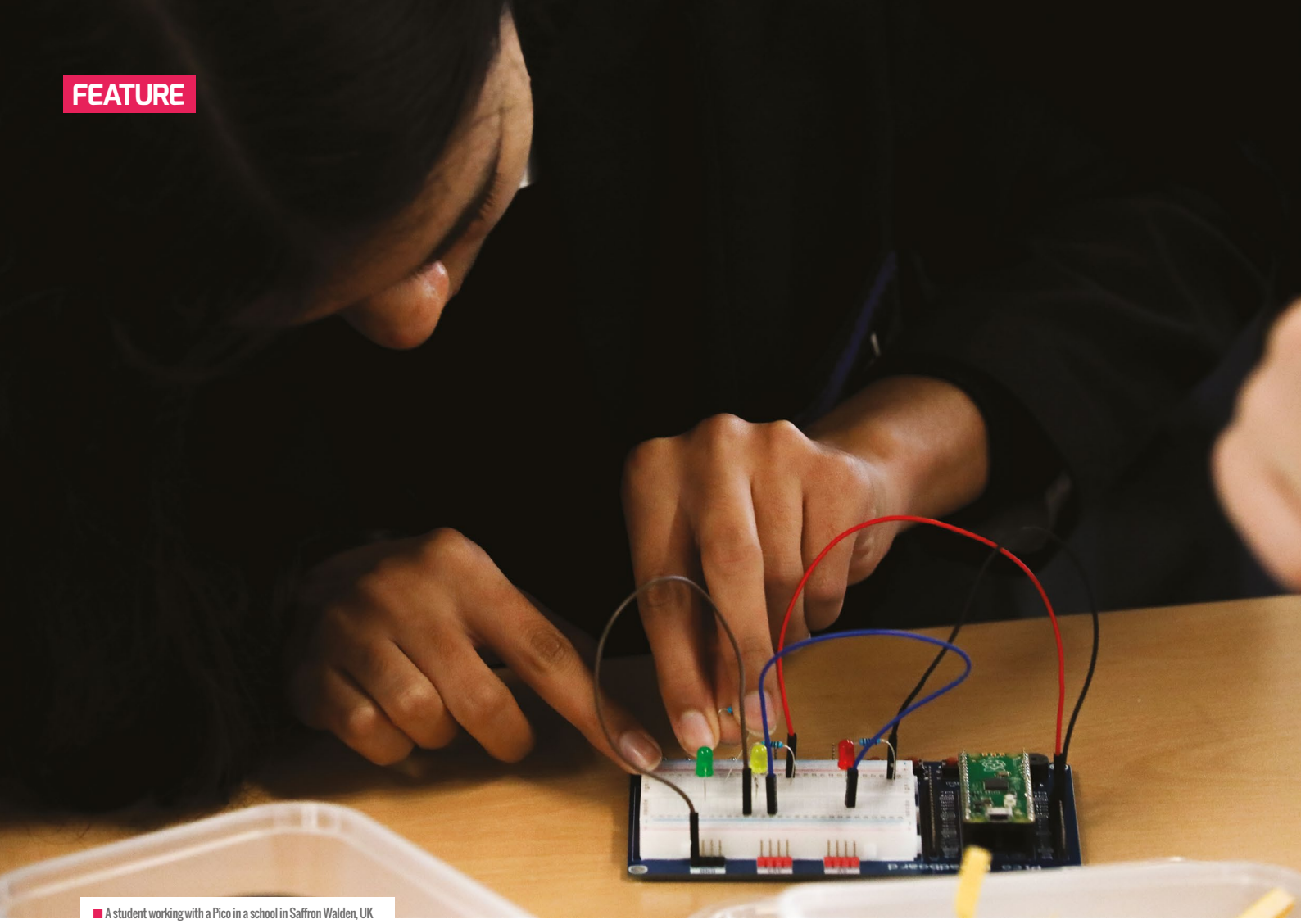
Finally, moving from industry to teaching has the advantage of making you more able to plug the gaps in what students are learning. You'll be able to critically analyse the content of syllabuses as to whether they are relevant to working in the industry. This has personally caused me some angst when there is a lack of practical skills in a syllabus, but you might be able to make some small adaptations to help build more relevant skills and knowledge in your students. I also recommend that you keep in touch with your old industry colleagues. This is a great way of keeping up to date with what's going on in the industry, not only keeping your own knowledge current, but also leaving the door open to ask those colleagues for advice and answers to questions that students might have about the industry.

Even though you've been a computing professional and you have extensive knowledge, you can still learn a lot from your students. It's incredibly rewarding when their enthusiasm for the subject is fed by your knowledge and help, so make sure you draw upon your valuable experience to inspire the next generation of programmers and software developers! (HW)



JULIA ROEBUCK

Julia has over 20 years' experience of programming in multiple languages and technologies. She teaches lower secondary, IGCSE, and A-level computer science via virtual classes with her company, LearnTec. She also teaches lower secondary and IGCSE at St John's School in Devon, UK.



A student working with a Pico in a school in Saffron Walden, UK

RASPBERRY PI PICOS IN THE CLASSROOM

Dan Elwick speaks to educators about their experiences using Raspberry Pi Pico to teach physical computing

Released in January 2021, Raspberry Pi Pico is a low-cost microcontroller device; a tiny computer that can be connected to another computer so users can learn how to program it using MicroPython. Against a background of school closures, reopenings, isolation periods, and restrictions for students and teachers, we were keen to find out how Raspberry Pi's foray into microcontrollers had been received in classrooms, and spoke to some teachers in England to hear about their experiences.

Extracurricular engagement

One key use of Pico at secondary schools has been at teacher-led lunchtime and after-school clubs. One teacher from a girls' secondary school in Liverpool described his Women in Tech club. With free rein over the content and a personal passion for Raspberry Pi, the eventual aim is for his 11- to 12-year-old students to build a line-following car. With only half an hour per week at lunchtime, the group started off by covering some of the basics from the *Getting started with Raspberry Pi Pico* project (**helloworld.cc/picoproject**), such as connecting it with a breadboard and making LEDs flash.

The teacher described how walking into a room with the kit grabs students'

TOP TEACHER TIPS FOR PICO

- It can be tricky to install Thonny (the software that is used to programme Picos) on school IT systems. Build in time to do this, and ask your IT technician for support.
- It takes time to unpack devices, connect them, and pack them back up again. Build this time into your plan, too!

attention: "It's massively more engaging than programming Python on a screen … They love the idea of building something physical, like a car." He has to remind them that phones aren't allowed at school, as they're keen to take photos of the flashing lights to show their parents. His overall verdict? "Once the software has been installed, they're just plug and play. As a tool in school, it gives you something physical, creating interest in the subject. If it gets just one person choosing the subject, who wouldn't have done otherwise, then job done."

Another teacher, from a school in Hampshire, used Picos at an after-school club with students aged 13 to 15. After about six sessions of less than 50 minutes last term, the students have almost finished building motorised buggies. The first two sessions were spent familiarising students with Picos, making LEDs flash, and using the sensors. Then in the next four sessions, the students worked their way through the 'Physical computing project' unit of the Teach Computing Curriculum (**helloworld.cc/tccpico**).

The students worked in pairs, and some learners initially had trouble getting the motors to turn the wheels on their buggies. Rather than giving them the code, the teacher gave them duplicate sets of the hardware and suggested that they test each piece in turn, to debug the hardware. They quickly worked out what they needed to do to make the wheels turn.

Reinforcing existing computing skills

Another key theme that came through in our conversations was how Pico can be used to reinforce existing computing skills. We interviewed a teacher from a school in Essex, who had been using Picos to teach computing to 12- to 14-year-olds in class, and talked about the potential for physical computing as a pedagogical tool for recapping topics that have been covered before: "If [physical computing] is taught well, it enhances students' understanding of programming. If they just copy code from the board, it becomes about the kit and not how you solve a problem; it's not as effective at helping them develop their computational thinking. Teaching Python on Pico really can strengthen existing understanding of using Python libraries and subroutines, as well as passing subroutine arguments."

Another teacher we spoke to, in Waterlooville, talked about the benefits of using Pico to teach Python: "It takes some of the anxiety away from computing for some of the younger students, and makes them more resilient. They can be wary of making mistakes, and see them as a hurdle, but working towards a tangible output can help some students to see the value of learning through their mistakes."

> "WORKING TOWARDS A TANGIBLE OUTPUT CAN HELP STUDENTS TO SEE THE VALUE OF LEARNING THROUGH THEIR MISTAKES

As someone who is relatively new to teaching, this teacher is keen for his students to get a sense of the variety of jobs that are available in computing, and not just in programming. He explained how physical computing can demonstrate to students how you can make inputs, outputs, and processing very real: "Give students a Pico and make them thirsty about what they could do with it — the device allows them to interact with it and work out how to bend it to do what they want to do. You can be creative in computing without just writing code; you can capture information and output it again in a more useful way."

One of the teachers we spoke to was initially a bit cynical about Pico, but had a much better experience of using it in the classroom than expected: "It's not such a big progression from block-based microcontrollers to Pico — it could be a good stepping stone between, for example, a micro:bit and a Raspberry Pi computer." Why not try it out in your classroom or club? It might be the engagement booster you've been looking for!

*Physical computing kits from England's National Centre for Computing Education, including class sets of Raspberry Pi Picos, Crumbles, micro:bits, and Raspberry Pi 3B+ computers, are now available for state schools in England to borrow from their local Computing Hub (**helloworld.cc/tcchub**). You can also find a guide to using the kits at **helloworld.cc/kitguide**. US educators can register for a free Raspberry Pi Pico kit at **helloworld.cc/pathfinders** (see the article on page 9 for more information). If you're not eligible to borrow the kit, you can buy Picos at **helloworld.cc/pico**.* (HW)



DAN ELWICK

Dan is a programme manager at the Raspberry Pi Foundation (**@DanWickPi**).

GOING BACK TO BASICS: PART 3

Rebecca Franks continues to share her experiences of taking a group of beginner digital makers through their first physical computing projects

This year I have been leading sessions with a group of beginner digital makers who wanted to learn how to use LEDs to make an art project. This group had no prior experience with electronics and I wanted to provide them with the right scaffolding to develop the confidence to make something they could be really proud of.

In issue 17 of Hello World I described the second session of four, which involved the makers using diagrams to create series and parallel circuits. In this issue, I will let you know how my makers added new components to their circuits and how they got an LED to blink without any code!

PUSH THE BUZZER KIT LIST

- 1 x yellow LED (3V)
- 1 x buzzer (3V)
- 1 x push button
- 3 x male-to-male jumper wires
- 1 x small breadboard
- 1 x 9V battery connector
- 1 x 9V battery

Using a 555 timer IC to create a blinky LED: the IC

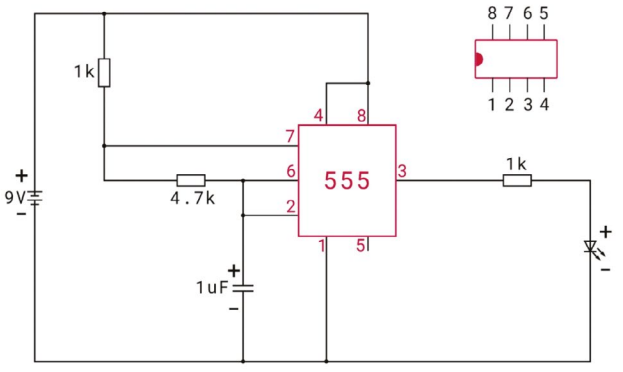


Figure 1 The blinky LED circuit that uses a 555 timer integrated circuit

Push the buzzer

By this session, my makers could remember which leg was positive and negative on an LED. They also had a good understanding of how the breadboard worked and how a circuit diagram could be recreated on a breadboard. This meant that they were ready to add in some new components, to see if they could apply their knowledge and skills to a different scenario. The first task was to push a button to sound a buzzer.

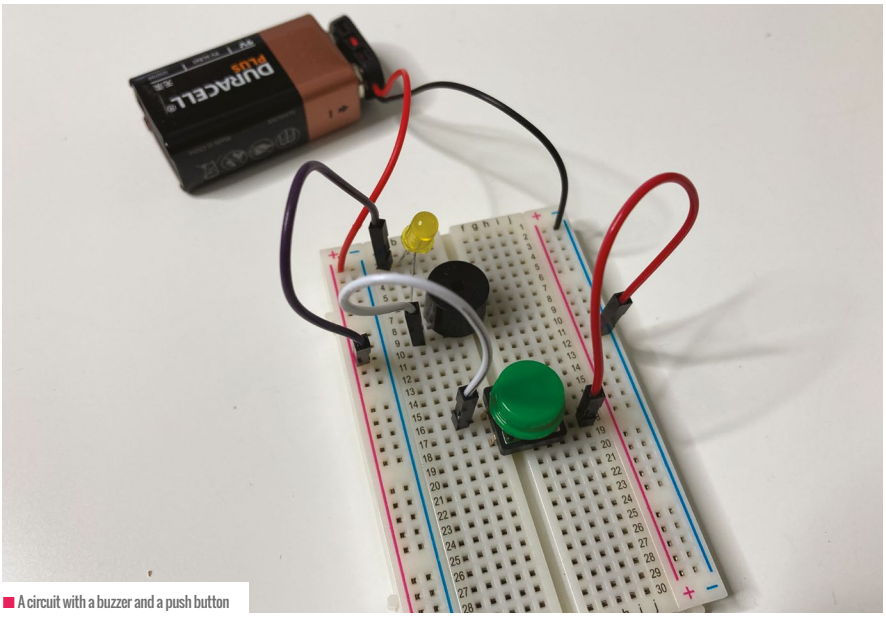
I gave them the components they would need and a circuit diagram to follow. I also gave them a few tips about push buttons, because they often work in slightly unexpected ways — sometimes, a push button will electrically connect on a diagonal line instead of straight across, for example.

This was quite a tense moment, as I wanted to give my makers a chance to make mistakes and try to fix them for themselves, but the fixer in me just wanted to help and show them what to do. I held back, though, and one by one, they each managed to follow the circuit and get their buzzers working.

Lighting an LED is fun, but there is something very different about sounding a buzzer at the push of a button. I think it allows you to bring out that inner child a little and be a bit silly for a while. You also have the added bonus of knowing that you connected the circuit that made it happen. Applying their understanding to a new circuit with

555 TIMER BLINKY LED KIT LIST

- 1 x small breadboard
- 1 x 9V battery connector
- 1 x 9V battery
- 1 x 555 timer integrated circuit
- 1 x LED
- 2 x 1k resistors
- 1 x 4.7k resistor
- 7 x male-to-male jumper wires
- 1 x 1µF capacitor



A circuit with a buzzer and a push button

new components definitely helped learners to cement their learning from previous sessions and increase their confidence. The knowledge of a series or parallel circuit could now be applied to many different scenarios, widening the scope of their maker skills.

Now for the main event

After some tinkering with other components, it was time to start the main event: the blinky LED circuit. I let my makers know that the circuit they were about to see was going to look unfamiliar at first glance. To start, I asked them to spot any components that they recognised. After a few moments they could find resistors, LEDs, the battery, and a capacitor.

Slowing down and looking carefully at the individual components in the diagram helped to make it become more familiar. They had seen most of this before, just in a different context. The only new component was the 555 timer integrated circuit.

A 555 timer has eight pins (legs). Each one is numbered anticlockwise from one to eight. When you see the same component on a circuit diagram, it looks as if all the pins have been mixed up. This can be a little confusing when trying to relate the diagram to the actual component. This is why I provided a graphic of the component, with its corresponding pins next to the circuit (see **Figure 1**). This definitely helped a lot, and I would highly recommend doing the same if you plan to use this with your learners.

I guided the makers through each connection in the circuit, highlighting the relevant section and using images to connect the diagram with the real components. They were surprisingly fast at following the diagram and connecting the wires. This was clearly becoming more of an automatic skill for them.

A few of them managed to get the LED blinking on the first try. Others were able to problem-solve and retrace their steps, realising that they had placed a jumper wire in the wrong hole or placed an LED in the wrong way. Eventually, they all had a blinky LED and a real sense of accomplishment.

> “ SOUNDING A BUZZER AT THE PUSH OF A BUTTON LETS YOU BRING OUT THAT INNER CHILD AND BE A BIT SILLY FOR A WHILE

What next?

After finishing the circuit, it was time to start thinking about how my makers could apply their new skills and knowledge to their own art projects. I showed them lots of examples of projects that other people had made using the same skills. I also showed them some projects that involved motors, because if you can sound a buzzer, you can spin a motor! I was very excited to see what they would come up with for their own art projects. You can find out too, in my final instalment of this series in the next issue of Hello World! (HW)



REBECCA FRANKS

Rebecca is a learning manager at the Raspberry Pi Foundation. She creates computing resources for teachers and young digital makers. She has over 15 years of experience teaching computing.

AGILE COMPUTING LESSONS

Matthew Wimpenny-Smith outlines how he trialled an agile methodology approach in his upper-primary computing lessons

As computing has become more established in curricula globally, so too has the amount of pedagogical research about the best ways to teach it.

In my own teaching, I have been developing my practice around these researched approaches, including Predict–Run–Investigate–Modify–Make (PRIMM), Use–Modify–Create, code comprehension, and paired programming. I recently read a book, *Invent to Learn* (**helloworld.cc/martinez2019**), which talks about applying project management models such as the waterfall model and agile methodology in the classroom. I had studied these methodologies during my degree, so this really piqued my interest in trying these real-world design models in my computing lessons for non-programming projects.

Around the same time as reading this book, my school started going through the process of redeveloping our curriculum for upper primary. I saw this redevelopment as a great opportunity to try my ideas of using a design cycle in my computing lessons, and I shared this with the wider STEM team at my school. The new curriculum is structured around termly themes (Literature and the Arts, Global World, and STEM), with a termly key question linked to the theme.

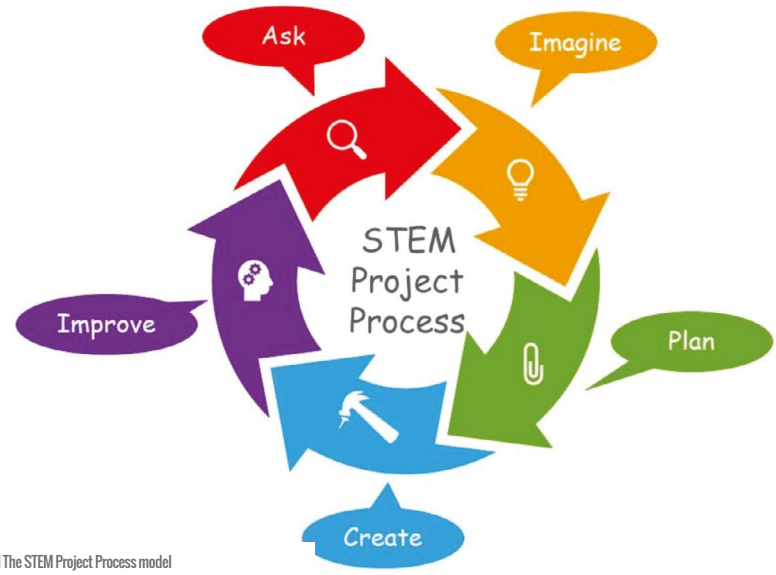


Figure 1 The STEM Project Process model

Developing a model

The autumn term was the STEM term for Year 6 (students aged 10–11), and the overarching question was, "Can we make it better?" (In this case, "it" referred to innovation and the engineering process.) With this question in mind, the STEM team decided to focus on an adapted agile methodology, which we called the STEM Project Process. Agile methodology has its roots in project management and is an iterative approach to software development projects. In short, this means a project is broken down into small increments, and after each of these small stages, the project or product being developed is reviewed and adapted based on feedback. We chose to use this methodology because it's swift, versatile, easy to understand, breaks projects down into manageable stages, and is an authentic model used in the real world. It also aligns nicely with the learning habits we are fostering through our new curriculum, including collaboration, imagination, and reflection.

Figure 1 was the model we came up with, along with a list of questions to go with each stage of the cycle (see **Figure 2**). Our model has five stages: Ask, Imagine, Plan, Create, and Improve. Each stage of this cyclical model helps learners to have a structured and scaffolded approach to their learning, which in turn reduces cognitive load and focuses them on what is doable.

Ask	Imagine	Plan	Create	Improve
What is the problem? What do we need? How much time do we have?	What are the possible solutions?	Choose a solution that looks good Gather materials	Build/Make Decorate Test	What are the new problems? How do we solve them?
What do we already know or have that could help us?	Brainstorm solutions What a good one looks like (WAGOLL)	Make a model create an algorithm	Play Tinker Program Experiment Construct/deconstruct	Share Get feedback
What are the needs? What are the constraints (e.g. time, resources)? What are the priorities? What is **not** important?	Plan solutions	Prototype design	Construct the prototype Test the prototype	Reflect & Refine Look at the problem from a different perspective
Define the problem Explore the problem		Set goals Decide who to work with Identify expertise Make predictions	Test strategies Observe others Document your progress Anticipate problems	Evaluate Communicate Share Get feedback

Figure 2 Questions for each stage of the STEM Project Process cycle

> AGILE METHODOLOGY HAS ITS ROOTS IN PROJECT MANAGEMENT AND IS AN ITERATIVE APPROACH TO SOFTWARE DEVELOPMENT

Applying the model to computing

I had planned for the first unit of my Year 6's academic year to be based on the Teach Computing Curriculum (TCC) '3D Modelling' unit (**helloworld.cc/tcc3d**), in which learners develop their knowledge and understanding of using a computer to produce 3D models. At the start of the unit, I gave lessons to introduce and develop learners' skills using SketchUp (**sketchup.com**), so that they would be ready for the Create stage of our STEM Project Process cycle.

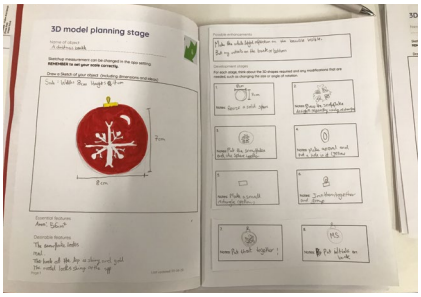
After a few lessons of this, I introduced pupils to the model. I explained that each stage would help them to develop an understanding of the process of planning and designing our 3D models. I gave them some context about how real-life architects, engineers, computer programmers, and scientists use models like this to produce projects. I also explained that the accompanying questions in **Figure 2** would be used like a checklist to guide their thinking around each stage, much like a story plan in English. It's important that learners understand that the process is as important as the finished project, and they shouldn't just dive straight into the Create stage.

I created slides for learners to refer to once they embarked on their projects, which included the cycle, the questions, and suggested strategies for each stage. For example, on the Imagine slide, I gave them examples of 'what a good one looks like', and then asked them to develop their own imaginative ideas and add these to the slide. For the Plan stage, I adapted the design booklet from the original TCC unit of work and I asked learners to create a sketch of their design, including details of its features and the steps they would need to complete to create a finished model. To link all the activities back to the model, I used coloured arrows and symbols to indicate which stage each lesson's tasks corresponded to.

Review of the model

At the end of the unit of work, I conducted a survey to gather the children's thoughts on the use of the cycle and what impact they believed it had had on their learning. I asked if they thought that using the cycle had improved their skills and knowledge and their final 3D model designs. Of the 40 children, 74 percent said that using the cycle had had a positive effect on their final designs and helped them to plan, stay on track, know what to do next, and know how to improve. Some positive comments were, "Now I have the steps to do, which helps me without just skipping and it's easier and I understand better," and, "This helped me because it helped me to know where to start and what to do next. It helped to make everting [sic] organized." What's more, 69 percent of pupils said that we should use the cycle more often.

This STEM Project Process cycle has clearly had a positive impact on the outcomes of learning. I feel that it has helped to develop the learners' understanding of the process of innovation, and I have decided that it's something that I am going to continue to develop with my learners. It really helps them to spend time going through this process to develop better skills, knowledge, and outcomes. (HW)



A pupil's design booklet



MATTHEW WIMPENNY-SMITH

Matthew is the assistant head of digital strategy at Headington Prep School in Oxford, UK. He is also the Oxon Teach Computing Hub primary schools lead, a CAS community leader, a Raspberry Pi Certified Educator, and a Fellow of the Chartered College of Teaching (**@MWimpennyS**).

E-SAFETY TIPS AND TOOLS

Zahra Amin Shelke shares insightful tips and fun ways to ensure your school and students are e-safe

I remember our parents teaching us how to walk safely on roads, and how to not accept anything from strangers.

As teachers and parents today, we have to extend these lessons to how to behave safely online, teach children not to talk to strangers over the internet, and so on. It should be our priority to teach our kids about online safety and what might happen if we aren't e-safe.

The safety of our students is of the utmost importance at our school, and I can proudly say that we have been following safety protocols and chasing this up with each and every child. The information can sometimes get overwhelming for pupils, but it is all done with the aim of improving their future. How did we adapt to ever-changing needs and implement e-safety in our school? I will walk you through our techniques, and hope that you will get some ideas to implement in your school.

Tools

- Create an anonymous Microsoft Form where students can voice any online safety concerns they have. There is an example at **helloworld.cc/safetyform**. This is a good format to use, so shy students don't have any obstacles to reporting their concerns.



A student's e-safety poster

- Use collaborative apps such as Nearpod (**nearpod.com**) to gauge student knowledge and get a discussion rolling on what information is and isn't safe to share.
- Use the Flipgrid app (**helloworld.cc/flipgrid**) and ask students to post videos about their thoughts on e-safety.
- Play some ready-to-use quizzes from apps such as Kahoot! and Quizizz (for example, **helloworld.cc/kahootesafe** and **helloworld.cc/quizizzesafe**). This is a fun and engaging way to learn about online safety.

Parents

- Get parents and the whole community involved in reinforcing the same behaviours at home.
- Share e-safety tips in the school newsletter and keep parents up to date with global e-safety news and initiatives.
- Conduct regular parent workshops on e-safety, including tips about parental controls, screen time, and what can go wrong when kids are online.

Everyday reminders and behaviours

- Display a dedicated e-safety slide at the start of each computing lesson, including the reporting form and a list of dos and don'ts.
- Show students how important it is to be an upstander. We often use case studies that ask students how they would have acted in a particular situation.
- Remind students that they should stand up for one another, and never cyberbully anyone.
- Tell students that once they post information online, they can't necessarily control it. We need to think twice before we post.



ZAHRA AMIN SHELKE
Zahra is head of the primary ICT department at GEMS Westminster School, Ras Al Khaimah, UAE. She has a master's in computer science from the University of Mumbai.

- Teach students that it is cool not to share all your life events online, and give examples of what information is OK to be shared.

Dedicated activities

- Celebrate e-safety week with class assemblies, and involve students in activities such as creating an awareness video for younger pupils, or creating an online safety mascot.
- Get your school the Common Sense School Accreditation, which demonstrates to the school community that you take e-safety seriously (**helloworld.cc/commonsense**).
- Dedicate an entire teaching unit to Common Sense Media's Digital Citizenship course about being safe online (**helloworld.cc/digcitizen**). (HW)

MUCH ADO ABOUT COMPUTATIONAL METHODS

Computational methods shouldn't be limited to STEM disciplines. **Tom Liam Lynch** makes the case for integrating computing into the study of literature and the wider humanities

Over the last year, our screens have been awash with data: of the spread of Covid-19, the number of hospitalisations and fatalities, and line charts predicting regional trends. Computationality undergirds such reporting, yet to limit our understanding of digital data to the world of STEM, as we so often do in school-age education, is inadequate. In the coming months and years, as schools cautiously emerge from the pandemic, I argue that we should rekindle and reimagine school-age computer science initiatives. Computational methods must become ubiquitous across wider subjects, especially in humanities classrooms. If the pandemic taught us nothing else, it taught us that the quantities we tally only matter because of the human qualities they attempt to represent.

Data for humanistic inquiry

When we embed computer science in English, language, and arts classrooms, we introduce computationality in the service of humanistic inquiry. Questions of character, ethics, truth, justice, equity, and morality can be richly posed and explored with the help of computational methods. Here's an example I have used with English teachers many times. In the chart in **Figure 1**, I offer two lines representing keywords from one of Shakespeare's plays. The words are 'love' (the red line) and 'death' (the black line). The x-axis lists the acts and scenes in the play. The y-axis indicates the number of times the words appeared in each scene. Forget what play it might be; just look at the data.

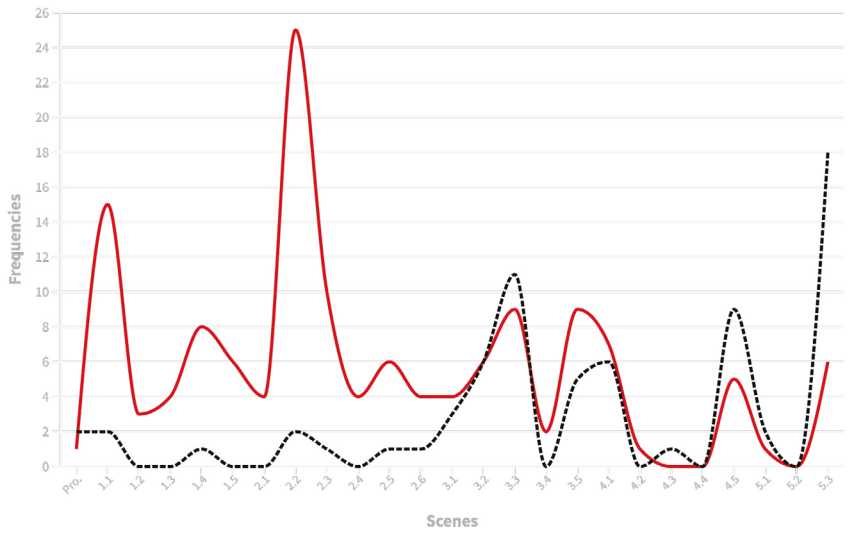


Figure 1 Plotting keywords across scenes in a Shakespeare play

Then ask yourself three questions. Firstly, what do I observe? Teachers will often observe that the frequency of the words have an inverse relationship. Love is way more popular in the beginning of the play; death is more frequently used in the latter half. Teachers will also often observe that in the third act, both words seem to be used more evenly. Secondly, based on your observations, what questions about the story emerge for you? Teachers have asked questions such as: What happens in Act 3 when the words are used with similar frequency? Do people die at the end of this play, because death is used far more often than love? What happens in the last scene that causes the use of the word love to surge one last time? Is there a wedding, or a funeral, or something else? Finally,

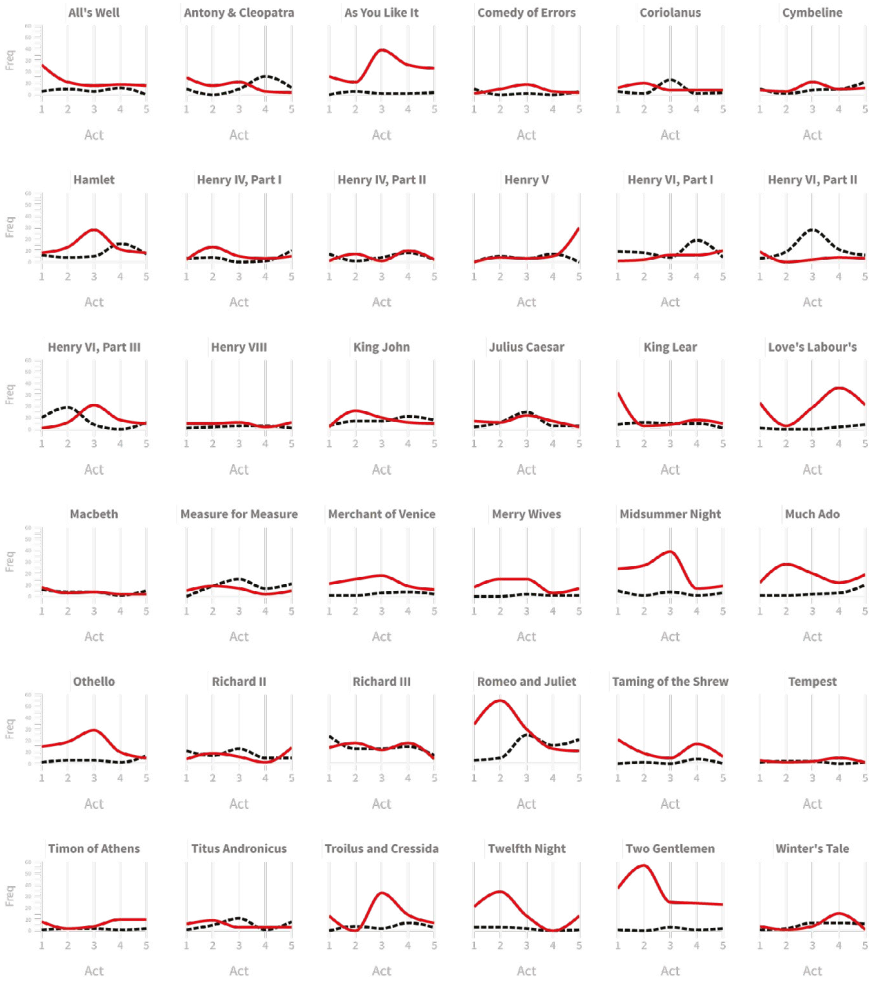


Figure 2 Plotting the keywords 'love' and 'death' across all Shakespeare plays

PROJECT IDEAS

- Explore a book using literary data for yourself at **helloworld.cc/plots**.
- When teaching poetry, try forefronting the concept of algorithms to explore with students how rhyme and metre serve as formulas poets use to increase literary effects.
- Upload any text into Voyant Tools (**voyant-tools.org**) to explore its language use using visualisations. Just note that the literary data will not be organised by chapters or scenes, but rather general percentage.
- Ask students to score each paragraph in a text for sentiment: negative (-1), neutral (0), or positive (1). Collect the data, calculate the average per paragraph, and create a simple line chart showing how sentiment rises and falls in the text. Finally, discuss what specific devices the author uses (such as the use of metaphors) to achieve this effect.
- Give students an excerpt from a literary text with keywords blanked out. Using 'if-then' statements, ask them to explain what words the author could have used and what effect they would have on the reader. For example, "If the author uses 'bloody', she makes the reader cringe and worry. If the author uses 'red', the reader just keeps reading."

what do you hypothesise about the plot and characters based on the data? Many rightly hypothesise that it is a nuanced love story that ends tragically, with some kind of important turning point in the third act. And if you guessed that it is *Romeo and Juliet*, in which Tybalt slays Mercutio and Romeo kills Tybalt in Act 3, you would be correct.

In this exercise, notice how computational methods (i.e. quantitative literary data visualised as a line chart) are used in the service of humanistic inquiry. In fact, readers can identify patterns in language and pose questions about a text using a data visualisation that they could not easily do if conducting a traditional close reading of the play alone.

Deepening our inquiries

Computational methods and quantitative data can help readers deepen and expand humanistic inquiry: deepen, because it actually forces us to look more closely at texts, and expand, because it offers new methods for doing so that complement existing practice. I taught *Romeo and Juliet* countless times as an English teacher. There is no realistic way to see patterns in the whole text at once as we do with the chart on the previous page. This method also provides myriad new points of entry for students to make meaning of the author's work, while simultaneously building a critical and humanistic understanding of how quantitative data operates in the world.

You can even extend the above example to all of Shakespeare's works at once. Instead of looking at scenes on the x-axis, we can look at acts in the play, because all of Shakespeare's plays have precisely five acts. Look at **Figure 2** for the frequency of love and death in all of his plays.

Again, what do you observe, inquire, and hypothesise? With just a quick glance, I observe that *Hamlet* has a similar pattern of frequency for our keywords. I wonder how Shakespeare's use of the words



FURTHER READING

helloworld.cc/litanalysis
Article discussing computational literary analysis

helloworld.cc/distantreading
Article discussing using algorithms and data visualisations to analyse literary texts

> THE BOUNDARIES BETWEEN NUMBERS AND LETTERS, OR COMPUTERS AND HUMAN BEINGS, ARE FALSELY DRAWN

compares across the two plays. Though they are both tragedies, I don't think of *Hamlet* as a love story primarily, but rather as a tale of madness. I hypothesise that on rereading *Romeo and Juliet*, I might explore whether the protagonists' affection for each other might be interpreted as an act of madness rather than frenetic teenage love. Does Shakespeare ultimately conflate love and madness? How do the actions of the star-crossed lovers compare to those of the Prince of Denmark? Those are valuable questions for students to pose, and ones that quantitative data and computational methods make it possible for us to identify and explore.

The pandemic has exposed our young people to the complex and sometimes traumatic relationship between digital data and lived visceral experience. In the coming months and years, our schools must help students explore what Covid-19 has heartlessly underscored: that the boundaries between numbers and letters, STEM and the humanities, and computers and human beings are falsely drawn. We must prepare students to contribute to the world in a way that sees the lives behind the lines on a chart, the human faces embodied in every data point. Computer science belongs in humanities classrooms because neither computers nor the sciences have very much value in the world unless they help us all understand and improve humanity itself — in the moment, and for generations to come. (HW)



TOM LIAM LYNCH

Tom has worked at the intersection of education, technology, literacy, and policy for over 15 years. A former English teacher and education technology professor, Tom is currently the policy director at the Center for New York City Affairs at The New School in the USA. He holds a doctorate in English education from Columbia University (**plottingplots.com**, **@tomliamlynch**).

INCREMENTAL WINS AND THE POWER OF PRAISE

Sam Green discusses the power of celebrating the small increases in students' understanding to support engagement and attainment

Over the past six years, we at Turinglab (turinglab.co.uk) have created many tools and resources for teaching programming. Almost 100,000 students have used these, but it hasn't always been plain sailing. One area in which we consistently struggled was progression and motivation. We often found that our materials required cognitive leaps that were too large. While a few students could take these in their stride, most were unable to follow along. They would eventually drop off, lose interest, or lose confidence in themselves, thinking that it was their inability rather than our poor curriculum design that was the problem.

I doubt these scenarios sound entirely unfamiliar. Teaching programming can be hard. In response to observing these patterns, we resolved to make the cognitive leaps as small as possible. We also decided to celebrate students for the minutest of victories. Internally, we talk about this approach as the power of incremental wins. In this article, I will discuss how Turinglab scaffolds progression, the power of praise, and how you can create an environment of celebration in your programming classes.

Scaffolding progression

When creating materials, we try to identify a student's likely existing knowledge and skills. This can be relatively straightforward if courses build from the ground up and use regular exercises to provide ongoing formative assessment. Having identified a student's incoming position, an incremental knowledge step can be derived. This could be introducing a new concept, such as teaching an 'else' statement once a student has already demonstrated ability in using 'if' statements; or it could be applying an existing concept in a context with more concept combinations. Crucially, the increments are kept small. While more capable students can fly through a course of small increments, a student with less natural ability will meet with disaster if the gaps are too large.

Let's explore how we might scaffold the introduction of the function `print()`, having checked that learners have the correct prior knowledge. We might state that `"print()` is a function that outputs the arguments provided to the console," and immediately follow with a task in which students apply this simple concept by completing a multiple-choice exercise:

Select the correct statement which outputs the string `"Hello World"` to the console:

```
print("Hello World")
print("Hello World"
print(Hello World)
```

The student is then given a series of incremental steps, such as the tasks in the box below. Each helps the student develop a more comprehensive and practical understanding of the concept of `print()`, and can be designed using either multiple-choice or fill-in-the-blank exercises.

SCAFFOLDING PROGRESSION

Task	Code scaffold	Desired outcome
Fill in a number or string of your own (fill in the blanks)	`print(____)`	The student is able to explore different data types being passed to the print function
Complete the function definitions to output the string `"Hello World"` (fill in the blanks)	`___("Hello") ___("World")`	The student is able to practise the feel of typing out `'print'` and observe how multiple print statements combine
Complete the syntax to print `"Hello World"` to the console (multiple choice)	`print__"Hello World"__` Options: `[ , ]  ( , )  :`	The student pays careful attention to brackets in their code
Print your name to the console (fill in the blanks)	`name = "_____"` `print(name)`	The student sees a variable being used in conjunction with the print statement



A typical topic slide on Turinglab, with immediate visual feedback

> TEACHING PROGRAMMING CAN BE HARD, SO WE RESOLVED TO MAKE THE COGNITIVE LEAPS AS SMALL AS POSSIBLE

The power of praise

While teaching with a carefully considered progression is a common idea, it's the winning that is so often forgotten in our classrooms. In computer science, students mostly have access to a computer, and we should leverage that. Computers can enable students to learn about a concept, then immediately apply their knowledge and have their application marked automatically.

Research shows that praise from a computer has similar positive effects to praise from people (**helloworld.cc/praise**). At Turinglab, we decided to throw everything but the proverbial kitchen sink at celebrating our students' successes. We introduced characters who would celebrate when learners' code runs correctly, buttons that change colour, pop-ups praising students, and experience points that learners earn when they successfully complete an exercise and can later be used by educators to highlight achievement and progression. In our latest Python course, they receive these incremental wins every 2.93 minutes on average.

We have seen time and time again that students who receive immediate praise like this for the progress they have made are more confident, more likely to be engaged, more likely to have better learning outcomes, and more likely to develop greater resilience when faced with harder challenges. Claire, head of computer science at Longsands Academy in the UK, said, "It was particularly beneficial for SEND students who could see their progress," and that the approach "provides students with revived enthusiasm with every small win". Claire also said, of her early-secondary students: "It was amazing to watch students who would usually struggle with programming concepts leading others." When we empower students with immediate feedback, students know when they are capable of supporting their peers, and those who can, do.

Try it for yourself

Of course, using tools with built-in widgets like ours is a great way to harness the power of incremental wins. However, everyone can recreate these techniques by breaking down course progressions into small chunks and rewarding students with sufficient frequency. For example, consider constructing a series of questions in an online form. Try to ensure that most of your students will be able to complete it in under three minutes. Ideally, your tool will be capable of delivering praise upon correct responses; if not, you will want to figure out how to praise all students more manually! This might mean providing a help sheet for those who need additional assistance to ensure they score highly, rewarding students for improvement, rewarding for high performance, or even rewarding for consistent effort.

You might also like to set coding exercises in which the output can only be achieved by writing the correct code, or in which the code is easily automarked. String at least five of these simple challenges together by linking to the scaffold in a tool such as Google Classroom. Ultimately, simply try praising your students a little more each day. At first, it can feel strange doing this for really small achievements. Rest assured, though, that receiving genuine praise more often really does improve confidence and engagement, and sets your classroom up for success. (HW)



SAM GREEN

Sam is a designer, developer, and educator at Turinglab, which he started in 2015 to help teach children programming. He is currently exploring ways of making this easier, while also keeping student engagement high and learning outcomes solid (**turinglab.co.uk**).

QUANTUM COMPUTING: AS EASY AS A PENNY FLIP

Andreas J. C. Woitzik and **Stefan Seegerer** introduce the world of quantum information through a quantum penny flip game

Quantum computing has become one of the hot topics in new technologies over the last few years.

Put simply, a quantum computer is "a machine that harnesses some of the unique properties of quantum physics to solve problems that are too complex for regular computers and even supercomputers" (**helloworld.cc/quantumc**). There are strong promises of a possible quantum speed-up of computers, though there are still many obstacles to overcome. In 2019, researchers claimed they had achieved quantum supremacy, a situation in which a quantum computer can solve a specific task much faster than any classical computer could (**helloworld.cc/arute2019**). The specific task they solved was highly artificial and not useful at all, but it showed us that quantum technologies are progressing fast. With many players from industry investing a lot of money and time in this technology, it cannot hurt for students to learn a little more about the topic.



A quantum coin can be in a state of heads, tails, or in a superposition of them both

So let us start you off. We are all used to traditional computers with their bits and bytes. Their power stems from being able to very quickly and efficiently manipulate those bits, which we interpret as either 0 or 1. Quantum computing is different: the fundamental bit of information is a qubit (quantum bit). Qubits are used to store quantum information. A qubit can take the values 0 or 1, but more than that, it can also store a superposition of them both. Being in a superposition means that the qubit can be partially regarded as a 0 and partially as a 1 at the same time.

Quantum penny flip game

Students can find quantum computing hard to grasp. To make it more approachable, we can describe superpositions, one of the core concepts, with a quantum penny flip game. David Meyer originally proposed this game in a 1998 paper, but we have created an online version of the game at **helloworld.cc/quantumpenny**. Before you continue reading, give the game a go — it is intended to be played by two people on a mobile phone.

In the game, two people, let's say Alice and Bob, compete in predictions about the outcome of a penny flip. In the classical world, if we spin a coin, there is a 50 percent chance of it landing on either side, heads (0) or tails (1). When it is spinning, we can consider the coin to be in a superposition of heads and tails. In this version of the game, Alice would prepare the penny as either heads or tails, put it in a box, and give the box to Bob. He would then decide whether to flip the box, and return it to Alice. Alice could also choose to flip the box again before opening it with Bob. If the coin showed heads, Alice would win.

In the quantum version, Alice gets a special quantum coin which she can prepare as either heads, tails, or in a superposition of both. The superposition is visualised by a spinning coin. If Alice decides to prepare the coin in a superposition, Bob's flip of the box does not alter the state of the coin. Since Alice can also revert the superposition and Bob cannot change it, she now has full knowledge of the state of the coin and therefore can always win the game.

Further discussions

This game functions as a motivating entry point to the world of quantum computing. While the classical coin behaves like a bit, the quantum coin behaves like a qubit. A subsequent discussion in class allows students to transfer the principle to



Credit: Annemarie Woeste

Students can explore the game, searching for a reliable strategy

computational ideas. For example, it is easy to see that a bit can be represented by a qubit, as the quantum coin has the states of heads, tails, and the superposition of heads and tails. With that in mind, it can be argued that a quantum computer can perform every computation a classical computer can do, as long as they both have the same number of bits and qubits. But by using its additional states, a quantum computer can, in theory, perform some tasks better than its classical counterpart.

> A QUANTUM BIT, OR QUBIT, CAN TAKE THE VALUES 0 OR 1, BUT CAN ALSO STORE A SUPERPOSITION OF THEM BOTH

You can also move to discussions of a more advanced algorithm, Grover's algorithm, which uses the concept of superposition to search in an unsorted list. Imagine your unsorted wardrobe contains 100 coats in 100 compartments and you want to find your yellow coat. In a worst-case scenario, you might need to look in all compartments before finding the coat. Using superposition, though, Grover's algorithm only has to look at the wardrobe ten times before revealing the right position of the object you are looking for (see **helloworld.cc/groversalgorithm** for more). This is useful in a lot of problems that involve an unstructured search.

The penny flip activity can also lead to a discussion about the fragility of quantum information and from there, to quantum cryptography. Once a superposition state is observed, it collapses, and from there, the coin can show only either heads or tails. This feature, certainly an obstacle for those wanting to build a quantum computer, forms the basis of many quantum cryptography protocols. The BB84 key exchange protocol, for example, uses superposition not only to exchange cryptographic keys securely, but also to uncover whether there is an eavesdropper (see page 34 for more on this).

Quantum computing is still very new, and the various unknowns and the abstract nature of it can make it hard for students to grasp. An activity such as the penny flip game, though, can provide an accessible entry point to a technology that may eventually change the way we understand the world. What better incentive could there be to give it a go? (HW)



ANDREAS J. C. WOITZIK

Andreas is a PhD student in quantum information science in the Quantum Optics and Statistics group at the University of Freiburg, Germany. He is interested in bringing quantum information to schools.



STEFAN SEEGERER

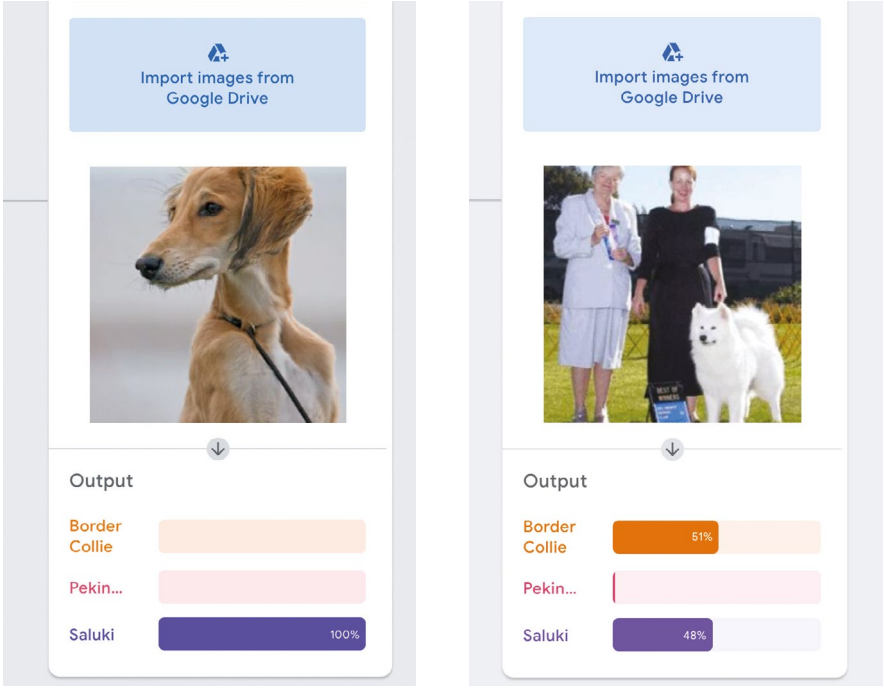
Stefan is the quantum education manager at IQM Quantum Computers, exploring ways to make quantum computing accessible to everyone (**@StefanSeegerer**).

MACHINE LEARNING: ACCURACY AND ETHICS

Michael Jones shares how to use Teachable Machine to investigate issues of accuracy and ethics in machine learning models

The landscape for working with machine learning/AI/deep learning has grown considerably over the last couple of years. Students are now able to develop their understanding from the hard-coded end via resources such as Machine Learning for Kids **(machinelearningforkids.co.uk)**, get their hands dirty using relatively inexpensive hardware such as the Nvidia Jetson Nano **(helloworld.cc/nvidia)**, and build a classification machine using the Google-driven Teachable Machine resources **(helloworld.cc/teachablemachine)**.

I have used all three of the above with my students, and this article will focus on Teachable Machine. For the worried, there is absolutely no coding involved in this resource; the 'machine' behind the portal does the hard work for you. For my Year 9 classes (students aged 13 to 14) undertaking a short, three-week module, this was ideal. The coding is important, but was not my focus. For this module, I'm more concerned with the fuzzy end of AI, including how credible AI decisions are, and the elephant-in-the-room aspect of bias and potential for harm.



Figures 1a and 1b The model may be confused if there are items that you're not testing in the image: this can lead to a useful discussion!

Getting started

There are three possible routes to use in Teachable Machine, and my focus is the 'Image Project', and within this, the 'Standard image model'. From there, you are presented with a basic training scenario template — see Hello World issue 16, pages 84–86, for a step-by-step set-up and training guide. For this part of the project, my students trained the machine to recognise different breeds of dog, with border collie, Labrador, saluki, and so on as classes.

Any AI system devoted to recognition requires a substantial set of training data. Fortunately, there are a number of freely available sets online (for example, download **helloworld.cc/dogdata**, where the folder is separated into a range of dog types). Be warned, these can be large, consisting of thousands of images. If you have more

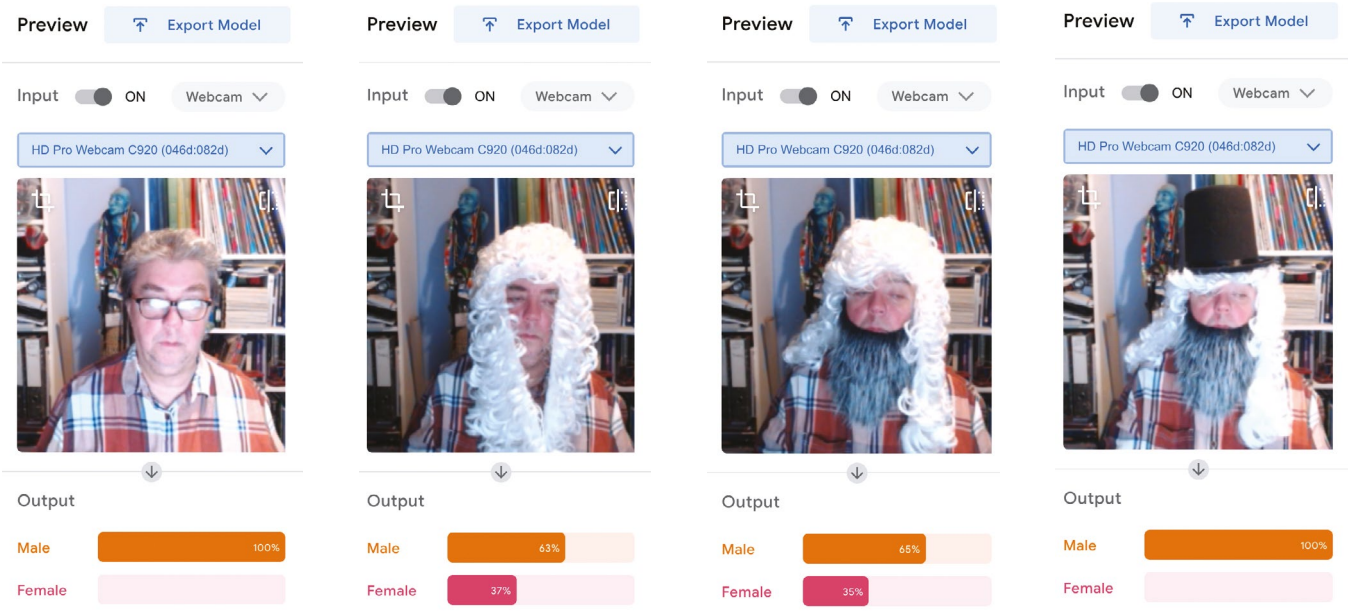


Figure 3 Confusing the machine

time, you may want to set students off to collect data to upload using a camera (just be aware that this can present safeguarding considerations). This is a key learning point with your students and an opportunity to discuss the time it takes to gather such data, and variations in the data (for example, images of dogs from the front, side, or top).

Once you have downloaded your folders, upload the images to your Teachable Machine project. It is unlikely that you will be able to upload a whole subfolder at once — my students have found that the optimum number of images seems to be twelve. Remember to build this time for downloading and uploading into your lesson plan. This is a good opportunity to discuss the need for balance in the training data. Ask questions such as, "How likely would the model be to identify a saluki if the training set contained 10 salukis and 30 of the other dogs?" This is a left-field way of dropping the idea of bias into the exploration of AI — more on that later!

Accuracy issues

If you have got this far, the heavy lifting is complete and Google's training engine will now do the work for you. Once you have set your model on its training, leave the system to complete its work — it takes seconds, even on large sets of data. Once it's done, you should be ready to test your model. If all has gone well and a webcam is attached to your computer, the Output window will give a prediction of what is being viewed. Again, remember there is an article in Hello World issue 16 that takes you through the exact steps of this process.

> WHICH FEATURES ARE BEING USED TO IDENTIFY THE DOG BREEDS? WHY ARE THE HUMANS CONFUSING THE MODEL?

Make sure you have several images ready

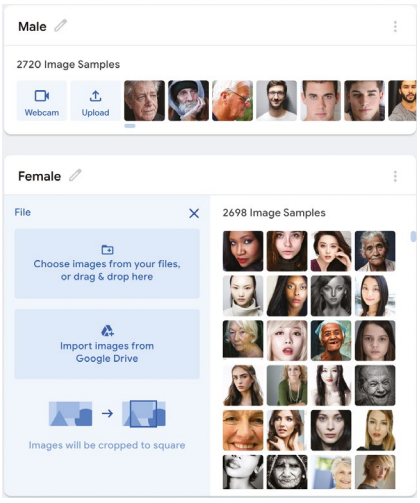


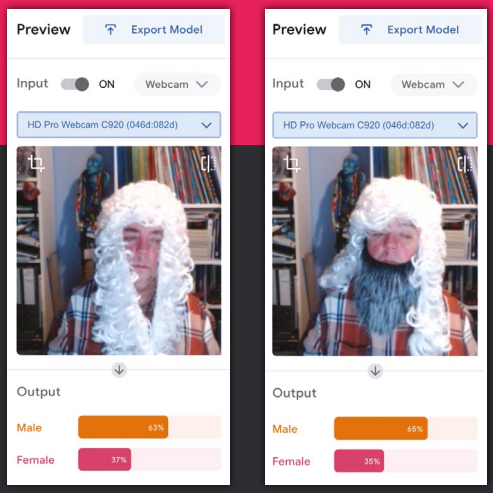
Figure 2 Using a large data set

to test. See **Figure 1a** for the response to an image of a saluki presented to the model. As you might expect, it is showing as a 100 percent prediction. It will spark an interesting discussion if you now try the same operation with an image with items other than the one you're testing in it. For example, see **Figure 1b,** in which two people are in the image along with the Samoyed dog. The model is undecided, as the people are affecting the outcome. This raises the question of accuracy. Which features are being used to identify the dogs as border collie and saluki? Why are the humans in the image throwing the model off the scent?

Getting closer to home, training a model on human faces provides an opportunity to explore AI accuracy through the question of what might differentiate a female from a male face. You can find a model at **helloworld.cc/maleorfemale**, which contains 5418 images almost evenly spread across male and female faces (see **Figure 2**). Note that this model will take a little longer to train. Once trained, try the

THE UNCERTAINTY PRINCIPLE

Machine learning uses a best-fit principle. The outputs, in this case whether I am male or female, have a greater certainty of male (65 percent) versus a lesser certainty of female (35 percent) if I wear a beard. Remove the beard and the likelihood of me being female increases by 2 percent.



> IT SOON BECOMES APPARENT THAT UNLESS YOU ARE WHITE AND MIDDLE CLASS, AI MAY BE PROBLEMATIC FOR YOU

model out. Props really help — a top hat, wig, and beard give the model a testing time (pun intended). In this test (see **Figure 3**), I presented myself to the model face-on and, unsurprisingly, I came out as 100 percent male. However, adding a judge's wig forces the model into a rethink, and a beard produces a variety of results, but leaves the model unsure. It might be reasonable to assume that our model uses hair length as a strong feature. Adding a top hat to the ensemble brings the model back to a 100 percent prediction that the image is of a male.

Bias

Within a fairly small set of parameters, most human faces are similar. However, when you start digging, the research points to there being bias in AI (whether this is conscious or unconscious is a debate for another day!). You can exemplify this by firstly creating classes with labels such as 'young smart', 'old smart', 'young not smart', and 'old not smart'. Select images that you think would fit the classes, and train them in Teachable Machine. You can then test the model by asking your students to find images they think fit each category. Run them against the model and ask students to debate whether the AI is acting fairly, and if not, why they think that is. Who is training these models? What images are they receiving?

Similarly, you could create classes of images of known past criminals and heroes. Train the model before putting yourself in front of it. How far up the percentage scale are you towards being a criminal? It soon becomes frighteningly worrying that unless you are white and seemingly middle class, AI may prove problematic to you, from decisions on financial products such as mortgages through to mistaken arrest and identification. Encourage your students to discuss how they could influence this issue of race, class, and gender bias — for example, what rules would they use for identifying suitable images for a data set?



MICHAEL JONES
Michael is the director of computer science at Northfleet Technology College in the UK. He is a Specialist Leader of Education and a CS Champion for the NCCE (@**MikeJonesCSTalk**).

There are some interesting articles on this issue that you can share with your students at **helloworld.cc/aibias1** and **helloworld.cc/aibias2**.

Where next?

In the classroom, you could then follow the route of building models that identify letters or words, for example. One of my students built a model that could identify a range of spoons and forks. You may notice that Teachable Machine can also be run on Arduino boards, which adds an extra dimension. Why not get your students to create their own AI assistant that responds to commands? The possibilities are there to be explored. If you're using webcams to collect photos yourself, why not create a system that will identify students? If you are lucky enough to have a set of identical twins in your class, that adds just a little more flavour! Teachable Machine offers a hands-on way to demonstrate the issues of AI accuracy and bias, and gives students a healthy opportunity for debate. (HW)

ME AND MY CLASSROOM

Etienne Dutoy reflects on how he used the move to a temporary classroom as a chance to forge a space with a positive impact on cognitive load

When my school said my students and I would be moving to a temporary classroom while our new learning centre was being built, the first thing I got excited about was that it was going to have air conditioning. I quickly realised, though, that it was a chance to make my classroom even more synonymous with creativity, innovation, and fun. It was also a fantastic opportunity to review cognitive load in computer science, and to see if the design of the classroom could help with this.

In the last year, in whole-school CPD, we have looked at cognitive load and been encouraged to review it in our subjects. Distractions in a classroom can increase cognitive load for our students, and make it much harder for them to turn working memory into long-term memory. In my new classroom ('Lovelace 10'), I have installed simple displays that act as bridges or links for my students to connect previous knowledge to new learning. A key in these displays was using magnetic tape to attach them to the walls. In the Scratch display, this means it works like the block-based approach that Scratch uses. It assists students in feeling less stressed about making syntax errors, as they can move it around on the walls easily.



Part of the Scratch display


More open classroom space means more unplugged activities!

I have also put objects in the classroom to encourage my students to have open-ended conversations with each other about computing. One of the most successful was my computer science periodic table, comprising key coding terms. One student even went as far as to comment, "Cool display, sir." From that lesson onward, Python data types seemed to be in a lot of learners' longer-term memories. They recognise the pattern of the table from chemistry, and realise that they need to remember the terms when programming.

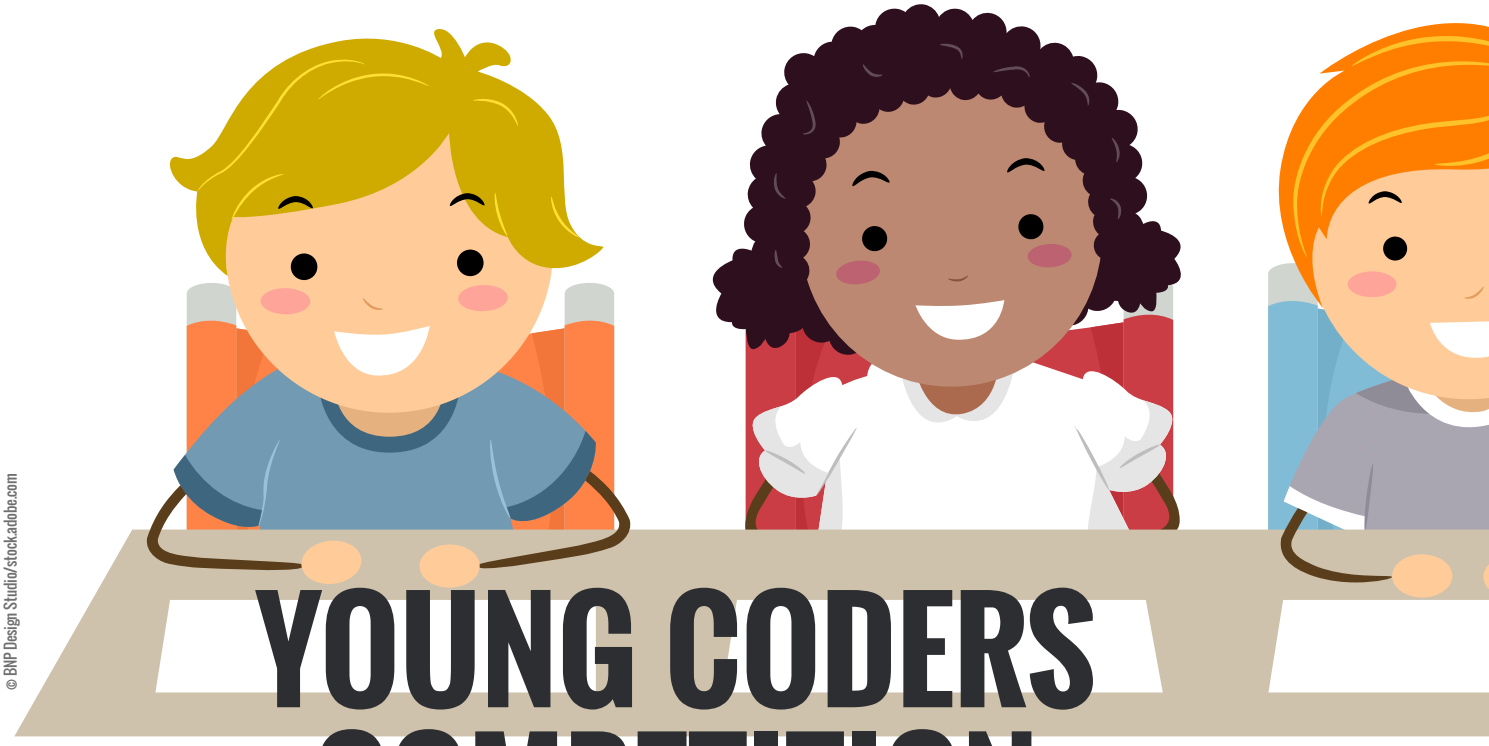
The big space in the new classroom has also allowed me to explore more unplugged approaches — for example, getting the whole class to 'become' the CPU and act out its functions, so they can see how it works. Having this classroom space helps reduce cognitive load, as students can visualise an abstract concept.

I always want my classroom to be a portal where my students discover that computer science is a universe filled with modern, dynamic, exciting opportunities. By helping my students with their cognitive load, I believe I am giving them the capacity to learn what they need for the careers they want, using the computers and the technology of the future. (HW)



ETIENNE DUTOY

Etienne has been a teacher for 14 years. He teaches computer science at Sprowston Community Academy, Norwich, UK. He has boundless energy for experimenting with new pedagogies, edtech, and innovation in his teaching.



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YOUNG CODERS COMPETITION

Shaun McMahon describes his experiences of the coding competition that his school has won for the last three years

Young Coders is an annual coding competition run by the Worshipful Company of Information Technologists, Leicestershire Education Business Company, Cranfield University, Canterbury Christ Church University, and the University of Northampton, in the UK. These groups have recognised that there is a shortage of coders, so the competition aims to spark interest in coding at an early age, to help create coders for the future. Young Coders has been growing ever since its founding in 2015 and now sees global entries, including teams from Nigeria and Canada.

Triple champions

Although the competition has now gone global, initially it focused on the Northamptonshire area in the UK, and that's where I joined the story. I found out about the competition and, due to the large number of children wanting to take part, ran a lunchtime coding group several times a week. I was working with several teams, and I gave each group their own dedicated time to support them with their entries. It was great to have an opportunity to be a part of the next generation of coders; the coders of the eighties and nineties are now the ones working on the cutting edge of programming, so who knows what technology my young coders will be working on in the future! As the closing date approached, the students came out of lessons and spent the whole day finalising and debugging their code, honing their entries to be the best that they could be. The time spent paid off: for the first three years of the competition, my school's teams won every time!

In recognition of the school's achievement and success, I was offered a place on the coding competition's committee for 2019/20 and my students became part of the final judging panel. The students judged a shortlist of games selected by the adult judges, filling out a form to score the games on their ease of controls, repeat playability, and whether the brief had been fulfilled.

Before they embarked on the judging, I explained how important this task would be, as they would have the final call in judging the games, and there were cash prizes at stake for the winners. The children took this on board and were mature and thoughtful in their judging and comments. The children gained an appreciation for the importance of being fair to every entry and gave constructive feedback on the games. They were also very excited to have the final say and felt that their opinions mattered. Although school closures during the pandemic hit entry numbers badly, the teams who entered through their schools' online portals showed great resilience, perseverance, and cooperation. Even lockdown couldn't keep good coders down!



The final judging panel included students

> SCHOOL CLOSURES HIT ENTRY NUMBERS BADLY, BUT THE TEAMS WHO ENTERED SHOWED GREAT RESILIENCE

2022: Join now!

Now the competition is back for 2022 with the theme of My World, Our Planet. Students are asked to produce an original game around the theme using Scratch. I think the best piece of advice that I can offer to any potential entrants is to try to keep it simple. Think of a simple idea, with simple code, and then make it shine. Pac-Man, Space Invaders, and all those older games have endured for so long because they are very simple in their game design and controls — anyone can pick them up and play.

Apart from the glory of becoming competition champions, each student in the three top teams also receives a signed copy of my book (**helloworld.cc/fowl**), a personalised trophy, a certificate, and a cash prize for the school(s). The competition is open to any group of up to six children aged 8 to 13, from any school, club, or organisation with an adult willing to support them and submit their entry. Registration is open now, and the competition closes on 27 May 2022. You can find further information at **codingcompetition.org** where, upon registering, you also get access to a range of free ICT teaching resources. (HW)



The 2021 winning game focused on fire safety



SHAUN MCMAHON

Shaun works as an IT technician at Park Junior School in Wellingborough, Northamptonshire, UK. He has worked in IT for 15 years, 12 of them in the education sector.



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COMPUTING AT SCHOOL OPEN DAYS

Gemma Coleman catches up with computer science teacher **Yasin Abbas** to discuss how to represent computing at school open days

What activities do you usually run on open days? Why do you choose those particular activities?

We have a heavy footfall on open days and due to Covid, we limited sessions at our most recent open day to 15 minutes at a time. This reduced our options for activities other than Q&A sessions and presenting work that our students had produced for their non-exam assessments. As an open day nears, I also ask students to engage with a quick-fire project of their own choice. I give them access to the hardware I have and see where they take it, with minimal intervention on my part. It works really well!

We tend to focus on showing off interesting projects that guests can interact with, such as robotics with our Cozmos (programmable robots that can detect objects and faces); coursework such as a train journey planner app; simple Pygame platformers; and a fun digital MIDI theremin using a Kinect (a motion-sensing input device). We also set up several computers in the lab with our digital school prospectus, an informative slide show, the exam board specification, and a game to explore algorithms called The Jewels of Heuro (**helloworld.cc/heuro**).

Our students really help out on the day, having discussions with prospective students and parents. I tell them to just be open and honest about their experiences. I personally have found that it works best to give students a two-week sprint before the open day to learn and create something new to talk about!

How do you help a student decide if choosing to study computer science is right for them?

Studying computer science is unique — it involves both logical thinking and creative problem-solving. It's also traditionally the hardest of STEM A-level subjects (for students aged 16–18) to gain an A* at (just 4.2 percent in the UK achieve this) and involves a substantial practical coursework element.

We don't sugar-coat, and we certainly tell it how it is. If you're going to do a computer



We show off interesting projects such as our work with Cozmos

science degree, you'll visit a lot of the first-year degree content in the A level, so it's a super-helpful base. If you're not going to do a computer science degree, you should think about doing it at A level because you will pick up enough practical programming skills to benefit any future STEM-based degree (as if you had done the first year of a computer science degree). It's a win-win.

What are the most common questions you get from students? And what are your answers?

- **What content is covered in the course?** We direct students to the specification.
- **How much of the A level is similar to the GCSE?** Quick answer: we cover somewhat more than the GCSE, including databases, assembly language, functional programming, and object-oriented programming (OOP).
- **What is the gender ratio?** Women make up roughly 30 percent of our intake, and we want to even out those numbers!
- **What are the admissions requirements?** We point them to our school prospectus.
- **What are the pass rates?** See my answer to a previous question. In short, don't take the subject if you're after an easy A*/A!
- **Which programming languages can you study?** We tell students that we run a language-agnostic course. We introduce both C# and Python, and the course additionally covers some Haskell, SQL, and AQA assembly (ARM-based assembly language). The practical paper for the specification we follow is available in five different languages. We give students the option to do any of them, and they can do coursework in any language, as long as it's not Whitespace or LOLCODE!
- **Can you take computer science at A level without a GCSE or prior programming knowledge, and does it affect outcomes?** You're welcome to do computer science A level without a GCSE and without knowing coding. It doesn't affect outcomes, because we make no assumptions about prior knowledge. We've known students who didn't have a computer science background who became very strong coders.
- **What other subjects do you recommend that we take?** We recommend taking STEM-based A levels, and especially maths, further maths, and physics. This is flexible, of course, but we really stress the importance of maths, as most computer science degrees set this as a requirement.

How do you convey the balance between the more typically exciting aspects of computing, and the perhaps drier theoretical aspects?

For open days? I don't think we get the opportunity to. In general, all topics have relevance, whether they're practical or theoretical, and so we focus on the whys. The more fun aspects of computer science are heavily based on theory, and an understanding of this generally drives the reasons to study. The Jewels of Heuro game, for example, introduces the concept of theoretical content, such as Big O notation and the travelling salesman problem. Most students aren't aware of how simple problems actually have a lot more to them under the surface.

Is there anything in particular you do to encourage girls to choose to study computing?

I'm in discussions with our female students at the moment to help me understand these issues better myself. I particularly keep in mind the notion that you can't be what you can't see; as a male teacher in this zone, I didn't appreciate that my own gender could be contentious. Personally, I didn't distinguish between genders, but I've since learnt that maybe I should. I'll describe my current approach below, but as I'm still learning about this from our students, this could change.

As our gender ratios are still unbalanced, I try hard to engage with our female students when it comes to representing computer science at open days. I have also noticed that prospective female students will talk more readily with our current female students.

I try to impress on prospective female students the nature of the A level, both its logical and creative elements. I also tell them that there's a very human component to the subject that's often missed, as I've found that this often seems to appeal to female students. I've found personally that women tend to be more driven by the long-term and not the short-term picture. I tell them there's a positive recruitment drive in the industry that could see them being recruited quickly, and this is mainly because studies have shown that mixed-gender departments work better. (HW)



YASIN ABBAS

Yasin is the head of computer science at Woodhouse College in London, UK. He has also worked as a lecturer at the University of Greenwich, at City, University of London, and as a teacher in Indonesia.

LESSON PLAN

The following three lesson plans are taken from the six-lesson 'Cybersecurity' unit in the Year 9 (age 13-14) stage of the Teach Computing Curriculum (TCC).

This unit takes learners on an eye-opening journey of discovery about techniques used by cybercriminals to steal data, disrupt systems, and infiltrate networks. It aims to increase learners' awareness of the importance of their data to cybercriminals, the most common methods of attack, and the measures used to defend against threats.

ABOUT THE TCC

Teach Computing

The Teach Computing Curriculum is part of England's National Centre for Computing Education and supports students aged 5-16.

Every unit of work in the TCC contains: a unit overview; a learning graph to show the progression of skills and concepts in a unit; and lesson content, including a lesson plan, slides, and formative assessment opportunities. Find them when you sign up for a free account at **helloworld.cc/tcc**.

SCRIPT KIDDIES

Introduce learners to the techniques used by hackers to steal data and cause disruption, as well as their legal consequences

Ben Garside

This is the third lesson in the TCC's 'Cybersecurity' unit, focusing on exploring the concept of hacking and the techniques used by hackers to exploit computer systems. (HW)

STARTER: HACK GEORGE'S FAKEBOOK ACCOUNT 10 MINUTES

George's phone is off and his family don't know where he is. Learners must hack into George's Fakebook account to see if they can find information on his whereabouts. Using clues from his social media, learners might be able to guess his password and find him.

Ask learners to navigate to **ncce.io/fakebook**, which will take them to a fake login page where they need to run the program and enter a password.

To work out the password, give the class clues in the form of public messages posted on another of George's social media accounts (**Figure 1**). You can download **Figures 1** and **2** from the slides at **helloworld.cc/scriptkiddies**.

They won't know the password, but a hint, 'colour TV', will appear if they guess incorrectly.

The answer is 'RedSimpsons'. The password is case-sensitive, so if the learners get the right answer but haven't used capital letters, encourage them to think about how to create strong passwords. Show the clues in **Figure 2** if they are struggling. Once learners get into the account, they can see that George is at the cinema. Ask them to consider the following questions:

- If you hacked into a friend's account, does that make you a hacker?
- Was hacking into George's account ethical?

Learners might believe that as they weren't given permission by George, and they used his social media to crack his password, their actions were unethical. Some might believe they were ethical, as they were doing it for what they thought was a valid reason: to help his worried parents.

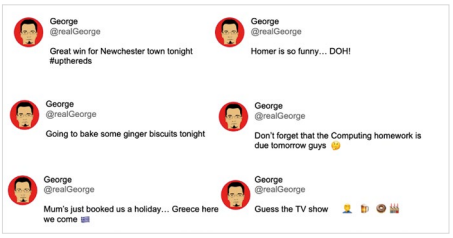


Figure 1 George's social media posts

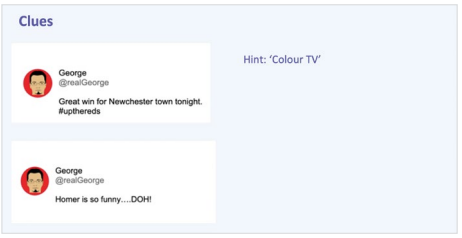


Figure 2 Clues for George's password

ACTIVITY 1: HACKING 8 MINUTES

After defining the term 'hacking', ask learners why people may want to hack. Give them a couple of scenarios to debate the ethics of different contexts. For example, is it ethical to hack into the systems of a company that you suspect is testing their product on animals and harming them, in order to expose their practice?

ACTIVITY 2: DDoS 12 MINUTES

Learners will now explore the Dyn cyberattack (**helloworld.cc/dyn**). Explain that it was a distributed denial of service (DDoS) attack that meant that many people couldn't access websites, as the services that provide the locations of the web servers were attacked. Explain that this was done by 'script kiddies' (hackers who don't have technical hacking knowledge but use downloaded software to do the hacking for them).

Set up an activity in which learners play the part of a server experiencing DoS and DDoS attacks from their fellow classmates (acting as clients). The job of the server is to catch requests in the form of paper balls being sent (thrown) by a student acting as a client. After 30 seconds, ask the client to start throwing them as fast as they can until the server stops catching them and can't handle the requests. This simulates a DoS attack. To simulate a DDoS attack, ask some more students to act as clients making requests. Ask clients to start slowly, to make it manageable for the server to handle the requests (catch the balls), before their requests become more frequent until the server stops being able to handle them all!

ACTIVITY 3: BRUTE FORCE ATTACKS 10 MINUTES

Introduce students to the term 'brute-force attack' (an attack that makes multiple attempts to discover something such as a password).

Ask learners to open and run the Python program at **helloworld.cc/bruteforce**. This runs through combinations of characters until it matches a string, recording how many attempts it took to do this and how long it took. Learners will discover how making a password more complex significantly changes how long it takes for a computer to crack it.

The password is currently set as 'ab' — ask students to change the password to 'abc', 'Abc', and 'Abc1' respectively. Each time they run the program with these different passwords, they should record the number of attempts and the time taken for the program to figure them out. Ask them to look at the results and explain why the password 'Abc1' would be more secure than 'abcd'.

You can then explain that the program has been set to check only for ASCII letters and digits. Ask learners to modify line 15 of the program to `print(guess_password(password,extended))` , so that it checks for punctuation and white space in the password. Now get learners to run the program with the passwords 'abc', 'Ab1', 'Abc1?', and 'AB C1', and record the number of attempts and the time taken for the program to crack each one. Having done these tasks, ask students what password rules they would set themselves to reduce the chance of a successful brute-force attack against them.

ACTIVITY 4: COMPUTER MISUSE ACT 5 MINUTES

This activity aims to highlight the law that exists in the UK to deter hackers. The Computer Misuse Act 1990 (CMA) prosecutes hackers for their actions, regardless of their intentions or technical expertise. After watching a short video (**helloworld.cc/ncavideo**), explore the three principles of the CMA (**helloworld.cc/cma**).

PLENARY ACTIVITY: DYN CYBERATTACK 5 MINUTES

Using their knowledge of the Dyn cyberattack and the CMA, ask learners the following:

- Which of the three sections of the CMA does a DDoS attack violate?
- Why do you think this?
- What is the maximum punishment for this crime under this act?

AGE RANGE

11-14 years

REQUIREMENTS

- A web browser

OBJECTIVES

- Define 'hacking' in the context of cybersecurity
- Explain how a DDoS attack can impact the users of online services
- Identify strategies to reduce the chance of a brute-force attack being successful
- Explain the need for the UK Computer Misuse Act (1990)

RELEVANT LINKS

TCC 'Script kiddies' lesson: **helloworld.cc/scriptkiddies**

AGE RANGE

11-14 years

REQUIREMENTS

- A web browser

OBJECTIVES

- List the common malware threats
- Examine how different types of malware cause problems for computer systems
- Question how malicious bots can have an impact on societal issues

RISE OF THE BOTS

Explore different categories of malware and help your learners understand the impact of malicious bots

Ben Garside

This is the fourth lesson in the TCC's 'Cybersecurity' unit. The purpose of this lesson is to make learners aware of malware and the different categories of malware, as well as understanding how they work and the damage they can do. This lesson focuses more on the technical side than on prevention methods, which is covered in the fifth lesson of the unit. (HW)

STARTER ACTIVITY: RANSOMWARE ATTACK 5 MINUTES

As soon as your learners enter the classroom, they'll realise something strange is happening. Ideally, if you have screen-sharing software, use it to place your screen on theirs to make it look as if all the computers have been infected by a ransomware attack (like the image in **Figure 1**). Using your inner thespian, enact the role of a panicked teacher and ask the class for advice. Should you pay the ransom or not? If they decide not to pay, switch the screen to a slide informing them that the data has gone. If they choose to pay, switch the screen to a slide informing them that 50 percent of the data has been decrypted, but more payment is required. The activity aims to highlight the potential damage that malware can do.

> PRETEND TO PANIC, AND ASK THE CLASS: SHOULD YOU PAY THE RANSOM?

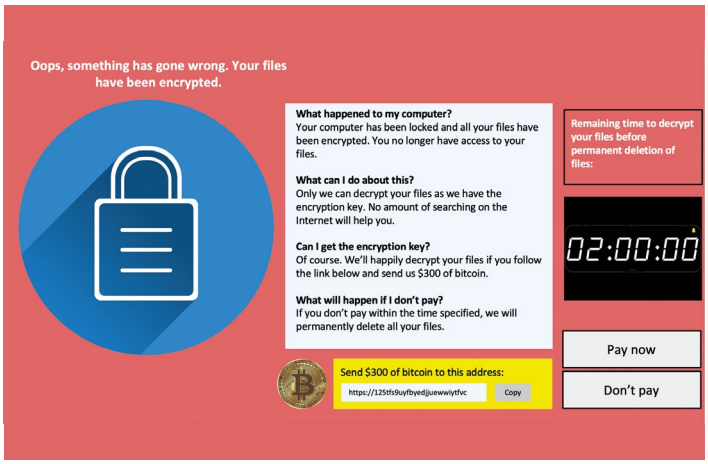


Figure 1 Enact a ransomware attack in your classroom!

ACTIVITY 1: MALWARE 10 MINUTES

Introduce learners to the term 'malware' and give a brief description of the following common types of malware:

- **Viruses**: Self-replicating software that maliciously modifies files.
- **Trojans**: Software that appears to perform a useful function, but unbeknown to the user, it also performs malicious actions.
- **Worms**: Self-replicating software that causes disruption by using system resources.
- **Adware**: Can be a worm, a virus, or a Trojan. It infects a computer and causes it to download or display malicious adverts or pop-ups when the victim is online.
- **Spyware**: Unwanted software that monitors and gathers information on a person and how they use their computer.
- **Ransomware**: A specific type of virus that locks a computer and encrypts files, preventing the user from being able to access the data.

ACTIVITY 2: QUICK READ 20 MINUTES

Set the scene with the learners that their local cybersecurity police force wants them to make a quick-read fact sheet to help educate the public on malware. Depending on your setting, you can either allocate a category of malware to the learners or let them pick for themselves. Whichever category they pick or are allocated, they must:

- Research the malware to give information as to what is it
- Describe how it would break the Computer Misuse Act 1990, or your country's equivalent (see previous lesson)

To stretch students further, you can ask them to find a case study of where the malware was used and the impact it had.

ACTIVITY 3: BOTNET 5 MINUTES

According to Cloudflare (2019), over 50 percent of internet traffic is bot traffic, and a significant proportion of that is malicious bots! Explain to the learners what bots are and the tasks they might perform in this context, with both positive and negative uses.

Explore two examples of malicious actions conducted by bots: the automation of social media accounts, and bots that look for vulnerabilities of internet-connected devices. Prompt the learners to think about what devices they have that might be connected to the internet, to exemplify the scale of possibilities that can be exploited, as well as the number of bots needed to work through all the devices around the world that are connected to the internet. This leads us to the term 'botnet', referring to a large collection of malware-infected devices (zombies). It is likely that the owner of the zombies is not aware that they have been infected. When an attacker chooses to make an attack, they use software to 'wake' the zombies to carry out an attack. For example, the zombies might be controlled to send multiple requests to a single server. Ask the learners to think about what this type of attack is called (a DDoS attack).

PLENARY ACTIVITY: INFLUENCING VOTERS 10 MINUTES

During a review of their platform after the 2016 US presidential election, Twitter announced, "We have identified a total of 50,258 automated accounts that we identified as Russian-linked and tweeting election-related content during the election period." Ask the learners to think about the following question:

What are the potential consequences of 50,258 automated accounts (non-human users) posting election-based content?

The aim of this activity is for the learners to think about the fact that these automated accounts have been made to target Twitter users, to try and influence their opinion and convince them to vote in a certain way. The political nature of this highlights a potential new form of warfare between governments, which can attempt to destabilise other countries. Encourage learners to reflect on the information that they see on social media and question the motives behind the messages.

RELEVANT LINKS

TCC 'Rise of the bots' lesson:
helloworld.cc/riseofthebots

AGE RANGE

11-14 years

REQUIREMENTS

- A web browser

THERE'S NO PLACE LIKE 127.0.0.1

How do you protect a network against cyberthreats? What are the risks, and how much of a threat are they?

Ben Garside

OBJECTIVES

- Compare security threats against their probability and their potential impact to organisations
- Explain how networks can be protected from common security threats

This is the fifth lesson in the TCC's 'Cybersecurity' unit. This lesson aims to help learners to develop their understanding of the risks that cyberthreats pose to a network, followed by an exploration of common methods of defending a network against attacks, such as firewalls. Learners will look at global threats before thinking about threats at the school network level. They will also discuss methods used by network managers to reduce risk. (HW)

STARTER ACTIVITY: THE STATS 8 MINUTES

As learners enter the room, display statistics on the board to focus their minds on the content of the lesson (see **Figure 1**).

These stats highlight that organisations have to invest a lot of money to protect themselves against cyberattacks. Ask learners to answer the following questions independently — you can give them multiple-choice answers for support:

- Trojans, spyware, adware, and worms are all examples of what?
- What is the term for when human users of a system are tricked into providing confidential information?
- What is the term for a large collection of malware-infected devices used to carry out an attack on a system?

The questions are designed to remind the learners of the concepts that they have covered that will feed into this lesson, but it is also an opportunity to address any misconceptions that may have arisen.

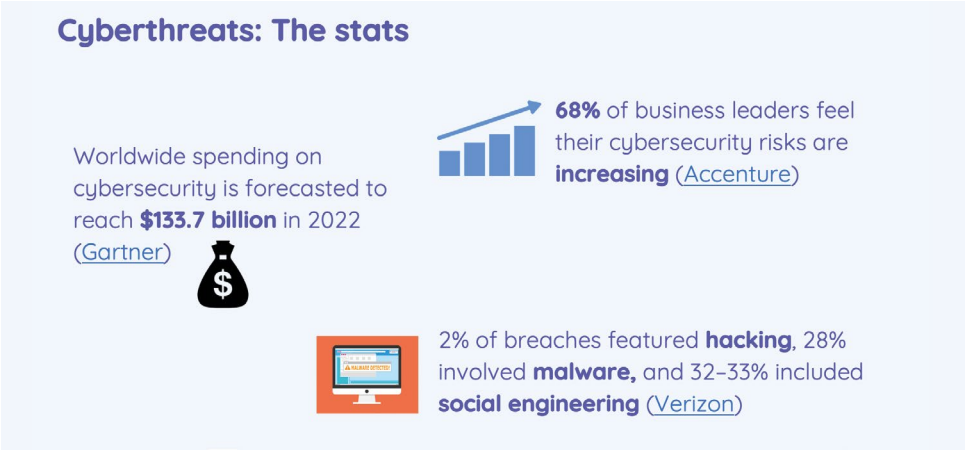


Figure 1 Cyberattack statistics

ACTIVITY 1: CYBERTHREATS 10 MINUTES

Ask learners to visit **helloworld.cc/threatmap**. This shows the global cybersecurity attacks taking place in near-real time. Ask learners to explore the website and answer the following questions:

- What are the top three targeted industries?
- What are the top three malware types?
- Which malware trend makes up the largest percentage of attacks in their country?

From the learning that has taken place so far in this unit, students should be able to understand a lot of the key terminology used on this site and get an understanding of the scale of cybercrime taking place globally.

ACTIVITY 2: RISK VERSUS IMPACT 8 MINUTES

Explain to students that network security provision is based on risk. Companies will often compare the possible impact of an attack against the probability of it happening. This helps organisations to plan their budgets. Ask learners to work in pairs to complete a cybersecurity risk assessment for the school network based on the potential of the following threats:

- Viruses
- DDoS
- Social engineering
- Ransomware
- Brute force
- Internal threat

Get learners to plot their threat analysis on a probability vs impact graph (with probability on the x-axis and impact on the y-axis).

ACTIVITY 3: SOFTWARE SOLUTIONS 10 MINUTES

Discuss some of the available software that can reduce the chance of cyberattacks being successful (for example, firewalls, anti-malware, auto-updates).

It might add value to the learners if you are able to get your school network manager to talk about the threats to a school network and discuss this software.

ACTIVITY 4: PERMISSIONS 15 MINUTES

Ask learners to consider what security methods are in place on the school network to prevent unauthorised users from accessing data. Ask them to think about the following questions:

- How do you log into the school system?
- What measures are already in place to make it secure?
- What measures could be put in place to make it even more secure?

You will then make them aware of the following methods that the network can use:

- Secure passwords (password managers)
- A maximum number of sign-in attempts
- CAPTCHA
- Biometrics
- Two-factor authentication (2FA)

Again, using the school network for context, pose the question, "Should this be the same for all users of the system?" This should prompt the learners to think about other users of the system besides themselves.

PLENARY ACTIVITY: ALLOCATE THE PRIVILEGES 5 MINUTES

Ask the class to discuss what privileges the reception staff should have on the school network. Discuss each one in turn:

- The ability to install new software
- Read/write access to the staff shared drive
- Read/write access to student shared drives
- The ability to see registers and pupil data

RELEVANT LINKS

TCC 'There's no place like 127.0.0.1' lesson: **helloworld.cc/noplacelike127**

CODING A CAESAR CIPHER IN PYTHON

This lesson introduces symmetric cryptography with a hands-on approach in which students use Python to create a Caesar cipher

AGE RANGE

11-14 years

REQUIREMENTS

- A computer that can run Python
- A web browser

Students really enjoy the idea of cryptography and sending secret messages! In this lesson, they will create the code for a Caesar cipher, which was famously used by the Roman Empire, and is the 'Hello World' of cryptography. This lesson is aimed at students aged 11 to 14, but the introduction and Scratch components can be taught to students as young as 9. For older students, it forms a good foundation from which to move onto modern ciphers, file management, or to make a simple GUI-style app (for example, see this sample from a Year 13 student: helloworld.cc/guicaesar).

Part of the joy of this lesson is that students see that this cipher takes some effort to decode manually, but they can decode it instantly by using a computer! This then really sparks their imaginations as to how they could create a cipher that would be much more difficult to crack. In the past, I have included punctuation, numbers, and upper-case characters, but this makes the encoding and decoding of the cipher much more cumbersome. With only 26 possibilities, the cognitive demand on slower readers is much more manageable. (HW)

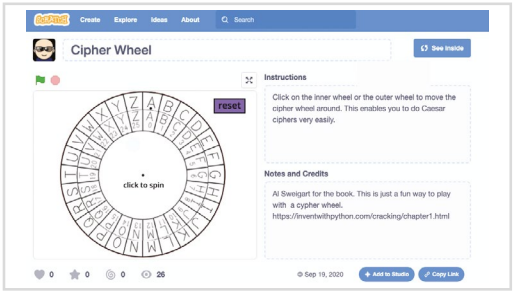
OBJECTIVES

Using iteration, lists, and string manipulation:

- ✔ I can understand how symmetric encryption works
- ✔ I can develop code to create a Caesar cipher

ACTIVITY 1: CIPHER WHEEL 10 MINUTES

Write "uhvlolhqfh" on the board and ask students if they know what it means. Once they've had time to guess, give them a cipher wheel and ask them if they think it will help. You can find an interactive cipher wheel at **helloworld.cc/wheel1**, or learn how to make a physical version at **helloworld.cc/wheel2** (login for Computing at School site required).



An interactive cipher wheel in Scratch

Introduce the concept of a shift, explaining that the Caesar cipher is a substitution cipher in which each letter is shifted a certain number of places down the alphabet. You can now demonstrate that "uhvlolhqfh" has used a shift of three for the message "resilience".

Here are the shifts:

```
0 uhvlolhqfh
1 tguknkgpeg
2 sftjmjfodf
3 resilience
```

Let students pick their own word and give it to a partner to crack. Students should now understand the concept of a Caesar cipher and how to crack one using shifts.

ACTIVITY 2: CODING THE CIPHER 40 MINUTES

Explain that if you have the key to a Caesar cipher, it's very easy to crack. If you don't, however, you have to go through all 26 options in the alphabet! With this context in place, you can now explain that an efficient way of cracking a Caesar cipher is to produce a program in Python to do it for you. For your reference, here is the finished code (you can also find the source code at **helloworld.cc/caesarencoder**):

```
letter=['a','b','c','d','e','f','g','h','i',
'j','k','l','m','n','o','p','q','r','s','t','u'
,'v','w','x','y','z','a','b','c','d','e','f','g
','h','i','j','k','l','m','n','o','p','q','r','
s','t','u','v','w','x','y','z']
```

```
def encode(plaintext,key):
    cipher = ""
    text = plaintext.lower()
    for lettersintext in text:
        if lettersintext ==" ":
            cipher+=" "
        else:
            for i in range(len(letter)):
                if letter[i] == lettersintext:
                    cipher += letter[i+key]
                    break
    return cipher
```

```
print(encode("resilience",3))
```

There are a few things worth going over with students before they start to figure out how to write the code. Firstly, check their understanding of 'for' loops in Python by asking them to predict the output of the following code:

```
my_variable = "down"
for i in myvariable:
    print(i)
```

Next, go through the flowchart of the Caesar cipher algorithm (see **Figure 1**). Highlight how to convert text to lower case and how to add to a string letter by letter.

You can also provide students with a list of letters (see **helloworld.cc/lowercase**) to ensure they do not mistype them. A list is useful here, because it is global and enables students to use the same list in several functions. I have done it in the past with strings, but that led to difficulties with dealing with the scope of the variables.

Finally, it's also worth checking that students have a method of dealing with the key when it goes beyond the 26 letters of the alphabet. You can solve this by having two copies of the alphabet in the list.

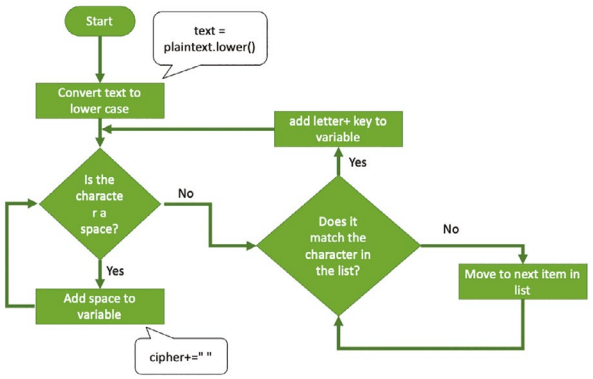


Figure 1 Flowchart of a Caesar cipher algorithm

ACTIVITY 3: QUICK SORTING EXERCISE 5 MINUTES

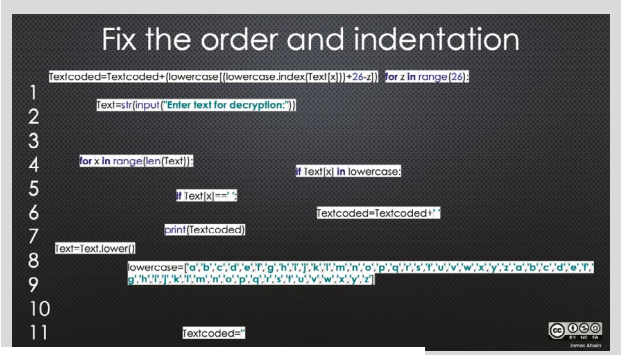


Figure 2 Ask students to reorder the decoding part of the Caesar cipher

In this consolidation exercise, we give students code that will enable them to crack the cipher text they have just encoded. This means that by the end of the lesson, they will have the code to both create and break the cipher. If you have a longer lesson or are working with more confident coders, you might want them to make this code without the scaffolding.

Give students a copy of the jumbled code from the image in **Figure 2**. Ask them to reorder the code and the indentation to create the decoding part of the Caesar cipher; you can find the correctly ordered decoder source code at **helloworld.cc/caesardecoder**.

DIFFERENTIATION

Further scaffolding

For students who really struggle with coding, I created a step-by-step video showing them how to do the encoding (**helloworld.cc/caesarvid**). Students can watch and rewatch the video as necessary, or you can use the accompanying step-by-step slides to guide them through the parts they are having difficulties with (**helloworld.cc/caesarslides**). The space character is dealt with separately so that it is easier for dyslexic students to track where words start and end.

Extensions to stretch students

- Can you disguise the space character so that it is harder to spot where a word starts and ends?
- Can you use a set of common words to guess the combination instantly? What are the most common words in English? Which of these are likely to be suitable?
- Can you make a menu so you can encode, decode, and crack in one easy-to-use program?
- Can you create a program with a stronger method of encryption?

Extensions for confident coders

More advanced students might want to install the encryption library (**helloworld.cc/cryptolib**) at this stage. Be sure to warn students that data encrypted with this library might not be retrievable without the key!

Students might wish to be able to load and save their files. To do this, they will need an understanding of reading and writing files (**helloworld.cc/pyfilehandling**).

PLENARY ACTIVITY: STRENGTHENING ENCRYPTION

5 MINUTES

To wrap up the lesson, start a think–pair–share discussion on the following three questions:

- What are the limitations of this program?
- Why is this encryption easy to crack?
- How could you make it stronger?

Some possible answers include:

Limitations

- It deals only with lower-case Roman characters
- It does not deal with numbers (but point out that students can use one, two, etc.)

Easy to crack

- It uses only 26 combinations; spaces tell you where the word is
- The key remains the same throughout the text

Make encryption stronger

- Use a less frequently used language, such as Gaelic or Maltese
- Use a much bigger reference guide; many people use books as references
- Change the key frequently, for example by using a rotor cipher, as used in the Enigma machine (**helloworld.cc/enigmarotor**)



JAMES ABELA

James is head of computing at Garden International School in Kuala Lumpur, Malaysia. He is a Raspberry Pi Certified Educator, founder of the South East Asian Computer Science Teachers Association, and author of *The Gamified Classroom* (**@eslweb**).

RELEVANT LINKS

You can find more Python cipher activities at **helloworld.cc/pythoncracking**.

AGE RANGE

7-10 years

REQUIREMENTS

- A computer capable of running Scratch
- Scratch 3 (either online or offline)

GENERATE COOL USERNAMES WITH SCRATCH

Young people should learn never to use personal information in their usernames online. In this project, they'll generate fun usernames they can use for their online accounts

Being safe on the internet means not giving away your personal information. Many young people have online accounts for their clubs, games, and even homework apps. For each of these accounts, they need to generate a username that is personally identifiable, interesting, and relevant, without mentioning things such as birthdates, real names, or locations. Even as adults, we often take the easy route and use the same old things for passwords and usernames: important dates, pet names, sports teams, number sequences — all easily guessable or identifiable.

This project creates a useful bank of possible usernames (or passwords), which are generated algorithmically on request by combining multiple terms from lists created by the learner. This allows the terms to be personally relevant to them, while also being unique, random(ish), and certain to contain no identifying information about them. The larger the lists created by the learner, the more unique username possibilities are available! (HW)



MARK 'MrC' CALLEJA

MrC is a teacher, hacker, surfer, D&D Dungeon Master, and maker. During the day he makes educational resources for the Raspberry Pi Foundation, which you can find on the Foundation's website.

ASSESSMENT

Discuss with your students the need for Gamertags and usernames and staying safe online.

Take group input on new adjectives and nouns that could be used in the project, and reinforce prior grammar knowledge. Ask for examples of their favourite usernames at the end of the session and check that the word types are correct.

DIFFERENTIATION

There are online non-English word generators that you can access to create new starter lists for your students. Remix the starter project, replace the word lists with your own, and provide the class with the link to your remix rather than the original starter.

RELEVANT LINKS

- Project: **helloworld.cc/usernamegenerator**
- Starter project in Scratch: **helloworld.cc/username**
- Make big lists of random words to import: **randomwordgenerator.com**

ACTIVITY 1: GENERATE PRELOADED USERNAMES 20 MINUTES

To start, open the Scratch starter project at **helloworld.cc/username**. If you have a Scratch account, log in and click 'Remix' to make a copy.

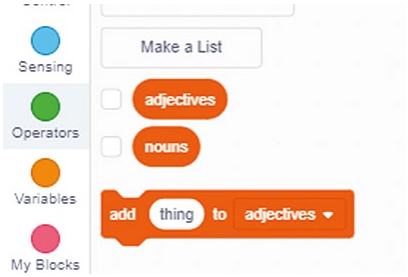
Once you've opened the project, you'll see two lists on the workspace — one titled 'adjectives' and the other 'nouns'. We don't really want to see the lists at this time, so in the Variables palette, click the checkboxes next to those lists to hide them. You can bring them back in the same way later.

Use the 'Make a Variable' button in the Variables palette to create a new variable called 'username', then hide it by also clicking the checkbox next to it when it appears.

Add a sprite. Any character will do; it's just something to hang the code on. Let the students pick a sprite they like and play with its costume for a little while until everyone catches up — we're about to start coding.

Add the code shown in **Figure 1** to your new sprite. Then add an adjective in the first slot from the Variables palette, as shown in **Figure 2**. Next, pick a random adjective between one and the length of the adjectives list, as demonstrated in **Figure 3**. You'll then duplicate everything in the first slot of the **join** block and pop it into the second slot. Copy the code in **Figure 4** to change the lists in the second slot drop-downs to say 'nouns' instead of 'adjectives'. Finally, copy the code in **Figure 5** to have your sprite **say** the variable 'username'.

Test the code by clicking the sprite. You should get it to say a new username every time. Encourage your learners to add new items to each list to increase the variety of their usernames before moving on. This is an excellent opportunity to reinforce some previous grammar learning!



The Scratch Variables palette



Figure 1



Figure 2



Figure 3



Figure 4

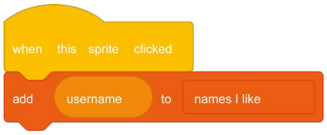


Figure 5

ACTIVITY 2: SAVE YOUR FAVOURITE USERNAMES 10 MINUTES

In the Variables palette, use the 'Make a List' button to make a list called 'names I like' (or 'favourites', 'liked', 'saved' — anything you want, really, as long as it makes sense), which will appear in your workspace.

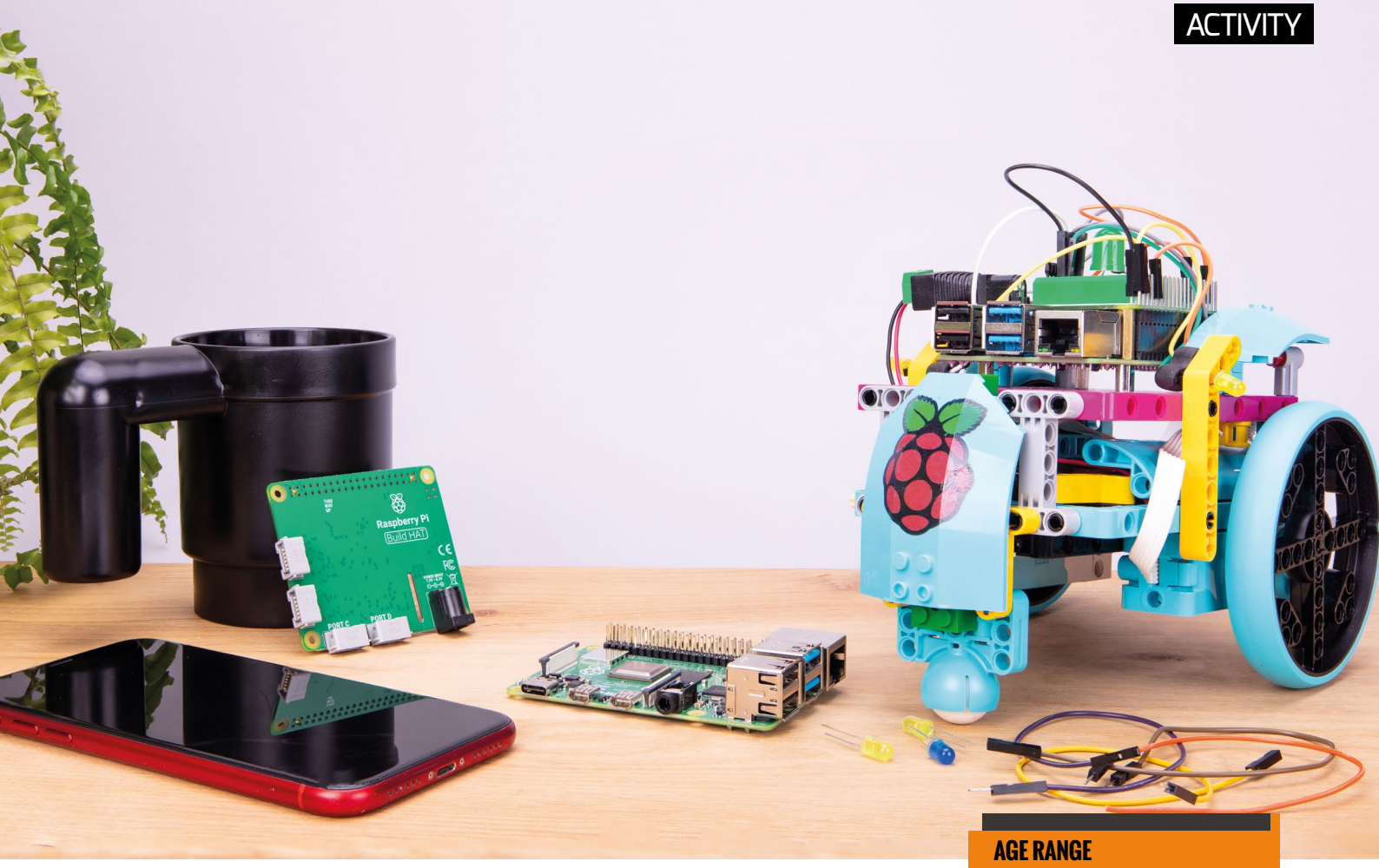
Add another sprite to your project, which will be used as a 'save' button. Make sure you can see the new sprite in the workspace, and that you have it selected below (rather than having your original sprite selected). Add the following code to the new sprite:



Test your code by generating a username and clicking the new save button sprite. You will see the current username added to your 'names I like' list.

You can export the list of saved usernames to a text file by right-clicking on the 'names I like' list on the stage, clicking export from the pop-up menu, and choosing where to save the list as a file.

From here, you can stretch your students by encouraging them to work out how they might **join** a number onto the end of their generated usernames, add another word type, or create customised costumes for their project.





MARC SCOTT
Marc works for the Raspberry Pi Foundation as a senior learning manager. He focuses on the production of educational resources for the Informal Learning projects at **projects.raspberrypi.org**.

LEGO REMOTE-CONTROLLED CAR

Use LEGO® and Raspberry Pi Build HAT to build your own remote-controlled car and learn how to use Bluetooth communication in your Python projects

At the end of last year, Raspberry Pi collaborated with LEGO® Education, launching the Raspberry Pi Build HAT to easily integrate LEGO® Technic™ motors and sensors with Raspberry Pi computers.

In this project, your students can learn how to build their own remote-controlled car. Its motion will be determined by two separately driven motors placed on either side of the car, allowing it to move forwards and backwards, and to turn. The car will be controlled from an Android device, using Bluetooth.

The project is an excellent introduction to simple robotics, and the perfect way to extend the use of the LEGO® Education SPIKE™ Prime Sets, using the power and versatility of Raspberry Pi computers and the Build HAT. Students will learn about basic motor control and how to bring Bluetooth communication into their Python projects. (HW)

AGE RANGE

11-14 years

REQUIREMENTS

- Raspberry Pi 3 or 4 and Raspberry Pi Build HAT
- BuildHAT Python library (sudo pip3 install buildhat)
- LEGO® Education SPIKE™ Prime Set or two LEGO® Technic™ motors
- An Android phone or tablet
- Five AA batteries and a holder pack, or a 9V battery with barrel jack
- Thonny or your preferred IDE
- The Blue Dot Android app and Python library (sudo pip3 install bluedot)

SAFETY REQUIREMENTS

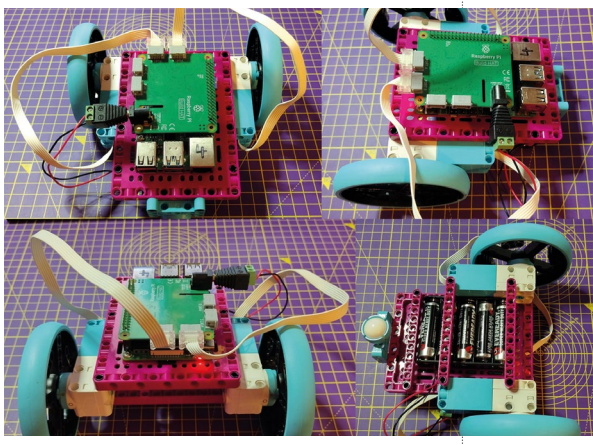
Ensure that you are powering your Build HAT and Raspberry Pi from a single power source. If you are powering the Build HAT using a barrel jack, you do not need to power Raspberry Pi separately.

ACTIVITY 1: BUILD YOUR LEGO CAR 10 MINUTES – A FEW HOURS

This is where your students can express themselves creatively and put their engineering skills to the test. There is no single correct way to build a car, and they could opt for a minimalist design to keep things simple, a scaled model of a real car, or just let their imaginations run wild and create whatever they like. Learners can use whatever LEGO bricks they can get their hands on and be as imaginative as they like. There are a few design requirements that your students will need to take into account, though:

1. Their car will need a place for Raspberry Pi and the Build HAT to sit.
2. Their car will need to accommodate a battery pack that can be plugged into the Build HAT.
3. Their car will need to accommodate two LEGO® Technic™ motors that can also be plugged into the Build HAT in ports A and B.

In the images to the right and on the next page, you can see examples of LEGO cars that we came up with.



An example model car with two LEGO® Technic™ motors, Raspberry Pi, and Build HAT

FUN FACT

The name Bluetooth was proposed in 1996 by Jim Kardach of Intel. At the time of this proposal, he was reading Frans G. Bengtsson's historical novel *The Long Ships* about Vikings and the tenth-century Danish king Harald Bluetooth. Bluetooth was King Harald's nickname, and he united the Danish tribes into a single kingdom, just as Bluetooth unites devices in a single communication protocol.

ACTIVITY 2: CONTROL THE CAR'S MOTION 30 MINUTES

Students now need to learn how to control the two LEGO® Technic™ motors so that they can drive their car forward and backwards, make it turn on the spot, and, most importantly, stop. To do this they will code a set of functions in Python, each of which will drive the motors in a particular way. To begin with, they need to import the BuildHAT library (**rpf.io/buildhat**), and then set up their motors:

```
from buildhat import Motor
motor_left = Motor('A')
motor_right = Motor('B')
```

Next, they can write five functions to control the direction of the motors. Encourage your students to experiment with different values for the speed and direction that the motors will turn. Positive values turn the motors one way, and negative values will reverse them. The speed of the motors can range from 0 to 100. When the learners run their program, they can use the Python shell to call the different functions and observe how the motors behave, then edit the values until the car drives in the direction and at the speed they need.

Here is some example code, but the values your students use will depend on how they have positioned and connected up their motors to the car:

```
def forward():
    motor_left.start(50)
    motor_right.start(-50)

def backward():
    motor_left.start(-50)
    motor_right.start(50)

def stop():
    motor_left.stop()
    motor_right.stop()

def left():
    motor_left.start(50)
    motor_right.start(50)

def right():
    motor_left.start(-50)
    motor_right.start(-50)
```

When they run their code, they can then use the Python shell to test out their functions by calling them:

```
>>> right() #test if the car turns right
>>> stop() #test if the motors stop
```

ACTIVITY 3: CONTROL THE CAR WITH BLUETOOTH AND ADD PORTABLE POWER 30 MINUTES

Blue Dot allows you to control Raspberry Pi projects wirelessly. With the Blue Dot library installed on Raspberry Pi and the app installed on an Android phone or tablet (**rpf.io/bluedot**), your students can remotely control their car.

They will first need to pair their Android device with Raspberry Pi, then open the Blue Dot app. To do this, make Raspberry Pi discoverable using the Bluetooth menu, then pair it using your Android device.

To use the Blue Dot library, you will first need to import it at the top of your students' programs and create a dot object:

```
from bluedot import BlueDot
dot = BlueDot()
```

Once this code is run, students should be able to see the Raspberry Pi connection when they open the Blue Dot app. The app is very simple to use. It detects where the large blue dot on the screen is touched and sends that data to Raspberry Pi. Different functions can be called in a Python program, depending on where the Blue Dot was touched; if you touch it near the top, the function to drive the car forward can be called.

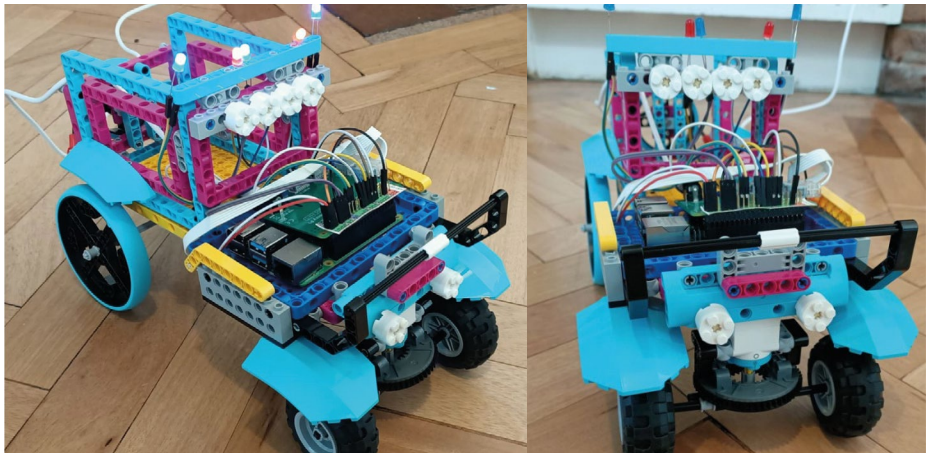
Students then create a function to move the car in different directions, depending on where they touch the dot, using the following code:

```
def move(pos):
    if pos.top:
        forward()
    elif pos.bottom:
        backward()
    elif pos.left:
        left()
    elif pos.right:
        right()
```

The three additional lines of code below will detect if the dot has been pressed, if a finger has been moved to a different location on the dot, or if fingers have been removed from the dot altogether. Different functions can then be called, depending on the action:

```
dot.when_pressed = move
dot.when_moved = move
dot.when_released = stop
```

Next, students can add a battery pack to supply power to Raspberry Pi and the Build HAT. The battery pack can be connected to a minimum of five AA batteries or a single 9V battery. Either will need to be connected to a barrel jack so it can be used to power the Build HAT. Students can now run their programs, then remove the USB cables and HDMI cable from Raspberry Pi, and drive their cars around the classroom!



■ Another example model car with two LEGO® Technic™ motors, Raspberry Pi, and Build HAT

RELEVANT LINKS

- More about this project: **helloworld.cc/legorobot**
- More LEGO projects on the Raspberry Pi Foundation's projects site: **helloworld.cc/legoprojects**
- LEGO® Education SPIKE™ Prime Set: **helloworld.cc/legospike**
- Blue Dot documentation: **rpf.io/bluedot**
- Build HAT documentation: **rpf.io/buildhat**

DIFFERENTIATION

You can provide younger students, or those who are not accustomed to using a text-based language, with the Python code for this project. Let them instead focus on the engineering and creativity that comes with building their own unique remote-controlled car.

MAKING THE MOST OF HELLO WORLD

Hello World offers educators support, inspiration, and a network of like-minded peers. **Alan O'Donohoe** shares his suggestions for making the most of the magazine

Years before there was a national curriculum for computing, Hello World magazines, or England's National Centre for Computing Education, I had ambitious plans to overhaul our school's ICT curriculum with the introduction of computer science. As the subject team I led consisted mostly of non-specialist teachers, it was clear I needed to be the one steering the change. To do this successfully, I realised I'd need to look for examples and case studies outside our school, to explore exactly what strategies, resources, and programming languages other teachers were using. However, I drew a blank. I couldn't find any local schools teaching computer science. It was both daunting and disheartening not knowing anyone else I could refer to for advice and experience.



"Hello World helps me keep up with the current trends in our thriving computing community" - Matt Moore

Thankfully, ten years later, the situation has improved significantly. Even with increased research and resources, though, there can still be a sense of being alone. With scarce prospects of meeting other computing teachers, there are few people to be inspired by, bounce ideas off, celebrate achievement with, or share the challenges of teaching computing with. Some teachers habitually engage with online discussion forums and social media platforms to plug this gap, but these have their own drawbacks.

It's great news, then, that there's another resource that teachers can turn to. You all know by now that Hello World magazine offers another helping hand to computing teachers searching for richer experiences for their students and opportunities to hone their professional practice. In this Insider's Guide, I offer practical suggestions for how you can use Hello World to its full potential.

Put an article into practice

Teachers have often told me that strategies such as Predict–Run–Investigate–Modify–Make (PRIMM) and pair programming have had a positive impact on their teaching after first reading about them in Hello World. Over the five years of its publication, there's likely to have been an article or research piece that particularly struck a chord with you — so why not put the learnings from that article into practice?

You may choose to go this route on your own, but you could also persuade colleagues to join you. Not only is there safety in numbers, but there are also shared rewards and motivation that come from teamwork. Start by choosing an article. It could be an approach that made an impression on you, or something related to a particular theme or topic that you and your colleagues have been seeking to address. You could then test out some of the author's suggestions in the article; if they represent something very different from your usual approach, why not pilot them first with a teaching group that is fairly open to trying new things? For reflection and analysis, consider conducting some pupil voice interviews with your classes to get their opinions on the activity, or spend some time reflecting on the activity with your colleagues. Finally, you could contact the author to compare your experiences, seek further support, or ask questions.

HELLO WORLD RESOURCES

- Back issues of Hello World can be downloaded as PDFs for annotating and printing: **helloworld.cc/issues**
- A selection of Hello World articles to read in your browser: **helloworld.cc/articles**
- Hello World podcast: **helloworld.cc/hwpodcast**
- A collection of Insider's Guide articles: **exa.foundation/press**
- Subscribe to Hello World magazine: **helloworld.cc/subscribe**
- Suggest your article idea: **helloworld.cc/writeforus**
- Buy back issues of Hello World in print: **helloworld.cc/buy**

Strike up a conversation

Authors generally welcome correspondence from readers, even those who don't agree with their opinions! While it's difficult to predict exactly what the outcome may be, it could lead to a productive professional correspondence. Here are some suggestions:

- Establish the best way to contact the author. Some have contact details or clues about where to find them in their articles. If not, you might try connecting with them on LinkedIn or other social media. Don't be disappointed if they don't respond promptly; I've often received replies many months after sending a message.

> IF AN ARTICLE MADE AN IMPRESSION ON YOU, PUT THE LEARNINGS INTO PRACTICE



"Professionally, writing for Hello World provides recognition that you know what you're talking about and that you share your knowledge in a number of different ways" - Neil Rickus



Hello World is five years old this year!

- Open your message by introducing yourself, then move onto some positive praise, describing your appreciation of the article and points that resonated deeply with you.
- If you have already tried some of the author's suggestions, you could share your experiences and pupil outcomes, where appropriate, with them.
- Try to maintain a constructive tone. Even if you disagree with the piece, the author will be more receptive to a supportive tone than criticism. If the article topic is a work in progress, the author may welcome your suggestions.
- Enquire as to whether the author has changed their practice since writing the article, and whether their thinking has developed.
- You might take the opportunity to direct questions at the author, asking for further examples, clarity, or advice.
- If the author has given you an idea for an article or project on a similar theme, they're likely to be interested in hearing more. Describe your proposal in a very short summary and see if they'd be interested in reading an early draft or collaborating with you.

WRITE FOR US!

"We strongly encourage first-time writers. My job is to edit your work and fix grammar and punctuation - so don't worry if this isn't your strength! Remember that as an educator, you're writing all the time. Lesson plans, end-of-term reports, assessment feedback ... you're more of a writer than you might think! If you're not sure where to start, you could write a lesson plan, or contribute to our 'Me and my Classroom' feature."
- **Gemma Coleman, Editor**

Start a reading group

Take inspiration from book clubs, but rather than discussing works of fiction, instead invite members of your professional groups or curriculum teams to discuss content from issues of Hello World. This could become a regular feature of your meetings where attendees can be invited to contribute their own opinions. To achieve this, firstly identify a group that you're a part of where this is most likely to be received well. This may be with your colleagues, or fellow computing teachers you've met at conferences or training days. To begin, you might prescribe one specific single article or broaden it to include a whole issue. It makes sense to select an article likely to be popular with your group, or one that addresses a current or future area of concern.

To familiarise attendees with the content, share a link to the issue for them to read in advance of the meeting.



"Hello World gives me loads of ideas that I'm excited to try out in my own classroom" - Steve Rich

If you're reviewing a whole issue, suggest pages likely to be most relevant. If you're reviewing a single article, you could make it easier by removing all other pages from the PDF and sending it as an attachment. Print-only subscribers should remember that you can also download back issues of Hello World as PDFs, which you can then edit or print.

Encourage your attendees to share the aspects of the article that appealed to them, or areas where they could not agree with the author or perhaps struggled to see working in their particular setting. Invite any points of issue for further discussion and explanation — somebody in the group might volunteer to strike up a conversation with the author by passing on the feedback from the group. Alternatively, you could try inviting the author of the article to join your meeting via video conference to address questions and promote discussion of the themes. This could lead to developing a productive friendship or professional association with the author.

> "WRITING AN ARTICLE FOR HELLO WORLD CAN BOOST YOUR CAREER PROSPECTS

Propose an article

"I wish!" is a typical response I hear when I suggest to a teacher that they should seriously consider writing an article for Hello World. I often get the responses, "I don't have enough time," "Nobody would read anything I write," or, "I don't do anything worth writing about." The most common concern I hear, though, is, "But I'm not a writer!" So you're not the only one thinking that!

Help and support are available from the editorial team. I for one have found this to be extremely beneficial, especially as I really don't rate my own writing skills! Don't forget, you're writing about your



"I love Hello World! I encourage my teaching students to sign up, and give out copies when I can. I refer to articles in my lectures" - Fiona Baxter



"One of the things I love about Hello World is the huge number of interesting articles that represent a wide range of voices and experiences in computing education" - Catherine Elliott

own practice, something that you've done in your career — so you'll be an expert on you. Each article starts with a proposal, the editor replies with some suggestions, then a draft follows, and some more refinements. I ask friends and colleagues to review parts of what I've written to help me, and I even ask non-teaching members of my family for their opinions.

Writing an article for Hello World can really help boost your own professional development and career prospects. Writing about your own practice requires humility, analytical thinking, and self-reflection. To ensure you have time to write an article, make it fit in with something of interest to you. This could be an objective from your own performance management or appraisal. This reduces the need for additional work and adds a level of credibility.

If that isn't enough to persuade you, for contributors based outside the UK (who usually aren't eligible for free print copies), Hello World will send you a complimentary print copy of the magazine that you feature in to say thank you. Picture the next Hello World issue arriving featuring an article written by you. How does this make you feel? Be honest — your heart flutters as you tear off the wrapper to go straight to your article. You'll be impressed to see how much smarter it looks in print than the draft you did in Microsoft Word. You'll then want to show others, because you'll be proud of your work. It generates a tremendous sense of pride and achievement to see your own work published in a professional capacity.

Hello World offers busy teachers a fantastic, free, and accessible resource of shared knowledge, experience, and inspiring ideas. When we feel most exhausted and lacking inspiration, we should treasure those mindful moments where we can sit down with a cup of tea and make the most of this wonderful publication created especially for us. (HW)



ALAN O'DONOHOE

Alan has over 20 years' experience teaching and leading technology, ICT, and computing in schools in England. He runs **exa.foundation**, delivering professional development to engage digital makers, supporting computing teaching, and promoting the appropriate use of technology (**@teknoteacher**).

YOUR HELLO WORLD PROBLEMS ANSWERED!

I no longer receive print issues. I used to, so I don't know why!
In spring 2021, Hello World emailed all print subscribers and asked them to resubscribe. If you didn't respond, this could well be the reason why. It's not too late - you can go now to **helloworld.cc/subscribe** and subscribe again. All back issues are available as digital downloads, or you can buy old print issues at **helloworld.cc/buy**.

I wish I had the time to read the magazine. Past issues are gathering dust on my desk in school!
Take these magazines home or better still, have them delivered to your home. Try keeping some in your car or bag when travelling. Hello World doesn't need to be read from cover to cover in one sitting; try dipping in and out at your leisure. You can also read a selection of articles on Hello World's blog or listen to the Hello World podcast on the move.

My students told me they didn't think the magazine was for them.
That's right! Although there are a few articles designed to be shared directly with older students (for example, the data science jobs profile in issue 16 and the healthcare research profiles in issue 17), it's not meant for your pupils. However, your students will, of course, benefit from the magazine indirectly when you try some of the different approaches with them.

I'm a teacher with 20 years of experience. Hello World has nothing to interest me.
If you don't feel that your teaching would benefit from fresh ideas or recently published research, and you know you have nothing to learn from other education professionals, then you're probably right. Would your students agree with you, though? Perhaps you could use your talents to support other teachers, sharing some of your insights, experience, and the solutions you have developed in a future article for Hello World. You're guaranteed to get a kick from seeing your work in print, even if you have already had other work published.

If only there were a Hello World podcast! I would definitely listen to that.
Great news - there is! Search for "Hello World podcast" in a podcast player, or listen in your browser at **helloworld.cc/hwpodcast**. There are other similarly titled shows, so look for the Hello World logo and subscribe.



THE BEBRAS PUZZLE PAGE

Each issue, **Chris Roffey** shares a computational thinking problem for students

Students taking part in the UK Bebras Challenge

THE PROBLEM: BREAK THE CODE

Data compression

In a prefix cipher, letters are transformed into a code made up of one or more digits, and no code starts with another code. For instance, if the letter A is transformed into 12, the letter B can be transformed into 2 (because 12 does not start with 2). In such a case, the letter C can be transformed into 11 (because both 12 and 2 do not start with 11), but not into 21 (because 2 has already been used for B) or into 121 (because 12 has already been used for A). Add bracket symbols (') in some of the blue boxes below in such a way that the digits that are then enclosed in brackets could represent the letters of the word 'Bebras'. *This problem was originally written by the Russian Bebras team. Solution on page 96.*

Further information

The prefix cipher described in the task is an example of a prefix code, in which objects are transformed into codes with the requirement that none of them can start with another code. This property of prefix codes is useful in information decoding, because there is no need to have separators between single codes.

Computer scientists often try to find a prefix code for a given text, which makes encoded messages as short as possible. This is a task often required for archiving data, i.e. decreasing its size while keeping all of its information. The method of obtaining an optimal prefix code is provided by Huffman coding. Prefix codes are widely used, including in popular media formats such as JPEG and MP3.

DOMAIN

Data, data structures, and representation

SKILLS

Abstraction, decomposition, evaluation, and generalisation

AGE

14-18 years

DIFFICULTY RATING

Ages 14-18 hard



COMPUTING KEYWORD SPOTLIGHT: **DATA COMPRESSION**

Defining everyday techniques used by problem-solvers

Data compression is the process of modifying data to reduce its size. Data compression techniques are of ever-increasing importance in our modern world. The amount of space that individuals and organisations require, for example for archiving data, is an obvious place where this may be important. There are also advantages of reducing the size of the data stored in data centres and in data transmission. For example, last November, 303,552 students took part in the UK Bebras challenge fortnight with, at times, more than 7000 concurrent users all requesting data and sending data from the UK to our servers in the Netherlands. This required a lot of bandwidth. Suppose that an image is stored as a 100kB SVG and that this is requested 100,000 times. This means that we would have to transmit, in total, 10 million kB of data. If we can reduce the image size to 10kB, this will save us from sending out 9 million kB of data. We actually did this with many of our images, and thus drastically reduced the load on our servers. This enabled us to provide a better service, while also reducing our carbon footprint.

There are many ways of compressing data, and these depend on the type of data source involved. Video data can be compressed by cutting out the number of frames per second; images can be reduced in size by looking for areas of the image with the same colour and avoiding storing information for every pixel; and sound files can be compressed by losing the data for sounds that are outside the normal range of human hearing.

Data, though, is all essentially stored as bits, so there are further techniques of data storage that can be applied to all data. These can be divided into lossy and lossless compression techniques. In lossy compression, data is lost from the original data source and the quality of the output may be reduced so that data transfer is at an acceptable speed. In comparison, lossless techniques, such as Huffman coding, find ways of reducing the space required to store all of the information from the original. The only cost involved is that the computer receiving the compressed data may have to work harder to rebuild the original artefact.

ABOUT BEBRAS

Bebras is organised in over 55 countries and aims to get students excited about computing and computational thinking. Last November, over 300,000 students participated in the UK annual challenge. Our archived questions let teachers create their own auto-marking quizzes at any time during the year. To find out more and to register your school, head to **bebras.uk**.





© Sashkin/stock.adobe.com

Data compression techniques are important for reducing the size of data stored in data centres

SURVEY RESULTS

Thank you to everyone who took the time to complete our annual survey at the end of last year — 1025 of you gave us your thoughts about Hello World and we've really enjoyed reading through your suggestions. The results are so valuable to us: your feedback guides the direction that the magazine takes.

I don't think I can get the print copy in the USA — I'd be happy to pay for it!

At the moment, we can only send free print copies to educators in the UK. If you're outside the UK, we sell print copies to a select number of countries for a small price at **helloworld.cc/store**. You can see whether we ship to your country at **helloworld.cc/shipping**.

I would love to know what type of articles we can write. Like do we write them and then submit, and hope it fits your theme?

We're always looking for new and interesting articles, especially from first-time contributors! Please send us your article ideas first at **helloworld.cc/writeforus**, rather than sending a complete draft — that way, we can support you better on your writing journey. This year, our remaining issues are going to be based on the themes of 'Computing and Sustainability', and 'Networking and Systems'. Your article ideas don't have to be based on these themes, though — read our fantastic Insider's Guide on page 90 for tips and suggestions on writing for us.

I would like to read inspiring stories of teachers in South America or other continents of the South.

We would love this too! We want Hello World to represent as many of our readers as possible, so please send your ideas and stories to us.

BEBRAS PUZZLE SOLUTION (PAGE 94)

Starting from the beginning, if **B** is encoded with the two characters **12**, then letter **E** has the code **1**, which is not possible because the code for **B** starts with the code of **E**. It is impossible for **B** to have a code longer than **2** (**121**, **1211**, **12112**, etc.) because this letter should repeat, but there are no repetitions of these sequences. Thus the code for **B** is **1**.

The letter **E** is followed by a **B**, thus it can only be encoded as **2**, **21**, or **211223332**. It cannot be **2**, because the word would then start with **BEBB**. It cannot be **211223332**, because the word would then be **BEB**. Thus the code for **E** is **21**. At this point, we know that (**1**) (**21**) (**1**) is the encoding for **BEB** and we need to separate **2233321**. Similar reasoning can be used to establish the codes for the letters **R**, **A**, and **S**.



It would be good if you could print a QR code as a direct link to the podcast.

Our survey made us realise that many readers still don't know about our podcast. We've got 15 episodes out so far, featuring conversations with educators on a variety of computing education topics. You can find out more about the podcast (including a QR code to send you straight there!) on page 20 of this issue.

I wonder if there is a possibility of moving towards more video content?

Thank you for the suggestion. This isn't something that we're likely to have time for this year, but we will definitely consider it in the future. In the meantime, do check out the Raspberry Pi Foundation's YouTube channel at **helloworld.cc/rpfyoutube**, where you can find videos about young people's digital making projects, code-alongs, support tutorials, and more.

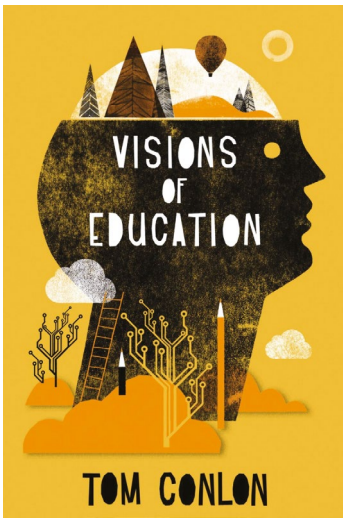
VISIONS OF EDUCATION

A book to make you think about how you think

INFO **BY** Tom Conlon | **PUBLISHER** The Word Bank | **PRICE** $19.87 | **ISBN** 9780993054488 | **URL** helloworld.cc/visions

Lorna Gibson

Often, you pick up a book with the expectation of learning something new or improving your understanding of a particular topic. And while this book offers plenty of opportunities to extend your knowledge, it offers something bigger, too. This book is about thinking, and as such, encourages you to think about the bigger picture: how do we think, how do we structure our knowledge to improve our thinking, how is this taught or modelled in schools, and is this way working?



The book presents a collection of academic papers written by the late Tom Conlon, who can comfortably be called a computer and education visionary. You might find it surprising that, although some of the papers shared are nearly 20 years old, the sentiments are just as relevant, if not even more powerful, today. At the heart of Conlon's work was his passion for enabling all learners (students and teachers alike) to develop and use effective tools for learning, including knowledge presentation tools such as decision trees, and mapping tools such as argument maps. He encourages learners to use these tools to build a solid foundation to their knowledge, so that this knowledge can be questioned, extended, and reasoned with, and ultimately, support the learner in the development of critical thinking skills.

One particularly poignant quote is, "The model that matters in education is not in the computer or the expert system, but is the one that the learner builds inside her own head." Gems such as this encourage the reader to reflect on the tools they use or interact with, in the classroom and beyond. This is not a book for bedtime; it is one to be digested one chapter at a time, with a long walk in the countryside to think it over. (HW)

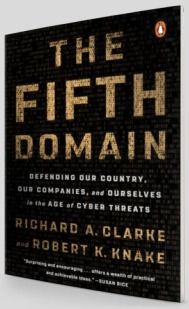
ESSENTIAL READING

Three books that focus on cybersecurity

THE FIFTH DOMAIN

BY Richard Clarke and Robert Knake
PUBLISHER Penguin
PRICE $18.00
ISBN 9780525561989
URL helloworld.cc/fifthdom

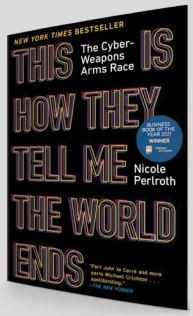
Written by two cybersecurity experts, including the USA's first cyberczar, this book explores how governments, businesses, and citizens can confront and defend against cyberwar.



THIS IS HOW THEY TELL ME THE WORLD ENDS

BY Nicole Perlroth
PUBLISHER Bloomsbury Publishing
PRICE $30.00
ISBN 9781635576054
URL helloworld.cc/worldends

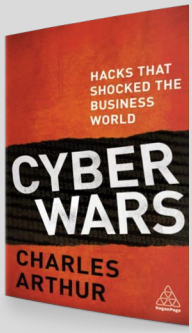
Written in the style of a thriller, this non-fiction book discusses the cyberweapons arms race. It explores the enormous potential for harm caused by 'zero-day' software vulnerabilities in the hands of hostile nations or criminals.



CYBER WARS

BY Charles Arthur
PUBLISHER Kogan Page
PRICE $19.99
ISBN 9780749482008
URL helloworld.cc/cyberwars

Ideal to use as real-life case studies in class, this book covers significant cyberattacks on businesses, including the techniques hackers use, the consequences, and the lessons we should learn from them.

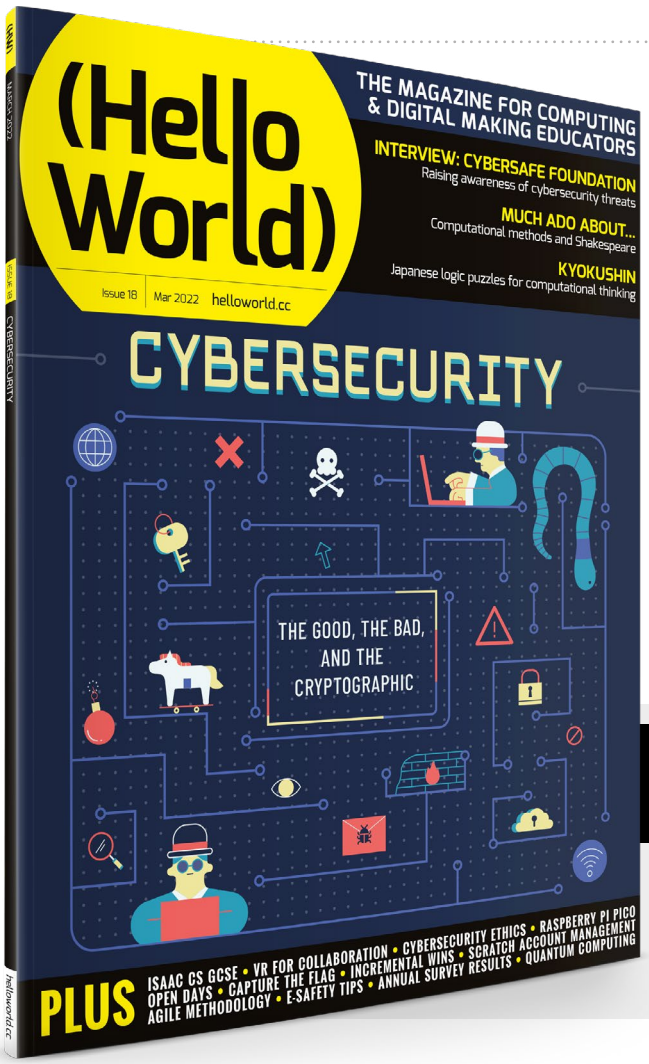


"HELLO, WORLD!"

Everything you need to know about our computing and digital making magazine for educators

Q WHAT IS HELLO WORLD?

A Hello World is a magazine and accompanying podcast for computing and digital making educators. Written by educators, for educators, the magazine is designed as a platform to help you find inspiration, share experiences, and learn from each other.



Q WHO MAKES HELLO WORLD?

A The magazine and the accompanying podcast are produced by the Raspberry Pi Foundation.

Q WHY DID WE MAKE IT?

A There's growing momentum behind the idea of putting computing and digital making at the heart of modern education, and we feel there's a need to do more to connect with and support educators, both inside and outside the classroom.

Q WHEN IS IT AVAILABLE?

A Your 100-page magazine is available three times per year. Check out our podcast at **helloworld.cc/podcast**, too, to get more great Hello World content between issues.

IT'S FREE!

Hello World is free now and forever as a Creative Commons PDF download. You can download every issue from **helloworld.cc**. Visit the site to see if you're entitled to a free print edition, too.

WANT TO GET INVOLVED?

There are numerous ways for you to get involved with the magazine — here are just a handful of ideas to get you started

- **Give us feedback**
  Help us make your magazine better — your feedback is greatly appreciated.
- **Ask us a question**
  Do you have a question you'd like to share? We'll feature your thoughts and ideas.
- **Tell us your story**
  Have you had a success (or failure) you think the community would benefit from hearing about?
- **Write for the magazine**
  Do you have an interesting article idea? Visit **helloworld.cc/writeforus** to submit your idea.

GET IN TOUCH

Want to talk? You can reach us at:
contact@helloworld.cc

FIND US ONLINE

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fb.com/HelloWorldEduMag

NEXT ISSUE OUT

JUNE 2022

THEME: COMPUTING AND SUSTAINABILITY



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