Computer Science in Schools in England and Ireland – context and current developments in 2017

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Abstract: This paper describes the current developments in computing in schools in England and Ireland, in the light of a historical account of educational computing since its early days in the 1970s. In England, the recent (2014) introduction of a "rigorous" computing curriculum was justified by politicians in the United Kingdom to address a digital skills crisis, and at the same time, the Information and Communications Technology (ICT) curriculum and examinations were set to be discontinued. However, uptake of the new courses is relatively low, and the outcome may be a less-well educated population in terms of both vocational capability and personal fulfilment. Ireland has had no single equivalent of the English ICT curriculum. Uptake of technology-related subjects has been rather low and heavily gendered towards males, while programming activities in recent years have taken place chiefly outside the mainstream curriculum. Current developments include a new Computer Science course for pupils aged about 16 to 18, to be available from September 2018; the draft specification is due to be finalised by the end of the year 2017. The strategies in both countries are contrasted and critiqued in view of their historical context and their current approaches; issues are identified that may be of relevance in other countries.

Introduction

In recent years, there have been moves to introduce – or re-introduce – courses on Computer Science in a number of school systems across the world. Different countries have followed different developmental paths, depending on their previous history with regard to computing in schools and also on the drivers for development in each country (see for example: Bell, Andreae, & Lambert, 2010; Keane & McInerney, 2017; National Academies of Sciences, Engineering, and Medicine, 2017). This paper describes the current developments with regard to computing in schools in two countries, England and Ireland, in the light of an account of educational computing in both countries since its early days in the 1970s. The aim is to highlight key issues by comparing and contrasting the events and the rationales that underpinned them. While the experiences in two jurisdictions – with strong historical links to each other, but also with major differences in the structure and culture of their education systems – cannot be generalised and applied elsewhere, nonetheless the analysis may raise questions that can be useful for other countries considering the implementation of Computer Science courses in schools, especially those in which the developments are at an early stage.

It is important to clarify the terms used in the paper. As pointed out by Bell, Andreae and Lambert (2010), "[digital technology] in school curricula is often diluted because it has to cover three quite different directions: (1) using computers as a tool for teaching (e.g. e-learning), (2) using computers as a tool for general purpose applications (sometimes called ICT), and (3) computing as a discipline in its own right (including programming and CS [Computer Science])" (p. 17). The focus here is on *Computer Science* as a curricular subject, as distinct from the curricular subject called Information Technology or Information and Communications Technology (ICT), and also as distinct from using digital technology to teach and learn other subjects. The term "computing" is often used as a substitute for Computer Science. However, in some cases "computing" includes elements of ICT; in this paper, its scope will be clarified in the contexts in which it is used.

Another term of relevance is "computational thinking" (Wing, 2006). While the best meaning for the term is the subject of debate, in this paper we consider it the capacity to make solutions by combining problem solving and design using the competences derived from computer science and computing. These competences are found in an overlap of knowledge (facts, mental models and strategies), craft (skills, making and practice) and character (affect, disposition and habit). It is of relevance here because of its value and application across the whole school curriculum: hence, outside as well as within computing courses.

Questions that arise with regard to Computer Science in school curricula include:

- Should a Computer Science subject be introduced?
- If so, under what conditions can it be introduced?
- Can its position in school curricula be sustained?

These are addressed in the paper by looking first at the current developments in England and Ireland, and then giving accounts of the events that preceded these developments, in the form of historical stories throwing light on the different forms that they are taking. Against that background, issues arising in the two cases are examined. These – their similarities and their differences – inform tentative answers to the questions, and may highlight aspects of relevance to the evolution of Computer Science in other countries. As the situation in Ireland is still very fluid and allows for many possible developments in the near future, it is discussed at greater length than that in England.

Current developments

In this section, current developments in the two countries are examined and their immediate roots traced. The dominant sources are policy documents and seminal contributions from a variety of stakeholders. A fuller account of events up to 2014, providing another source for the paper, is given by Bresnihan, Millwood, Oldham, Strong, and Wilson (2015).

Current developments in England

Computer Science had an established place in the senior cycle of the English secondary curriculum (for students typically aged 16 to 18), leading to a qualification at “A-level”, but between 2000 and 2010 there was a marked decline in uptake (see Figure 1). By comparison, the subject ICT, which was concerned with a broader curriculum related to computer applications, attracted many students. However, the ICT qualification was perhaps unkindly considered by some as not rigorous, permitting a low level of intellectual engagement, and asking students simply to learn to operate office applications, and thus not meeting industry demands for competent programmers and analysts. This led to concerns that the economy of the United Kingdom might suffer from a lack of competent employees (Department for Innovation, Universities & Skills, 2009)

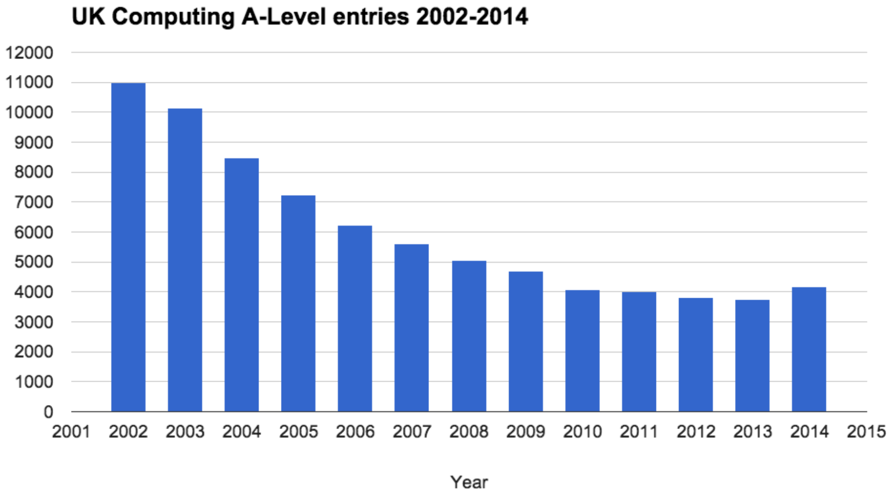

Figure 1: UK Computing A-Level entries 2002-2014 (Joint Council for Qualifications, 2015)

The British Computer Society, with others, campaigned for a new subject of Computing to be introduced which would focus more strongly on programming and computer science than the existing ICT subject (Brown et al., 2013). In 2008, a grassroots organisation called Computing at School was formed to argue this case, establishing an online community and recruiting well; at the time of writing in October 2017 it has over 28,000 registered members (https://www.computingatschool.org.uk/).

In the years that followed, significant calls for Computer Science as a core subject were made, for example in the "Next Gen" report (Livingstone & Hope, 2011) and by Google chairman Eric Schmidt (Schmidt, 2011, p. 8). These were referenced in January 2012 by the then UK Education Secretary Michael Gove when he announced the development of a new curriculum to support "new, high-quality Computer Science GCSEs [examinations for students typically aged 16]" (Gove, 2012, January 13). This move clearly reflected industry pressure. A few days later, the Royal Society published a review of computing in UK schools, advocating the introduction of Computer Science as "a rigorous academic discipline" (Furber, 2012, p. 6).

Ultimately a national curriculum for age 5-18, leading to Computing qualifications for age 16 and 18, was introduced in 2013 (Department for Education, 2013). Computer Science has a central place, with children as young as five expected to learn how to program. As well as providing a foundation for producing Computer Science graduates, the curriculum also emphasises the broader educational role of the subject in developing computational thinking, stating that "A high-quality computing education equips pupils to use computational thinking and creativity to understand and change the world" (Department for Education, 2013). Computing eventually replaced ICT in the national curriculum, the latter subject being phased out in 2016.

However, figures from 2015 show that only 28% of schools entered pupils for the new GCSE in Computing (for pupils aged 16) and only 24% for A-Level (for pupils aged 18) (Kemp, Wong, & Berry, 2016). Assuming that A-Level is only offered in schools that also offer GCSE, this could mean that no course leading to a qualification in Computing is actually being offered in almost three quarters of all schools at worst, and makes the opportunity for learning about computing very slight now that the ICT qualifications are discontinued. This is probably because the new Computing qualifications will demand greater knowledge from teachers, few of whom are Computer Science graduates. The outcome may be a less well educated population in terms of both vocational capability and personal fulfilment.

Current developments in Ireland

In the Republic of Ireland, the starting situation was rather different from that in England. The mainstream curriculum contained neither Computer Science nor ICT, so the question of replacing existing courses did not arise. For subjects that involve technology, as distinct from information technology, uptake has been rather low and heavily gendered towards males (State Examinations Commission, n.d.). Moreover, within the Department of Education and Skills, the main concern was the use of digital technology in teaching and learning rather than its role in curricular subjects; this is reflected in the publication of a *Digital Strategy for Schools 2015-2020* focusing on pedagogical issues (Department of Education and Skills, 2015). Thus, programming activities have taken place chiefly outside the mainstream curriculum (Ryan, 2015).

The moves towards introducing Computer Science gained momentum rather later than in England and are perhaps less clearly sequential. They are best described by looking at the drivers of policy in the area – economic issues, the needs of the third level (university / college) sector, parental interests, and educational arguments – together with responses and interventions associated with them, where relevant.

At the level of policy-making, the chief drivers have been economic: providing Computer Science graduates and those in allied areas who would work in the knowledge industry. That sector has burgeoned in Ireland, attracting many international IT companies, but the supply of young candidates for the resulting jobs is insufficient. In 2012 the Department of Education and Skills released an *ICT Action Plan*, the subtitle of which – "meeting the high-level skills needs of enterprise in Ireland" – clearly indicated that its focus was economic and skill-based, rather than broadly educational. It sought, among other goals, "[actions] aimed at providing more opportunities for students to gain a greater understanding of computer programming before entering higher education" (Department of Education and Skills, 2012, p. 9) and aimed to double the number of graduates in the ICT area to 2,000 by 2018 (p. 8). It is perhaps worth noting that the plan does not mention Computer Science, though – bearing in mind the confusion of language in the area, mentioned above – the point should not be laboured unduly.

Over the years that followed, a place for Computer Science was increasingly recognised, again chiefly in an economic context. In 2016, under the heading "Promoting Creativity and Entrepreneurial Capacity in Students," the document *A Programme for a Partnership Government* stated: "We will further accelerate the Digital and ICT agenda in schools by including a coding course for the Junior Cycle and introducing ICT/Computer Science as a Leaving Certificate subject" (Department of the Taoiseach, 2016, p. 91). An unambiguous commitment to Computer Science emerged in the *Action Plan for Education 2017* (Department of Education and Skills, 2017). In the section entitled "Increase subject choice for learners in Senior Cycle to equip them with the skills and knowledge to participate in a changing world," the document states: "Introduce Computer Science as a subject at senior cycle (for September 2018 implementation)" (p. 22). Primary level education is also mentioned in the document: "Commence consultation on the new primary maths curriculum, including computational thinking, creative thinking skills and coding" (p. 19). Recommendations with regard to ICT in teaching and learning are appropriately treated in a different section.

A second driver of change in the area is the third-level sector: the universities, colleges and institutes of technology. These are looking for entrants who are not only suitably qualified but also suitably informed, realising that there is much more to computer science than using computers, and especially that it is not chiefly about using applications packages and browsing the web. Support has been channelled through the Third Level Computing Forum, a body that brings together heads of academic departments, representatives of Irish industry, members of the Irish Computer Society and other players in the field. It addresses such issues as relevance of programme content, graduate supply and quality, gender imbalance, and research and innovations in computing (see https://www.ics.ie/news/view/231). Latterly, it has been notably active in addressing the need for Computer Science in the school curriculum, through representations made to the Minister for Education (Ryan, 2015). When the National Council for Curriculum and Assessment (NCCA) commissioned a report on good practice with regard to Computer Science in other countries – the "Lero Report", so described because the authors worked for the company Lero – Forum members contributed to the research (Keane & McInerney, 2017).

A third constituency is that of parents; their influence on the system may be chiefly as voters! "A recent survey revealed that a third of parents believe computer coding is a more essential skill to master than Irish, with two-thirds viewing it as being on a par with mathematics, science and languages" (Maguire & Power, 2015). The motivation may again be chiefly economic, in the sense that parents hope that such activities will increase their children's employability. It would be pleasant, but probably unrealistic, to think that equal weight would be given to student interests. These are reflected in the success of the CoderDojo movement, which started in Ireland in 2011 and allows children to engage in coding in areas that interest them (Langhammer, 2014).

The purely educational arguments – notably developing students' problem-solving skills and allowing them to exercise their creativity in areas of interest – have not figured prominently in the public discourse. However, the educational research community has addressed the issues. Considerable attention has been focused on computational thinking, examining its role not only in Computer Science and allied subjects but more generally across the curriculum (Keane & McInerney, 2017; Oldham et al., in press). Kirwan (2017) has pointed out that the media (which may also have a role in driving policy) have taken up the phrase "computational thinking", but the meanings they ascribe to it are diverse and often unclear. A pedagogical focus has been emphasised by the Trinity College Centre for Research in IT in Education, notably through its initiative "Bridge21" ("Bridge to 21st Century teaching and learning"), which promotes an innovative learning environment that is team based, technology mediated, project based, and cross-curricular (see for example: Byrne, Fisher, & Tangney, 2015; Conneely, Girvan, Lawlor, & Tangney, 2015). Appropriate pedagogy is emphasised also by the Computers in Education Society of Ireland (CESI), a voluntary professional body including teachers from all levels in the education system, which has been prominent as both a support group and a pressure group with regard to digital technology education for over 40 years. For example, pedagogical aspects were a major focus of a recent submission to the NCCA on coding in the junior cycle, discussed below (CESI, 2014).

Unlike in England, the reaction has not been uniform across different age-groups.

- When the 2016 *Programme for a Partnership Government* (Department of the Taoiseach, 2016) was published, a "short course" on Coding had already been developed by the NCCA as an option in the junior cycle of second-level schooling, for students typically 12 to 15 years of age (NCCA, 2016). Formal implementation supported by teacher professional development began in 2016; 22 schools took part in the first phase, and the number of participating schools has now been increased to around 50 (McInerney, Carey, & Power, 2016; Fred Boss, personal communication, October 20, 2017).
- The commitment to introduce a Computer Science course into the senior cycle in September 2018 is being honoured. This provides for a very short time-frame compared with the normal one for course development – though the availability of the Lero Report (Keane & McInerney, 2017) means that considerable background work has been done in identifying the likely content of the course. A development group representing the stakeholders was brought together, and has produced an imaginative draft specification (NCCA, 2017). It emphasises learning through team/group-based project work, reflecting the approach taken by Bridge21 as described above; the assessment envisaged is a combination of a formal examination (70%) and coursework (30%). During the consultation period that followed publication of the draft specification, CESI convened a symposium involving a wider range of stakeholders, and collated their feedback into a report to the NCCA (CESI, 2017). Many of the comments were positive, but potential problems were identified, and some are discussed below. The consultation period has only just ended, so what will be approved for introduction in Autumn 2018 has yet to be determined at the time of writing. A call for participation in Phase 1 of the implementation, likely to involve at least 24 schools, is due to go out in November 2017 (Paul Behan, personal communication, October 21, 2017). Moreover, in line with the recommendation of the Lero Report (Keane & McInerney, 2017, p. 9), CESI is setting up a Community of Practice for educators, researchers and commercial interests to support this endeavour, connecting all levels of education to ensure that continuity and progression for learners are properly addressed.
- Discussions about the place of relevant work in the primary curriculum have started. Issues to be addressed include whether – as suggested in the *Action Plan for Education 2017* (Department of Education and Skills, 2017) – coding activities should find a home in the Mathematics curriculum, currently being revised, or whether the appropriate focus in Mathematics would be on computational thinking, with coding situated elsewhere (John Behan, personal communication, October 19, 2017).

The historical stories

The historical story in England

In secondary level in England, the subject was first known as Computer Studies, and was initially regarded as learning about the computer mechanism and how to program it. In addition, the subject addressed the historical development of computers and the applications in society: business, government and leisure. Computer Studies was primarily seen as an education for students rather than as a means to supply skilled workers to industry (Millwood, 2010).

In the early 1970s, few schools were engaged in teaching Computer Studies and few students got to see a real computer. The introduction of the microcomputer changed this, and in the early 1980s the Microelectronics Education Programme was funded with £12M to involve all schools. The government provided 50% of the purchase cost of one computer per school and offered two teachers one day of training. State examinations were first offered by different Examining Boards in the 1970s, in some cases developed by collaborating teachers, reflecting the decentralised nature of the system especially before the introduction of a National Curriculum in 1988.

In the late eighties, computers became widespread in society and in schools; office applications for word-processing, spreadsheet and database – the so-called "applications approach" – became the focus. In the nineties, multimedia, CD-ROM and finally the internet led to the introduction of the subject Information and Communications Technology (ICT) in 1997 (Stevenson, 1997). Many teachers felt that ICT appealed to a wider group of students, permitting a creative and fulfilling use that replaced the role of Computer Science in schools. However, in the late "noughties", around 2007 onwards, ICT was seen not to involve enough rigour and depth, leading to the development of a Computer Science curriculum, as outlined earlier.

The historical story in Ireland

The story initially was not very different in Ireland (Oldham, 2015). By the 1980s, the drivers seem to have been more heavily focused on educational goals than was the case in England: preparing students for living in the information society – rather than producing people to work in the information industry – and aiming to encourage problem-solving for all in a way that Latin and Mathematics had been supposed to do, but had not. When the Department of Education inspector responsible for computer studies was recently asked the reason for introducing the module that eventually appeared in the senior cycle Mathematics course, he said "thinking" (Con O'Keefe, personal communication, April 27, 2015).

Formalisation in the curriculum came a little later than in England (and one computer was eventually supplied to each second-level school, but the provision of professional development courses was more limited than in the English case). The senior cycle "Computer Studies" option in the Mathematics course was introduced in 1980, supposedly as an interim measure (Oldham, 1981). Its formulation was sufficiently general to allow teachers flexibility in interpreting it as the relevant subject matter evolved; the fact that the assessment was by coursework (and was not part of the state examinations) allowed for further flexibility. In fact the module specification survived unchanged into the "noughties", but uptake was very low at that stage. The module was formally abolished only in 2013 – just before the press for Computer Science gained momentum (Department of Education and Skills, 2013).

At junior cycle, a free-standing Computer Studies course was introduced in 1985 (Oldham, 2015). It was intended to focus on the concept of *information*, and prefigured later work with applications packages as well as programming and other "computer science" aspects. Professional development courses and resources were provided, but, to reduce pressure on teachers who might not have profound knowledge of the subject, it was decided that there would be no state examination or assessment at the end of the junior cycle. While well intentioned, this decision probably led to the subject being undervalued in an increasingly examinations-driven system. Moreover, like in England, greater emphasis on applications and the emergence of email, multimedia and eventually the internet offered a more attractive option for many students. The subject faded out, and its existence is scarcely remembered.

The twin challenges of providing a specialist subject versus one using digital technology for all students, and of clarifying the difference between subjects in the curriculum and approaches to teaching and learning, were addressed in the 1990s and early 2000s, but were not resolved. A report to the NCCA, revealingly entitled *Computers and curriculum: difficulties and dichotomies*, highlighted many potential problems, including those of equity and gender balance in offering a Computer Science course (O'Doherty, Gleeson, Johnston, McGarr, & Moody, 2004). The outcome – unlike in England on this occasion – was that neither Computer Science nor ICT found a place in the national curriculum. Relevant work did take place in many schools, but outside the framework of that curriculum.

Issues

When the current moves started, those of us who had been around thirty or forty years earlier had a distinct sense of "Back to the Future." This time round, it is important to try to avoid the pitfalls that led to the move away from computing in earlier years. With this in mind, we now consider a range of issues.

Issues in England

The main issue in England has already been identified. When Computing was introduced, it was partly as a result of criticism of the ICT curriculum and this led to the elimination of the ICT qualifications, thought to lack rigour and depth. A shortage of suitably qualified Computer Science teachers and the challenge for ICT teachers to step up to teach new content has led to a decline in the number of schools offering computing qualifications, and this means that England may be short of the technically skilled workforce it needs and students will not be able to access courses to fulfil their interest in computing. It could be said that the government and the parties that campaigned for computer science, in their hurry to provide more rigour and more depth, have "shot themselves in the foot" – in other words, have not foreseen the consequences of their actions nor provided the funding necessary for teacher education to respond.

Issues in Ireland

The situation in Ireland is still developing, so we pose and discuss the following questions:

1. *Will the specification contain suitable content and recommendations with regard to pedagogy, flexible enough to accommodate future developments?* To investigate this, it may be wise to increase investment in the curriculum research and development required – especially during the first phase of implementation – through a combination of centrally (or even commercially) funded intervention and appropriately supported practitioner research.

2. *Will the assessment process match the intended pedagogy – and will the intended pedagogy actually be implemented?* If the format of the examination does not adequately reflect the aims of the curriculum, then teachers may be driven to instil factual knowledge rather than follow the innovative group collaborative model suggested in the draft specification. This may occur especially if teachers disagree with the underlying philosophy of teaching and learning through project work, or do not have the skills to implement it. Deeper issues arise here about the culture of teaching and learning in Ireland. In the case of Mathematics, for example, successive curricula have emphasised learning for conceptual understanding as well as

procedural fluency, but over-predictable examinations have allowed teachers and students to focus disproportionately on the procedural rather than the conceptual aspects (Oldham, 2001, 2007); anecdotal evidence is suggesting that it has taken the rather traumatic reform of the design of examination papers – and substantial provision of professional development courses – to start to break this cycle. There is a lesson here for Computer Science.

3. *Will there be the teachers to teach Computer Science – and will, or how will, their qualifications be recognised?* Currently in Ireland, to be accredited to teach a subject at second level, one must hold degree-level qualifications in that subject satisfying detailed conditions on course content laid down by the Teaching Council (www.teachingcouncil.ie). For a new subject, this leads to a "chicken-and-egg" situation. On the one hand, graduates in the subject have not been able to become teachers because they were not qualified to teach existing subjects; on the other, the current teaching force contains few people whose qualifications allow them to be accredited in the new area. Flexibility in devising the initial accreditation criteria, so that they facilitate rather than inhibit development, is of importance here (Fisher, Oldham, Millwood, FitzGibbon, & Cowan, 2016). Fortunately, it appears that the Teaching Council is prepared to address the issue suitably (Tomás Ó Ruairc, personal communication, October 14, 2017).

4. *If and when there are suitably qualified teachers, will schools be in a position to offer the Computer Science course and hence to employ them?* There will be pressures with regard to resources, including time in the timetable, and questions will be asked as to whether students should drop another subject (and what that subject might be) in order to take Computer Science. Introducing a new subject in the senior cycle always entails risks, especially in a system – such as that in Ireland – in which the high-stakes nature of the terminal assessment is very marked. It would be disappointing if only a small percentage of schools were to offer the subject in Ireland, as for the current situation in England as described above (John Hegarty, personal communication, November 4, 2017).

5. *Are we in too great a hurry?* In each of the issues raised above, problems can be avoided by taking time to implement the new developments, ensuring that resources and labour are in place before rushing to teach Computer Science. It is worth noting that in the Netherlands, such innovation is taking place in a planned process over five years (Barendsen, Grgurina, & Tolboom, 2016).

Conclusions

The three questions raised in the Introduction can now be addressed.

In spite of the issues that we have identified in England and Ireland, the authors do consider that there is a place for a Computer Science subject and qualifications to match (Millwood, 2007). It should be suitably future-proofed against changes in technology and practice that can be readily anticipated, based on the historical development of technology in society that shows no sign of slowing. Also, we know that not all learners will be fulfilled in their studies of computer science unless the curriculum adopts an imaginative pedagogy and forms of assessment to match. For this reason, the authors welcome the new senior cycle course in Computer Science being proposed in Ireland, with its emphasis on collaboration and team/group-based project work. Also, a Computer Science subject should complement rather than compete with other approaches to the place of computers in the curriculum. The warning from England's story is that we may reduce students' opportunities if we do not encourage diversity of courses and qualifications around the computer and its applications in creativity and communication as well as business and industry.

Judging from the cases considered, the conditions for successful introduction include a strong recommendation that it must not be rushed. Adequate time needs to be given for research, piloting or other form of gradual implementation, teacher support and development of resources. Some flexibility in existing arrangements for state assessment and teacher accreditation may be required in order to scaffold the implementation.

As regards sustainability, the Lero Report points out that "participation rates in Computer Science programmes have been found to be initially low internationally. As other jurisdictions face the challenge of sustainability, an opportunity exists to learn what works well and not so well in early adopters" (Keane & McInerney, 2017, p. 11). This is a clear call for ongoing evaluation and research. Finally, there needs to be extensive support for the teachers to find continuing professional development courses and qualifications that can prepare them, and communities of practice to support their practice and sustain their growth. In fact, "the … strategy of fostering communities of practice, integrated with multiple professional development approaches (such as training, mentoring, research, accreditation and peer to peer knowledge sharing) was found to be both a welcome and effective approach…" (Keane & McInerney, 2017, p. 9). Politicians are called upon to take this last point very seriously, if they are to make an effective change towards Computer Science in schools.

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