GCSE Reform: A New Dawn of Computer Science

By Eleanor Dallaway

In November 2015, it was announced that the ICT GCSE and A-level would be scrapped as part of the government's qualifications reforms.

From 2016, the revised computer science GCSE will replace the legacy ICT, IT and computing GCSEs.

When announcing the reform, the Department for Education (DfE) released a consultation document explaining that the reformed computer science GCSE and A-level will provide a strong foundation for further academic and vocational study, and for employment.

The document said: "Students will develop the computational thinking skills needed for today's economy – including coding and important information technology topics such as cybersecurity, networking and data storage."

Whilst the revised curriculum for the computer science GCSE has been widely commended and welcomed, there are many critics who argue that the extinction of the ICT GCSE was a bad call.

R.I.P ICT

Despite the increasing popularity of the computer science GCSE – a 50% increase between 2015 and 2016 – ICT currently has three times more entries, and the examination boards are not confident that when ICT ceases to exist, that students will migrate to computer science.

Although both subjects are about technology, they are fundamentally different. Whereas computer science focusses on the inner-workings and programming of a computer, ICT is about how best to employ the technology for business needs.

According to Steven Kenny, qualification manager at examination board, AQA, "many schools were jumping ship and choosing to offer the computer science GCSE rather than ICT, because the new computer science GCSE is regarded more highly due to its English Baccalaureate (Ebacc) status."

Also of concern is that historically the ICT GCSE has had a fairly equal balance of boys and girls sitting the examination, whereas computer science has always attracted more boys. At The Chase secondary school in Malvern, 85% of computer science students are male.

Sue Nieland, director of education at the Tech Partnership, explains how they, alongside AQA, petitioned for the development of a GCSE in IT that would stand alongside computer science. "We remain convinced that there is a place and a need for an alternative to computer science, but our views and arguments were ignored."

Ian Glover, president of CREST, agrees. "We need computer literate young people for the workplace. The issue with the ICT GCSE was that it was seen as being a very Microsoft-centred syllabus, but this could have been fixed. Not all young people need to understand how computers work or want a career in IT, but industry needs these basic skills. In addition, there must be a pathway for those that do want a career in IT and the new Computer Science GCSE helps to provide this", he argues, suggesting that for those who don't, the ICT GCSE was a good alternative.

"Getting rid of the ICT GCSE was a mistake," argues John Palmer MBCs, faculty leader for IT, computing and business at The Chase secondary school. "I understand that we need more students studying computer science, but for the students that don't want careers that will involve writing code or understanding how to write code, they still need a quality technological education." The computer science GCSE isn't for everyone and is not a replacement for ICT, he adds. "It needed re-thinking, not chucking away completely."

Alun McCarthy works for WJEC, the largest examination provider in Wales. He explains that there will likely be a short extension for the ICT GCSE in Wales. "We are in a period of extensive curriculum reform in Wales, and one of the recommendations will have a major impact on digital literacy. We need to know more about the Welsh government expectations regarding this and then have a conversation with the regulator here about a potential new GCSE, separate to computer science, that will support this," he says, describing a consideration that many in England would welcome.

A Rigorous Qualification

The computer science GCSE was first launched by examination board OCR in 2012.Its revision, although technically premature, was welcomed by the industry, following a campaign for a qualification that was more rigorous, more technical, and better aligned to the knowledge and skills required in the workplace.

Although there is dispute over how aligned to industry the curriculum, really is, there is unanimous agreement that the GCSE is more academically challenging with a greater emphasis on the inner workings of computers. Rob Leeman is computer science subject specialist at examination board, OCR, which has 80% of the computer science GCSE market. "The qualification is certainly more rigorous and more challenging, with a bigger emphasis on problem solving," he says of the revised curriculum.

Jason Davies works for TechnoCamps, a Welsh government-funded initiative that runs coding clubs in schools. "For the last 10-15 years, they've been teaching Microsoft Office instead of coding," he said of the legacy GCSE. "Suddenly, with computer science we're teaching the right things, but the teaching hasn't caught up".

One of the more notable revisions, the introduction of cybersecurity content, has been welcomed across the board. Topics such as encryption, social engineering, DDoS and penetration testing have been added to the curriculum.

"It's very positive that cybersecurity is so well featured, but [the curriculum] is not aligned to what the industry want to see", comments Jason Stanton, schools programme manager for Cyber Security Challenge UK.

Nieland has a similar opinion. "We were pleased to see inclusion of cybersecurity, but remain concerned that the content is largely theoretical, and does not address many areas of study that our employers are concerned about."

Alan O'Donohoe has more than 20 years' experience teaching and leading technology & ICT in schools, and has since launched Hack To The Future and Raspberry Jam events and has been involved with many school roadshows and coding clubs. He considers the new curriculum "fit for purpose, with opportunities for practical problem solving elements."

"However, the national curriculum by itself isn't enough to inspire or engage children," he continues, "it includes what children should be able to know, understand or do, but the enrichment comes from extra-curricular clubs and events."

Calling on Industry

When revising the computer science GCSE, the Department for Education (DfE) invited industry to contribute their expertise and advise on the curriculum.

The Tech Partnership were involved at several stages, explains Nieland, including the original discussion when ICT became computing and since with awarding organisations. "We fed back on content, and shared employer concerns about the very theoretical approach to computer science at the expense of equally important topics, but the concerns were mostly ignored."

Louise Stanhope teaches computer science at a grammar school in Sussex. Whilst she sees many positives in the revised GCSE, she shares apprehension regarding the quantity of content in the time that is available to teach it. "The computer science GCSE is where we needed to go. The IT GCSE would only teach the absolute bare minimum of what children should leave school knowing. Looking at systems and learning how to use them is far more useful," she says of the new curriculum.

However, she expresses concern that the industry board set up to advise the DfE is too far removed from teaching and students, and that as a result, some of the syllabus is "out of touch." What they may not understand is that computer science is way down the list of priority for timetabling." At Stanhope's school, one in six students take computer science; a number she believes could be increased if more time was afforded.

"The board to determine the syllabus needs to be made up of both industry and education. I believe there's a skewed perception of how much you can teach in the time given. It would be useful to get [those determining the curriculum] in to see what they can teach children in an hour," she suggests.

In addition to the topics dictated by the national curriculum, awarding boards are able to add additional content to their syllabus. OCR's Leeman explains how they collaborate with key stakeholders, a forum of industry and academia, to ensure the right topics are added. "But whilst we do have support, we would always welcome more support from the cyber industry."

Those Who Can – and Can't – Teach

With the revised curriculum more challenging, a primary concern is the short supply of subject specialists teaching computer science. Some schools do not even offer the subject as an option because they can't recruit the teachers to teach it.

Although the number of computer science GCSE entries is dramatically increasing, the supply of teachers qualified to teach the topic is not growing to meet the need.

"It's a legacy problem," suggests Adrian Davis, MD (ISC)^2 EMEA, an organisation which has aided examination boards with curriculum. "We've not had a pipeline of teachers come through in this space because this generation weren't educated in computer science themselves."

Non-specialist teachers are therefore often drafted from other subjects to fill the gap, sometimes with a knowledge deficiency that has a negative consequence on delivering the GCSE, and further still, the A level.

Statistics suggest that only 15% of computer science teachers are subject specialists, although many teachers interviewed for this report believe that it is actually less.

According to former computing teacher, Jason Stanton, who now works for Cyber Security Challenge UK, this is because "computing has been forgotten about in schools for a generation."

Louise Stanhope has a forensics computing degree. At her school, she is the only subject specialist teaching computer science. When asked why there aren't more, she references the huge pay difference between what industry can offer versus a teaching salary.

In 2012, it was announced that a £20,000 golden handshake would be given to graduates training as computer science teachers. Whilst certainly an incentive, the potential for future earning in industry is typically three to four times superior.

John Palmer claims that all the "constant tinkering with the curriculum, the qualifications, and how they're assessed" also acts as a deterrent.

Stanhope suggests that "finding teachers that aren't afraid of computer science" is the first hurdle to overcome. She explains that even teachers of the legacy subjects, ICT and IT, don't have the knowledge to competently teach the computer science syllabus.

"IT was fairly simple to teach," explains Jason Stanton. "So schools had business, art, and music teachers teaching it with few problems. " The complexity of the reformed computer science GCSE and A level, however, means that it is much harder to teach and above the knowledge of non-subject specialists. "Alongside further maths, computer science is the hardest qualification to get at the moment."

Sue Nieland is disappointed that "there is no real funding to upskill ICT specialists to become computer science specialists," something that she feels would be very beneficial. "The Tech Partnership are working with employers to provide teachers with help in key areas that we know are problematic. But more needs to be done", she asserts.

John Palmer also considers the revised computer science GCSE equal only to further maths in terms of difficulty. "We should be encouraging students to take computer science, not making it so difficult that nobody can do it."

The complexity of the computer science A level means that even with a degree in computer science, some of the elements were new to Stanton. And given that computer science is still a relatively new topic, "there's not much resource out there", he complains.

In 2016, the national entry of children taking the computer science GCSE is 70,000, 14% of children taking GCSEs. With more specialist teachers and the right messaging, this number could increase exponentially.

(ISC)²'s Adrian Davis suggests that a possible solution to the teacher shortage is to aid and support the upskilling of non-specialists. "Industry should be providing mechanisms for other subject teachers to upskill and gain the knowledge needed to teach computer science. We should look for talent wherever it can be found, encourage it, and nurture it."

Dr Kuan Hon is a consultant lawyer in data protection and technology issues, a senior researcher at the Microsoft Cloud Computing Research Centre, and did a PhD in law and computer science. She agrees that the answer to the teaching crisis may be in recruiting outside of computer science graduates. "Couldn't graduates in maths, science, etc be encouraged to teach computer science in schools?"

Whatever the solution, experts agree that there is no quick fix.

Coding Clubs to the Rescue

One way of supporting non-specialist teachers and their students is to run coding clubs, taught mostly by industry experts.

Although coding clubs have no requirement to fulfil the criteria of the national curriculum, they are based on fundamental concepts so there will naturally be an overlap.

The magic of coding clubs, explains O'Donohoe, is being able to enrich the national curriculum and make things "much more exciting and engaging. Hacking games (remove consoles) isn't included in the curriculum, but activities like that can really engage children leading them to study Computer Science GCSE."

Rik Cross is the senior content and curriculum manager at Code Club, a nationwide network of volunteer-led after school coding clubs for children. Code Club does have its own curriculum, but is closely and strategically aligned to the national curriculum, teaching coding elements from key stage two and three.

"When shaping our curriculum, I look at the GCSE and A level requirements, because we want to make sure we give children the skills they need to lead them into the GCSE," explains Cross. "But code club is about more than just supporting a qualification. It's about giving kids the skills and confidence to shape their world and become pro-active creators of digital content."

Jason Davies teaches TechnoCamps coding clubs. He explains that when coding classes are available to pupils before GCSE selection, the take-up for the GCSE is better.

TechnoCamps is often invited in to teach classes when GCSE students are doing their final assessments. "This allows the students to ask us any technical questions that their teachers don't have the expertise to answer," explains Davies. "As teachers rarely have coding experience or technical knowledge, the industry is called upon to fill in the knowledge gap." In his opinion, the education that children can acquire from code clubs is far superior to what they're getting in timetabled lessons.

"It's a sorry state if you have to go out to external clubs and competitions for kids to learn what they should be learning in schools," declares Stanton.

Teaching Computing on Paper

The new computer science GCSE is weighted with a written exam worth 80% and a non-exam assessment worth 20%, taken in a classroom with close teacher supervision.

The non-exam assessment is a problem-solving exercise, where students work on computers to programme a solution, and then write about how they did it. "This is flawed, because the most talented programmers I know can programme solutions but wouldn't be able to explain how they did it," says Stanhope.

"Computer science is a practical subject which needs to be taught in a practical context. There's only so much you can examine," says Palmer.

Stanton would like to see the GCSE more heavily weighted towards non-exam assessment, and the testing of practical skills. "The actual method of writing things down is not as important as being able to demonstrate problem solving," he argues. "Speaking as a teacher, I don't like the fact that the GCSE is now two 90 minute papers worth 80%, or that there are no team-work elements. The GCSE measures whether students can remember facts, not whether they can work practically in teams."

Rob Leeman explains that OCR is investigating how to teach and deliver the GCSE with more practical elements, rather than on paper. "Getting their hands dirty makes it more fun and engaging for the students", he believes.

Whilst examination boards have considered delivering the exam on-screen rather than as a tradition paper exam, the assessment does not allow it, and practical concerns around infrastructure, bandwidth and equipment have prevented this from coming into fruition.

In Wales, the computer science GCSE includes an on-screen exam component, weighted at 30%. "This allows candidates to demonstrate problem solving and prove practical understanding", explains Alun McCarthy at WJEC. The on-screen exams are taken in classrooms but under examination conditions on a set date.

A Generation of Micro:Coders

Experts believe that hands-on practical experimentation is key to engaging students in computer science.

The micro:bit, a 4cm by 5cm single-board computer, which looks like a slightly smaller, black Raspberry Pi, has been developed by the BBC, in partnership with Microsoft, Samsung and many other partners, to inspire this generation to get hands-on with coding. "The micro:bit is a really accessible and fun way to get started and then take on more complex coding challenges," explains Cerys Griffiths, Executive Producer, BBC Learning.

The micro:bit will be given away to every year seven pupil in the UK, a process which has already begun. "We have already delivered BBC micro:bits to the majority of secondary schools in the UK and expect to complete this in the next two weeks", says Griffiths.

John Palmer is very positive about the micro:bit and the impact it will have on his pupils. "We're interested in anything we can do to get them excited about computer science. The micro:bit is visual and practical and the students can do really cool things with it. We love it," he says, hopeful that the roll-out of micro:bits will encourage more students to take the computer science GCSE.

The BBC shares that hope but insist that the main objective "is that more young people feel inspired to get creative with coding", explains Griffiths.

Teachers can access teaching support materials on the micro:bit website, and training sessions have been held in conjunction with micto:bit partners.

21st Century Delivery, Please

Due to the non-exam assessment (NEA), the computer science GCSE cannot be taken by home-educated pupils as the NEA has to be marked by someone who has been to an examination board's training event. Computer science, according to the examination boards, is considered a subject that could lend itself to cheating and parental help.

AQA's Kenny explained that as a general rule, private candidates can't take any qualification that has non-exam assessment, as there is concern around malpractice.

Home-educated children could, however, link with a centre and be entered to take the written exam and NEA on-site in school.

The Tech Partnership's Nieland, however, argues that this is restrictive. "I have always felt that those outside school and college should have opportunity to acquire qualifications without input from a provider".

Ian Glover couldn't agree more. His wish is for a technology which would allow people to study remotely. "A technological-based solution needs to be developed so as not to exclude the home-educated and those who wish to sit the GCSE early in their school career or more mature candidates, long after they've left school. We should be enabling people to take this qualification, not restricting it and making it hard to take."

His vision is for anyone to be able to take the computer science GCSE, anywhere and at any time. "For bright, talented teenagers it's about enabling them to learn and achieve the qualification as soon as they are able, rather than allowing them to instead showcase their talent in hacker forums."

Given that it is not compulsory for schools to offer the computer science GCSE, it's even more important that the qualification be

available to anyone who wants to take it. "Why do we have to have exams in school halls when tests for driving theory are available at private test centres?" questions Glover.

In 2011, two computer scientists at Stanford University, Sebastian Thrun and Peter Norvig, announced that their introductory artificial intelligence class would be available as a massive open online course – MOOC – available to anyone in the world over the internet, at no cost. Since then, the MOOC trend has continued and evolved, although concerns about ensuring that qualifications are awarded to the same person who actually completes the course and takes the exams is a challenge that has continued to surface.

Glover acknowledges this challenge, but suggests that if "easy anti-cheating measures were combined with regular biometric based validation, weekend retreats, and independent marking with proctors", that his vision for an online computer science GCSE could become a reality.

There are alternatives to the GCSE and A level that offer qualifications to any individual, whether they are a current student or not.

The Cyber Security Challenge UK, for example, has developed a level three qualification, equivalent to an AS level, called the Extended Project Qualification in Cyber Security. The qualification is delivered online, and partners with Worcester College, Bletchley Park, (ISC)[2] and City & Guilds.

Stanton explains that the qualification is an easy addition for those studying in schools and colleges, but can also be studied in an independent capacity. "There are not always clear pathways into the industry, particularly as qualifications to date have begun at university level. The EPQ makes it possible for students to consider working in cybersecurity at a younger age."

A (Very Low)Level of Cybersecurity

The computer science A level was reformed in phase one of the government's qualification reforms. In January 2014, the subject content was finalised, with very minimal reference to cybersecurity. AQA's Steven Kenny explains that this is unlikely to be reviewed for the next five to eight years. "An examination board could choose to add it to their syllabus in the meantime, but they would then have to apply for re-accreditation and risk it not being approved." It is therefore highly unlikely that they would do so, he explains.

Stanton is concerned with the "huge gaps in consistency with cybersecurity learning." Secure coding, he believes, should be on the curriculum from primary school age. "In the A level, there is a very small section on encryption and secure programming, but it's hard to understand why it isn't more significant," he laments.

Dr Kuan Hon not only believes that any computer science qualification – including A level – needs to include cybersecurity, but that all school children, not just computer science students, should be taught the basics. "Computer science courses at degree level and A level must include secure coding as well as basic cyber-hygiene," she says.

Adrian Davis is also a huge proponent for teaching children how to be safe online as part of the general curriculum. "The main objective, of course, it to keep children safe and secure online, but the secondary purpose is that it gives children exposure to the opportunities in the cybersecurity industry."

In 2015, it was determined that all computer science degrees should teach cybersecurity. Universities are therefore demanding cybersecurity knowledge from students who haven't been taught it since GCSE.

Sue Nieland believes there's a real need for cybersecurity to be taught throughout key stages one to five, without exception.

"There's just no logical progression for cyber through education," adds Glover, who expressed concern that the lack of A level cybersecurity content could result in lost interest from potential industry talent.

Adrian Davis shares the same concern. "The government wants to see a cybersecurity pipeline, so they need a student pipeline to provide the core of people to staff the industry and the national coding centre in the future." If the government were to agree the importance of cybersecurity on the A level curriculum, they may mandate an addition and re-accreditation process, says Davis, hopefully.

Alternative vocational qualifications, equivalent to GCSE, A or AS level, have much higher cybersecurity content, and can work as a good alternative. The OCR Cambridge Nationals, for example, are more closely aligned to what happens in industry than to theory.

Resource, Support, Finance, Resolve

The reformed computer science GCSE certainly isn't without criticism or controversy, but there are many ongoing initiatives to address some of the issues highlighted in this report.

Many organisations are working on ways to support and aid teachers that may not have the subject knowledge required to teach computer science effectively.

CAS – Computing at School – is part of the BCS, and is funded by Department for Education. It's a community for those passionate about giving children an education in computing,

and provides networking, and a place to share ideas and access teaching resources. John Palmer is a hub leader and a regional coordinator for CAS. "Our remit is to deliver effective computer science teaching and train teachers in the new computer science curriculum," he says. Several of the teachers interviewed for this report referenced CAS as an excellent resource.

The BCS also offer a Certificate in Computer Science Teaching, open to all teachers, including – perhaps most usefully – non-specialists. John Palmer, who has the Certificate himself, explains how the certificate takes about a year to complete and includes a programming project and an investigation into an element of computer science teaching.

The Cyber Security Challenge UK has spent time analysing the new computer science specification and the syllabus of each examination board. "Teachers are scrambling to work out how to teach it as it's new, so Cyber Security Challenge UK can help by delivering CPD and offering resources," explains Stanton.

WJEC examination board are offering an extensive CPD programme for teachers who will be teaching computer science from 2017, when the reformed computer science GCSE launches in Wales, a year after England. Whilst there will be slight structural differences between the English and Welsh computer science GCSE, Alun McCarthy explains that the content will be very similar.

The Tech Partnership online learning hub (**https://learning.thetechpartnership.com/**) is also designed to support teachers with e-learning on computer science principles and cybersecurity. Whilst over at Code Club, they provide lesson plans, curriculums and projects that code clubs and teachers can use for free.

TechnoCamps also offers a remote email service to answer students' questions in the instance that their teacher doesn't know the answer.

In addition to teaching resources, money is also being spent to try and encourage more computer science graduates to go into teaching.

"The Cabinet Office is putting money forward, coordinating activities, and doing a really good job," observes Glover, "but the bureaucracy of delivering the computer science GCSE means that there are problems that aren't being addressed."

Jason Davies explains how the Welsh Government has increased funding to give bursaries to computer science graduates to study their PGCE. "It's positive because they've acknowledged that we need experts. But demand is moving way faster than supply, and the funding may work, but it will take years to fill that pipeline. That's where coding clubs can help in the interim."

Time for Action

In the dawn of the revised computer science GCSE, there remains notable lack of clarity around the cull of the legacy ICT and computing GCSEs, and the reforms to the new computer science replacement.

Despite differences of opinion regarding the choice to discard the ICT GCSE, the method of delivery for the qualification, and the appropriateness of complexity, there are some matters that industry, examination boards and teachers agree on.

Concern surrounding the level of non-specialist teachers is unanimous, with all stakeholders expressing concern that the issue has been exasperated by the increased difficulty of the qualification. All parties also agree that coding clubs are incredibly useful in filling the knowledge gap and appealing to students with an engaging, hands-on approach to the curriculum.

Concerns about the difficulty of the qualification aside, the reformed computer science GCSE has been widely commended for the quality of content, the addition of cybersecurity to the syllabus, and the non-exam assessment element of the GCSE.

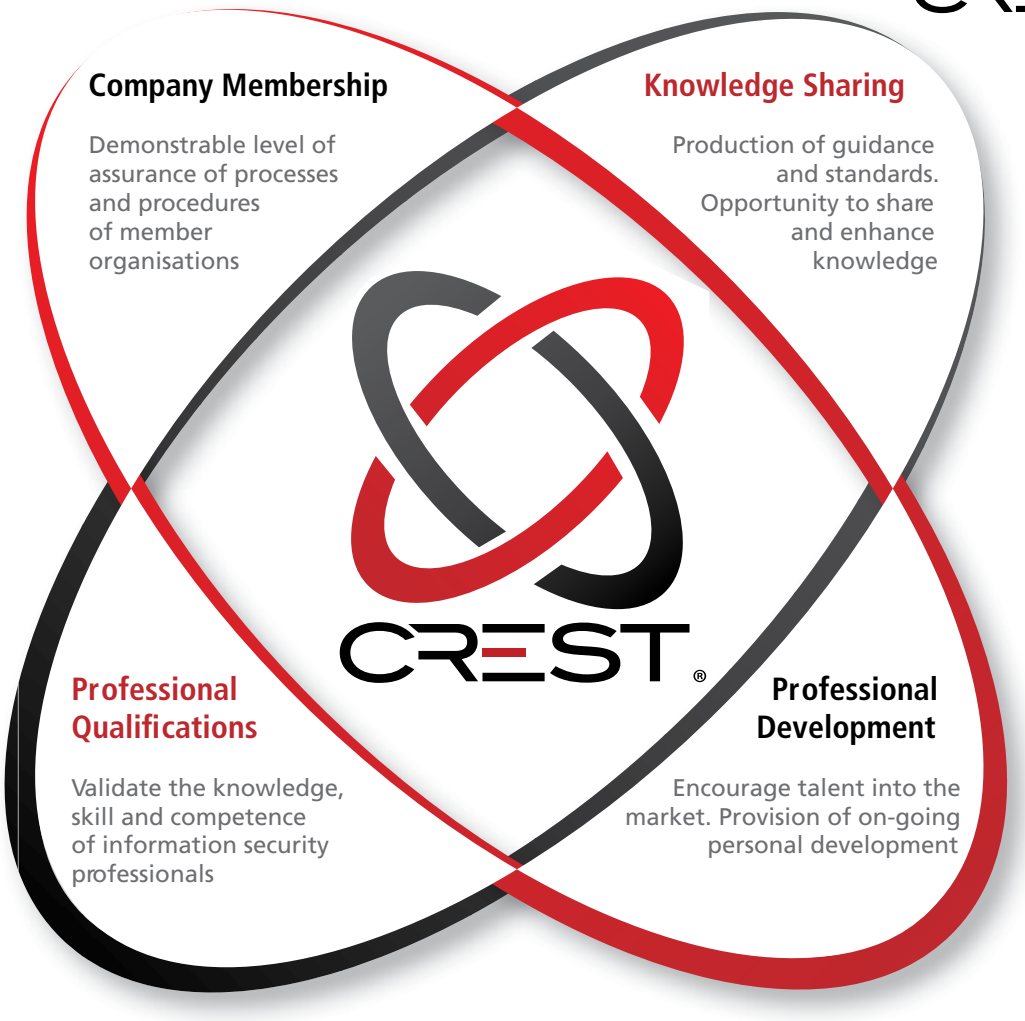
Yet industry remains concerned about the disconnect between the syllabus and the knowledge required for the workplace, the lack of cybersecurity content in the computer science A level, and the traditional paper-based assessment of a topic which, they argue, should be delivered – on screen – in a 21st century fashion.

There are many parties working on great initiatives to fill the teaching pipeline, supply teachers with the materials they need, and offering new and alternative qualifications.

But Adrian Davis is concerned that none of the initiatives are joined together. In his opinion, the communication between industry and examination boards needs to be improved, and an ongoing forum with the industry, boards and DfE is essential. "This should be an ongoing dialogue to ensure that taught principles match what students will later need in the workplace. A forum will help curriculum developers to focus on key principles and foundations that will last their students for a long, long time."

What the industry must do, Davis argues, is "be more open to those that take the GCSE, and stop demanding five years of industry experience. We need to tailor the entry-level professions so that there are jobs in industry waiting for them."

More important still, is enabling individuals to take the computer science GCSE wherever and whenever they wish. Given the skills gap in the cybersecurity industry, making it as easy as possible for those who want to develop their education is essential. The industry needs to be inclusive, and that should start at education.



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