# Bringing Computer Science Back Into Schools: Lessons from the UK


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## ABSTRACT

Computer science in UK schools is a subject in decline: the ratio of Computing to Maths A-Level students (i.e. ages 16–18) has fallen from 1:2 in 2003 to 1:20 in 2011 and in 2012. In 2011 and again in 2012, the ratio for female students was 1:100, with less than 300 female students taking Computing A-Level in the whole of the UK each year. Similar problems have been observed in the USA and other countries, despite the increased need for computer science skills caused by IT growth in industry and society. In the UK, the Computing At School (CAS) group was formed to try to improve the state of computer science in schools. Using a combination of grassroots teacher activities and policy lobbying at a national level, CAS has been able to rapidly gain traction in the fight for computer science in schools. We examine the reasons for this success, the challenges and dangers that lie ahead, and suggest how the experience of CAS in the UK can benefit other similar organisations, such as the CSTA in the USA.



## Categories and Subject Descriptors

K.3.2 [**Computers and Education**]: Computer and Information Science Education—*Computer science education*; K.4.1 [**Computers And Society**]: Public Policy Issues

## General Terms

Human Factors

## Keywords

Computer Science Education, High School, Teachers




## 1. INTRODUCTION

The computing industry is prospering and evolving: the smartphone 'app' market has become worth billions of dollars within a few years of its inception [7], the video game industry is now worth more than the film industry [16], which itself uses increasing amounts of technology [10] – not to mention the growth of companies such as Google and Facebook. Computing is also increasingly being used in a wide range of disciplines – such as bioinformatics, which is forecast to soon be worth billions of dollars [8].

UK industry reports a shortage of quality computer science graduates to support this growth [5]. However, the computer science education pipeline is stalling. The number of UK computer science degree entrants remains relatively static: a decline until 2007/2008 has been followed by a recent slight uptick (see Figure 1), with a similar pattern in the USA [17]. The situation in schools is worse, where the numbers taking the pre-university A-Level qualification have roughly halved since 2005 [9] (see Figure 1).

Increasing the computing workforce requires more computer science graduates. However, computer science take-up in higher education cannot realistically be increased simply by improving advertising of the course to 18 year-old degree applicants; typically, UK students choose their degree subject much earlier, as they must choose their subject specialisms at ages 16–18 (and even at ages 14–16) to support their degree choice. Thus, the drive to increase interest in computer science must focus on schools, not universities.

It is against this backdrop that Computing At School (CAS) was formed in the UK in 2008, to promote the cause of computer science in schools. This paper examines the challenges that were/are faced in promoting computer science in schools, and highlights successes and failures of CAS in the UK, which can inform efforts in other countries, such as the USA.

## 2. A BRIEF GUIDE TO UK EDUCATION

This paper will discuss computer science education in the UK, specifically. As a brief guide to education in the UK: typically, students will be given little choice in their subjects (and take no qualifications) before age 14. At age 14–16 they will usually study for around ten GCSE qualifications.

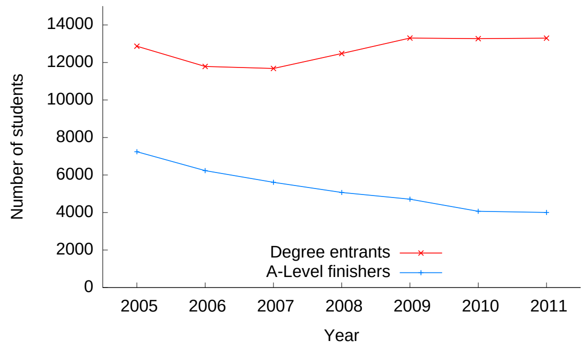


**Figure 1: Numbers of A-Level completions and degree entrants for computer science in the UK. Source: UCAS and JCQ.**

Sufficient grades will allow students to take 16–18 qualifications: normally, three or four A-Levels. Grades from A-Levels (commonly, dependent on subject) will allow entry to universities for a degree taken from age 18–21.

GCSE and A-Level exams are designed and examined by a small set of government-approved awarding bodies. Other qualifications do exist at these age groups, and due to devolution the system differs in some regions (especially in Scotland), but that will not be discussed in this paper.

## 3. THE DECLINE OF COMPUTER SCIENCE IN UK SCHOOLS

One reason for the decline of computer science in UK schools is the poorly-focused nature of the curriculums. They were a mix of dull and overly fastidious software engineering (which bored many students) and a focus on technology which easily became outdated, such as questions on parallel ports in 2008 [1], seven years after Microsoft classified them as legacy technology [11].

The state of computer science A-Level qualifications has become such that it is not considered suitable support for any degree [4] – including computing itself [2] [13, p67]! Many teachers have told the authors of advising students not to take computing A-Level despite an intention to take a computer science degree. In part, this is a chicken-and-egg problem: not enough schools offer computer science so universities cannot rely on it at entry, meaning that many universities are indifferent to prior qualifications in computer science. This can be seen numerically in Figure 1 – the number of students entering computer science degrees is not related to the number taking computing A-Level. Maths, physics and so on do not suffer the same problem.

Another reason for the decline of computer science in UK schools was its overshadowing by ICT. Some teachers delivered excellent ICT or bent the curriculum to teach computer science, but too often ICT featured basic IT skills, which were considered dull and pedestrian, and which are also of little relevance to computer science [12, 14]. To give an idea of the impact of ICT on computing: in 2003, computing A-Level split into ICT and computing [14, p59]. Before the split, 28,000 students took computing. Immediately afterwards, 16,000 took ICT and 8,000 took computing, dropping to 11,000 and 4,000 respectively by 2012 [9]. By contrast, maths went from 56,000 in 2003 to 85,000 in 2012.

In the late 2000s there was no organisation that was advancing the cause of computer science. ICT had its own subject association, Naace, but computer science did not. BCS, The (UK) Chartered Institute for IT[1], was focused on professional development, not schools. Universities were aware of the problem, but did not have enough contact with schools and awarding bodies to make a difference. Computer science in schools had no visible champion.

## 4. COMPUTING AT SCHOOL GROUP

The *Computing At School* (CAS) group was founded in 2008 to investigate ways to improve the teaching of computer science in UK schools. CAS started as a truly grassroots initiative, with no organisation or funding, but was unified by a shared recognition that the representation of computer science in UK schools was dismal and a collective desire to improve the situation.

A wide variety of institutions was represented at the founding meeting, with people from a range of backgrounds: school teachers, academics, as well as representatives from industry and awarding bodies. The lack of hierarchy and composition of the group turned out to have a significant impact on the operation of CAS, which lasts to this day. While some formal structures were slowly added over time, its flat-structured grassroots origins remain, and are hugely influential in the way CAS operates.

Over the last four years, CAS has transformed from a small action and lobbying group into a membership organisation for UK school teachers with over 2,000 members. Its activities have diversified, and include the development of model curriculums, political lobbying, organisation of training for teachers and the staging of an annual national conference for teachers.

At its foundation in 2008, CAS seemed to fight a lonely battle against the odds. While many individuals agreed that the state of computer science teaching in UK schools was problematic, few organisations or institutions of influence seemed inclined to act to improve it.

In 2011, however, the tide started to change. Several organisations became actively involved in promoting improvements in UK computer science teaching, including e-skills UK [6], UCU [15], and the *Next Gen.* Report [10], culminating in a highly-noted report by the Royal Society, the UK's Academy of Sciences [14]. These reports were supported by various statements from industry, one of the most publicised being a speech by Google's executive chairman Eric Schmidt in Edinburgh in 2011[2]. As a result, in early 2012 the UK Department for Education declared the re-introduction of computer science teaching into UK schools an official goal. The CAS agenda had become mainstream.

With this rising tide of various organisations and individuals pushing in the same direction came, however, problems of success: thousands of teachers now have to be trained, curriculums need to be developed, infrastructure put into place. CAS is one of the organisations working on supporting these changes.

## 5. CHALLENGES

[1] `http://www.bcs.org.uk/`

[2] `http://www.guardian.co.uk/media/interactive/2011/aug/26/eric-schmidt-mactaggart-lecture-full-text`

The CAS activities fall broadly into two major categories: initiatives for teachers, and activities opposite established organisations of influence, such as awarding bodies and government. For teachers, CAS aims at providing support for the delivery of computer science content in the classroom. For decision makers, CAS aims at influencing overall policy and strategy to improve the environment that computer science teachers work in.

Initially, one of the main problems for teachers was a lack of infrastructure for communication and exchange of ideas. Teachers worked in isolation from each other, with no overarching organisation or support. This isolation of individual teachers contributed greatly to stifling progress. Even for dedicated, motivated and capable teachers it was essentially impossible to engender change beyond the boundaries of their own school. Accordingly, many of the teacher-related initiatives of CAS aim at improving exchange of experiences between teachers and provide platforms to communicate. This includes communication online, local face-to-face "hub" meetings, and a national conference.

## 5.1 Peer communication

One of the first actions of CAS was to create a static website[3] and set up a national mailing list for anyone interested in furthering computer science teaching at school. Members subscribed to this list included many school computer science teachers, but also academics, representatives from industry, members of awarding bodies and other regulatory bodies [3]. As membership grew and the number of activities diversified, these tools were insufficient to maintain good group communication. Members started complaining about the amount of traffic on the mailing list and many unsubscribed from the list, losing some contact with CAS.

In August 2012, the mailing list was replaced by a custom-designed community web site[4], which provides richer functionality for communication. In addition to providing discussion forums, the community site offers functionality to share resources and collaborate on their development, organise and browse those resources, disseminate news items and display geographical locations of other members and CAS Hubs (see Figure 2). Early indications of the effect of the new technology on member communication are very promising. There is also an active CAS community of UK computer science education blogs, written by teachers and academics[5].

## 5.2 The CAS Hubs

In addition to online communication provided by the mailing list and community website, CAS aimed very early on to facilitate face-to-face contact between teachers. This is most feasible where teachers are geographically close, and is supported by CAS Hubs.

CAS Hubs are run by volunteers from the CAS membership and serve a geographical region. Their activities vary in nature and frequency, depending on the situation of the local hub leader and members. A typical pattern would be monthly or quarterly meetings in the evening, often at the school of one of the hub members. At these meetings, members share knowledge, often via demonstrations of particular teaching tools and general discussions.

[3] http://www.computingatschool.org.uk/

[4] http://community.computingatschool.org.uk/

[5] http://planetcas.org.uk/

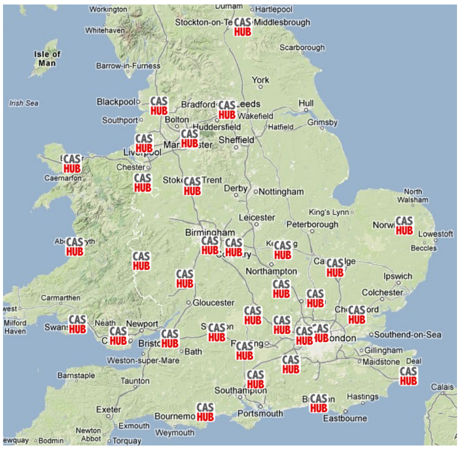


**Figure 2: The CAS Hubs in England and Wales.**

Establishing a local hub is supported by CAS through the provision of a hub handbook to get started, and technology infrastructure (mainly on the community website) to promote the hub and its activities. CAS also provides advice, suggestions and contacts for external speakers (typically volunteers from industry or academia), and can provide funding for those speakers' travel expenses.

At the time of writing, around 40 CAS Hubs exist in the UK – most of which are shown in Figure 2. This provides a density where most teachers have a CAS Hub within an hour's travel of their home location.

## 5.3 The CAS conference

Since 2009, CAS has organised an annual national conference. Attendance at the conference has been free for all participants. Teachers have to pay only for their own travel and accommodation, and speakers donate their time free of charge. The conference programme usually spans one full day (with a social reception the evening before) and consists of a number of plenary talks and a set of workshops.

The conference has been very successful from the start, with over 200 participants attending in its first year. The capacity was increased to 250 in following years, with the event booked out every year since then. Feedback for the conference has been very good, and afterwards teachers usually report an increased level of excitement and enthusiasm; the conference serves to seed new ideas and to encourage teachers to start new initiatives. However, the nature of the conference has given rise to several challenges, which can be seen as representing larger challenges to CAS as a whole.

One challenge is the size limit of the venue, compared to growing interest in the conference. The conference has been held each year in space made available to CAS free of charge by the University of Birmingham. CAS has greatly benefited from this arrangement, but it imposes a hard limit on the size of the conference. It is unrealistic to be able to continue to increase participation without switching to paying for the conference venue. More generally, it is increasingly becoming a problem that where CAS used to be able to rely on freely donated time or resources, scaling up will require a switch to having a more traditional funding scheme.

One possible method of funding is registration fees for attendees, but an alternative is sponsorship from industry. In the past, the conference was essentially non-commercial and vendor free: it contained no commercial booths or sales talks. This purely collegial and academic nature has created a positive atmosphere that has contributed much to the success of the conference, and sponsorship may jeopardise this. More generally, as CAS scales, it must continue to monitor and adjust its position with respect to vendors and commercial interests, treading a line between useful cooperation and vendor-independence.

In summary, the conference is one of the clearly successful activities with high impact. For any teacher organisation, this is an activity well worth considering. As CAS—and with it, the conference—evolves and grows, a number of challenges arise in managing the increased interest and scale. This model has been successfully replicated by CAS Wales in both 2011 and 2012, with an inaugural CAS Scotland conference planned for October 2012.

### 5.4 Teacher Professional Development

One obvious activity for CAS from the start was the organisation and provision of training for existing teachers. Initially, this consisted of occasional courses, scheduled irregularly and on demand, varying in duration from a few hours to several days. Topics and technologies covered in these workshops included Greenfoot, Python and Scratch/BYOB. Some courses also offered more theoretical background of specific areas of computer science, such as algorithms, but workshops on specific technologies—especially programming technology—were the most frequent and most popular.

More recently, demand for teacher CPD (Continuous Professional Development) has increased sharply. With the goal of increasing computer science teaching in schools now widely supported by a broad alliance of organisations, including the Department for Education, many schools aim to improve their offerings. Very often, this necessitates further training for teachers, who frequently have no formal training in computer science or programming [2].

One reason for the lack of expertise in computer science teaching is the continuation of a problem in ICT. When ICT grew in the 2000s, many teachers were conscripted from other subjects without any additional training [14, p72]. CAS now faces the challenge that many ICT teachers may be expected to now transfer to computer science, again without training.

This increase in demand for teacher CPD opens up a number of new questions and challenges. Teacher CPD is currently not well funded, nor centrally organised. Teachers often have a low or non-existent budget for training, and some teachers end up paying for training using their own personal money. Not only is paying for the training an issue, but teachers must either attend in their own time (evenings, weekends, holidays) or a substitute teacher must be found to cover their classes – which is either logistically difficult/impossible, or too costly for the school to allow it (often overshadowing the cost of the training itself).

CAS is preparing to play a role in the planning and provision of teacher CPD. It cannot provide the content itself, but can have a role in organising and advertising courses provided by partners, such as universities or other organisations. Due to the aforementioned problems, to be currently accessible to teachers, these courses must be both short and cheap to attend. Many initial courses are being run at cost or at a loss by enthusiastic universities or other teachers, but this is not sustainable in the long term.

A long list of problems thus remain to be solved as CPD is scaled up in future. These include questions of funding, setting content, unified certification, and quality control of course delivery. It is envisaged that CAS-certified CPD will be delivered by a number of independent institutions, with CAS providing administrative support, announcement and advertising, coordination and certification. The exact nature of the relationship of CAS and the content providers, including the formalisation of certification and quality control, remains to be decided.

### 5.5 Organisation

A further challenge caused by the growth of CAS is that of organisation. The initial CAS membership was a group of concerned individuals who fit in one meeting room. Small working groups were often formed at regular group meetings or via the mailing list, e.g. to produce a model curriculum. Members were always encouraged to volunteer and take the lead on issues that concerned them, with the motto "*there is no them, there is only us*".

While the organisation has had much success, it is hard to measure the opportunity cost, where issues may not have been followed up due to the lack of a volunteer with an interest. There is also the issue of scale: having no organisational structure may not scale well enough to accommodate the increasing membership. Currently, CAS has only two paid, part-time members of staff (funded by the BCS), supporting over 30 hubs and 2,000 members. It is anticipated that more staff will be needed to support future growth.

## 6. POLICY

While CAS has been successful at getting teachers to support each other, the struggles of computer science as a subject could not have been solved solely at this low level. CAS has also engaged successfully with government and awarding bodies (examination boards) at a policy level.

### 6.1 Government

Government were initially unconcerned with the problem of computer science in schools. The subject of ICT was widely taught in schools, and as far as most government officials were concerned, ICT addressed all computing-related needs. This belief was only unseated by the publication of several reports, combined with interventions by industry[6]. An early leader was the *Next Gen.* report [10], headed by two respected industry members, followed by a comprehensive report from the Royal Society [14] in January 2012.

These interventions made the government aware that there was a problem to be solved, and that it was not just computer science teachers who felt this way. This contact was followed first by a campaign by CAS to educate government ministers on the difference between computer science (academically rigorous, long-lasting core principles that did not change year-to-year, full of programming and software creation) and ICT (too often changing to fit the latest technology, dependent on specific applications such as Microsoft Office, focused more on using existing software than creating new software).

[6]For example, see `http://academy.bcs.org/upload/pdf/cs-school-gove.pdf`

Once this difference had been made clear, government became more understanding of the issues, and more willing to act on them, ultimately culminating in the Education Secretary declaring in a January 2012 speech[7] that the ICT curriculum would be rewritten and that they supported the development of "new, high-quality Computer Science GCSEs". The speech made explicit mention of the *Next Gen.* report and of Eric Schmidt's comment and, not coincidentally, preceded the publication of the Royal Society report by only a few days.

CAS has had a remarkable impact at the policy level. Its weight when talking to government was boosted by several factors. One factor was the support of industry and other bodies to whose needs government was attentive. Another factor is the core aspect of CAS: the teachers who are members. Being an organisation that represents hundreds (and now thousands) of school-teachers gave more weight than being purely a lobbying organisation. The final factor was that CAS gained the support of the BCS, an established organisation, helped to legitimise them as representing the wishes of industry as well as education.

## 6.2 Awarding Body Engagement

In England and Wales, qualifications (syllabuses and assessment) are the responsibility of a small number of awarding bodies (a.k.a. examination boards, primarily: OCR, AQA, Edexcel, WJEC), audited by the government agency Ofqual. In order to have computer science as a subject in schools, it was necessary to ensure that exam boards were offering computer science qualifications with a suitable syllabus that focused on computer science, rather than ICT.

The OCR exam board decided to design a computer science GCSE (ages 14–16), which was piloted in 2010/2011, then made available to all in 2011/2012. Following this and various other policy developments, the other three largest exam boards announced (in late 2011/early 2012) the development of their own computer science GCSEs, targeted for launch in 2012/2013.

The focus on GCSE is an interesting development. An initially more obvious route would have been to work "backwards" from universities (where computer science was still reasonably popular) and develop a new A-Level. However, students only take three or four A-Levels, so taking computing A-Level (which is not well respected by universities, including by "neighbouring" subjects such as maths or physics) is of little benefit – even if they want to take computer science at university. The GCSE (of which students typically take ten) is more likely to see uptake from those who are not already dedicated to the subject.

## 6.3 Schools

Although CAS has a large number of computer science teachers as members, many of whom are heads of department[8], their influence within their own school was typically quite limited. Headteachers were generally unreceptive to the idea of increasing computer science teaching: like government, they believed that ICT covered all the computing-related educational needs of the students. Furthermore, without a computer science GCSE, there was no possibility of offering computer science at ages 14–16 (when almost all teaching is towards a GCSE) nor before age 14 (without an ensuing GCSE to follow, it would be seen as a dead-end).

The GCSE issue being taken care of, CAS have worked to try to inform and support headteachers with regards to computer science in schools. One significant step was a mass mailout to every headteacher of a state school in England and Wales [9], explaining how and why computer science could be delivered in their school, and offering an invitation to join the CAS/BCS Network of Computer Science Teaching Excellence. This network will get underway in the 2012/2013 academic year, headed by a seconded teacher and university academic, who will look to support schools in the new push to teach computer science.

## 6.4 Devolution

The UK is comprised of four major geographical regions: England, Wales, Scotland and Northern Ireland. England is the biggest region geographically and in terms of population (over 80%), and thus tends to dominate politically. Since 2000, devolution has seen power shifted to local assemblies in Wales, Scotland and Northern Ireland (but not in England, which has no separate government than the overall UK government). Education (and in particular, school qualifications) has historically differed between the four regions, and devolution means that some aspects of education policy are devolved to the three regions, while some power remains with the overall UK government.

Devolution brings advantages and disadvantages when trying to effect change. The smaller governments in the devolved regions can be more accessible and more agile when it comes to making change, allowing easier and more effective access to policymakers. On the other hand, it can also mean fighting the same battle four times over to convince different regional governments. (Thankfully, this problem is not as large as, say, in the USA, where each of the fifty states may have power over their own education systems.)

Nevertheless, there has been significant success in driving the computer science education agenda in the devolved nations, especially by leveraging commitments made in the others. At the 2012 CAS Wales conference (in partnership with the Technocamps project based at Swansea University), the Welsh Government's Minister for Education and Skills announced a £3m investment in computer science and digital literacy, along with clear commitments to promote and support computer science education.

# 7. CONCLUSIONS

The Computing At School (CAS) group was formed in 2008 against the backdrop of a decline in computer science in UK schools: declining numbers, declining visibility and declining respect. In just four years the organisation has grown to over 2,000 members, has successfully lobbied the national government to support computer science in schools, has contacted all state headteachers regarding re-introducing computer science, has begun to set up a national network of excellence for computer science in schools with over 250 member schools, has been instrumental in the reintroduction of rigorous computer science qualifications in schools and has set up over 30 hubs nationwide to support teacher commu-

[7] `http://www.education.gov.uk/inthenews/speeches/a00201868/michael-gove-speech-at-the-bett-show-2012`

[8] A computer science department in a UK school typically has 1–3 members, including the head of department.

[9] Strategic Information Pack: `http://academy.bcs.org/category/16655`

nication, as well as organising an annual national conference and many teacher training sessions.

One key aspect to the success of CAS has been the composition of its membership – a mix of teachers (albeit rarely headteachers), industry professionals, university academics and members of various other stakeholder bodies. The teachers formed a large grassroots membership which could perform peer support (nationally through the Internet, and locally through face-to-face meetings), which in turn gave weight to the policy-level lobbying performed by some of the industry-based and academic members.

One of the first, vital steps was re-education about the nature of computer science. In the UK, too many people – both in society at large, but also specifically in government – conflate computer science (which involves programming and rigorous analytical thinking, with a consistent set of core principles) with ICT (which typically involves learning to use – rather than create – current computer software). The success in lobbying the government only followed after this distinction was made clear.

The process of promoting computer science required addressing several fronts at once. Some teachers were keen to re-introduce computer science, but needed a suitable qualification (determined in the UK by awarding bodies) to be allowed to teach it at ages 14–18. Many schools felt that ICT was sufficient and saw no need for computer science – taking their lead from government, who in turn became more receptive after reports from distinguished academic bodies [14] and industry [10]. (In the UK, recent governments' education policies have, sadly, been more receptive to industry views than the views of schools or universities.)

Although CAS has managed to grow quickly, not all teachers have been receptive. Some ICT teachers feel threatened by the push of computer science: some because they are worried that they will be called on to teach the subject they are unfamiliar with, some because they feel computer science is a niche subject, some because they worry that the computer science bandwagon may now overshadow (or denigrate) their own subject of ICT. And indeed, computer science runs the risk of falling into the same trap that damaged ICT's reputation: demand for running computer science in schools may outstrip the supply of trained teachers, which could lead to computer science being taught by a cohort of undertrained teachers. Without the funding from government for teacher training, this is a major concern.

The CAS grassroots activities, coordinated locally, have been very successful, and have scaled well, with new regional coordinators volunteering to serve each area until the point has been reached where most of the country is served by a nearby hub (see Figure 2). The forthcoming challenge will be to scale the national coordination of CAS activities (particularly teacher training) effectively as more teachers continue to join the organisation. Pleasingly, there has been much industry support for CAS, but a further challenge is how to make effective use of industry goodwill, by encouraging liaisons between developers and their local teachers, or coming up with some other partnership of the two.

## 7.1 Lessons

Each country will have its own unique set of challenges when looking to promote the cause of computer science in schools, but here is a summary of the lessons from the UK:

- A varied composition (featuring many or all of: teachers, headteachers, industry, academia and other organisations) will provide strength – for example, teachers can provide weight to lobbying carried out by non-teachers.
- Part of the challenge will be making clear what computer science is (rigorous, academic, centred on programming), and how it differs from digital literacy and computer maintenance.
- It is key to understand the pressures and motivations of different interdependent stakeholders – teachers, headteachers, government – and solve the problems of each.

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