Enthusing and Informing Potential Computer Science Students and their Teachers

Q. I. Cutts, M. I. Brown, L. Kemp, C. Matheson
Department of Computing Science
University of Glasgow
Scotland
+44 141 330 5619
[quintin, mbrown, lynsey, mathesoc]@dcs.gla.ac.uk
Project Website: http://csi.dcs.gla.ac.uk

ABSTRACT
School curricula contain little direct Computer Science (CS) content, and pupil surveys confirm that pupils have little idea what CS is. A range of initiatives have been introduced by universities to address this problem, and so attract more CS students. This paper presents the Computer Science Inside... project, one such initiative, the primary goals of which are to provide materials for use in secondary school classrooms, and to motivate and prepare the teachers to deliver them. The materials are principally workshops, to be conducted away from machinery and which bring out key CS concepts underpinning ubiquitous IT products such as the mobile phone or internet. All materials are available on the web, to encourage delivery widely by academics, students or teachers. Our evaluation has shown the approach to be broadly successful, and has also highlighted directions for future work.

Categories and Subject Descriptors
K.3.2 [Computers and Education]: Computer and Information Science Education – Computer Science Education, Curriculum, Literacy.

General Terms

Keywords
High School Computer Science Education, Declining Computer Science Enrolment, High School Curriculum Design.

1. INTRODUCTION
Computer Science is a discipline misunderstood. The 2005 UK Grand Challenges conference on computing education [8] noted that "there is often a very poor understanding by new [university] students of what the subject is and what they will study". Increasingly in the western world, computing is being marginalised in school curricula – an LTSN-funded, 2000-participant survey in Scottish schools determined that the pupils are saturated with classes involving the use of ICT and now perceive that computing as a discipline is more of the same. A similar survey in the US found that 80% of pupils had no idea what university CS courses contained[2]. This is hardly surprising: the ACM’s Computer Science Teachers Association admits in its latest report that there is no nationally recognized CS curriculum for schools [9]; UK schools curricula have been steadily reducing the CS content of so-called computing courses in recent years, replacing it with ICT training material.

Given the relative lack of information at schools level, university CS departments have attempted to give pupils an insight into what they can expect in a higher education CS course in a range of ways. One of the earliest and most significant approaches from the point of view of this paper, the Computer Science Unplugged programme, has developed a series of workshops to be used away from machinery and with any age group, although principally primary-age pupils[1]. The First Lego League[7] is an example of the introduction of programming and problem solving concepts through regional, national and international competitions. The CS4FN project[4]'s main deliverable is a series of magazines with catchy articles about the application of CS in a wide range of areas as well as games and puzzles involving CS concepts. Many university CS departments develop a liaison programme with schools in the local neighbourhood, making use of visits, presentations, masterclasses, open days and so on to deliver information about the subject, for example [5]. Websites and on-line materials are being delivered that introduce pupils to some of the complexity and excitement in CS. For example, the POOPLeS project [3] provides on-line educational components to support the first steps in the learning of Object-Oriented programming concepts.

The paradox in all of this is that our society is being radically shaped by end-user information technology (IT) products such as the mobile phone, internet, and MP3 players. These products are underpinned by concepts developed in fields under the general umbrella of computer science. Pupils and the wider public are largely ignorant of the discipline that evidently has so much power to shape their lives.
This paper introduces Computing Science Inside… (CSInside…), a project funded under the UK Engineering and Physical Sciences Research Council’s public engagement programme, and currently entering the second of its three year duration. The project blends techniques described above with some new approaches. Its name comes from the intention to bring to life the CS to be found inside the end-user IT products mentioned above. What CS concepts underpin the mobile phone, the internet, and so on? Successful Physics, Chemistry and Biology courses attract students partly because they help to explain the working of the physical world as it applies to pupils. Pupils become fascinated with the question “How does it work…?” in relation to an electric motor, the eye, or different smells. The CSInside… project attempts to answer the same question applied to aspects of the pervasive IT world surrounding pupils. The remainder of the paper describes the intervention model developed by the project, gives an example of one of the interventions, summarises our evaluation findings so far, and outlines our next steps.

2. CSInside… PROGRAMME
The project is centred around the development of a series of 40-minute, or lesson-length, workshops. These workshops are designed to be delivered by academics or students on school visits or teachers during their normal classes, and aim to bring out the CS underpinning some aspect of a technological device with which the pupils are familiar. For example, pupils often run many applications simultaneously on their PCs, and so one workshop explores scheduling in this context.

The format of the workshops is principally either worksheet or role-play based. Typically, the beginning of the workshop engages the pupils with some aspect of their everyday technology. For example, the scheduling workshop mentioned above simply asks the pupils if they use MSN in the evening (they all do, of course!), and then asks them what other applications are running (music player, e-mail, “the internet”, games are typical), and poses a final question “There’s one processor in the machine, how can it be doing all those tasks simultaneously?” For most, this seems to be enough to get them interested. The next stage is to explore the topic area, in this case with a role play in which groups of six pupils work as processor, scheduler and four tasks, running initially a first-come, first-served scheduling algorithm, followed by a round-robin. In between, and at the end, questions are posed about their experience — is this how they think their machine works? This is the time to really engage their experience of the exercise with their experience of real life, and pupils can often now explain with just a little prompting the behaviour they see when their machine slows down under heavy load, in terms of context-switch overheads, long task queues and so on. Finally, the context of the topic area is broadened to include other aspects of their lives that are influenced by it. In the case of scheduling, this includes traffic lights, air-traffic control, timetabling, etc.

The workshops are aimed at secondary school pupils from ages of around 12-17, an age range that contains many curriculum decision points. In Scotland, at around 13, pupils need to decide whether to take specific computing courses, having previously only taken compulsory ICT training courses, then again at 15 and 16, and finally at 17 they are deciding whether to take CS at university level.

Altruistically, we, the academics, want more of the population to know what CS is. Pragmatically, though, we also need more pupils to be choosing CS subjects at age 17 to maintain university numbers. Our access into schools is principally through those teachers in charge of computing related subjects. These may range from introductory ICT classes through to upper-level classes that teach both programming and CS. Such teachers are motivated like ourselves, with both altruism and pragmatism: they need more students to convert from the introductory ICT classes into the more advanced computing classes in order for their departments to stay healthy. There is a synergy between academics and computing teachers therefore, aiding the adoption of our materials.

A second offering to the teachers, beyond making computing courses seem more attractive to pupils, is that the workshops relate in some way to, and therefore support the delivery of, the existing curriculum that they must teach. To this end, we have thoroughly researched the Scottish school curricula, and have an extensive table linking the workshops into the various relevant sections of each curriculum. At a glance, a teacher can see which workshop would suit the current progress point of his/her class.

The content of each workshop is therefore balanced between satisfying the pragmatic curriculum need of the teacher whilst at the same time introducing inspirational CS content.

Awareness of such motivations for teachers to adopt our materials themselves is crucial. Although visits from academics to schools are undoubtedly valuable in terms of awareness-raising, not to mention relieving the teacher for a session, they are not a sustainable method of changing attitudes. For a start, it is hard for a university to visit all the schools in its local area even once per year. Our viewpoint is that pupils will only be significantly influenced if the teachers can be encouraged to make use of the materials in their own teaching, so that the pupils are exposed to inspiration CS material several times a year. Additionally, the teacher is a more powerful influencer in a pupil’s life than a visiting academic is likely to be.

Encouraging adoption of the materials by teachers is therefore essential to the success of the project, and we do this in a number of ways. Firstly, we provide a pack for each workshop containing the following items:

- Overview of the workshop, consisting of a short description of the topic area and the activity.
- List of curriculum links, enabling a teacher to quickly assess the relevance of this workshop for his/her pupils.
- Presenter instructions, giving a timeline of the way we expect the workshop to run, and explaining broadly what to say, what questions to ask, when to hand out sheets. This can of course be tailored to suit a particular presenter.
- Electronic presentation, optionally to be used by a presenter.
- Hints and tips, developed as the workshop has been trialed, and on-going as evaluation reports come in. Explains different tacks presenters have taken, and also what to do if the presentation is running to fast or slow for the available time.
Additionally, and particularly for academic visits to schools, we have introductory motivational material to be used at the start of a workshop. This principally helps to start identifying the difference in pupils’ minds between ICT and CS – the crucial first step. Less is more however, and the quicker a presenter moves on to the workshop material itself, the better.

These materials are made available to teachers via the website given at the start of the paper. The website requires simple user verification and enables us to track workshop downloads, and post reminders to users to provide feedback on their use of the materials. These materials are freely available, and we encourage anyone, whether at university or school level, who is involved in enthusing people about CS, to sign up and make use of them.

From our communications with teachers, it is clear that many of them do not feel confident in delivering some of the CS topics touched by our workshops. Teachers have difficulty finding good Continuing Professional Development (CPD) materials in the CS domain, and often believe they are well behind on recent developments. Additionally, computing-related subjects are increasingly taught in Business departments (because of the business IT connection, and the view of computing generally as a technology subject, not a science), and these teachers often have a limited CS background.

Our final tactic therefore to assist in the take up of the workshops is the development of a CPD programme. At the simplest level, this involves inviting the teachers into the university after school, in a so-called twilight session, and presenting two or more of the workshops to them, with them taking on the role of pupils and working through the material. Such an activity will provide CPD credits for the teachers and through its experiential nature, is the easiest way to prepare to present the workshops themselves. For those who wish to take this further, teachers may identify a programme of workshops they intend to run during the year, along with additional reading around the topics, a commitment to write a short reflective report after each workshop use, and then a longer reflective essay on the year’s activities to be reviewed by academics at year end. Through agreement with the school, this may all be counted as CPD activity, a requirement now for most teachers.

3. EXAMPLE: TABLETS OF STONE

In this section, one of the workshops will be described in more detail. The Tablets of Stone workshop is designed to bring out concepts involved when communicating across an unreliable network, mirroring some of the complexity found in a TCP/IP network.

The first section of the workshop invites the pupils to consider aspects of the communication mechanisms they use, such as land-line and mobile phone calls, txt messages, e-mail, paper mail, MSN messaging, and face-to-face conversations. The pupils identify the protocol they use for each of these methods, and the reliability of each method – including whether they can tell if the message reached its destination. All the pupils can take part in this discussion, because they are all familiar with these methods of communication. In an easy conversational way, the fundamental concepts needed for the workshop can be drawn out.

The pupils are then introduced to a scenario for which they have to develop their own communications protocol. The scenario, used elsewhere to deepen understanding of the TCP/IP protocol, is as follows:

“In an ancient city there are 6 very important Governors, each living in different houses all over the city. They often need to communicate, by sending and receiving messages to and from the other Governors. They each have at least one slave who works for them whose job it is to deliver the messages. The only way to send messages is by writing them on large stone tablets which the slaves carry to their destination. The stone tablets are a fixed size and are very heavy so can only be carried one at a time. Longer messages are often split over a number of tablets. The slaves cannot be trusted to always deliver the message correctly, they are forgetful and lazy. They often stop for long breaks during working hours and even try to escape from the city. The Governors want to find a way of making their communication reliable, they want to develop a set of rules that they will all follow. By doing this they can tell whether or not their message has been delivered and if the message was correct.”

In groups of five, the pupils consider the scenario and attempt to develop a communications protocol that will give the governors the required reliability. Initially, pupils will talk at the wrong level – for example, they often want to apply stricter controls on the slaves. Of course this is quite against the scenario, and it can take a little while to explain that the slaves are inherently unreliable and absolutely cannot be made reliable. This stage usually requires group by group input from the presenter and any available helpers to keep the group moving forward.

Once all groups have a protocol of sorts, the groups are split into two pairs and a single. The pairs form a sender/receiver partnership and are instructed to sit on opposite sides of the room, while the single remaining pupil becomes a slave and stands in the middle of the room. Senders and receivers are given scraps of paper for tablets and instructed that no more than 4 words can be written on each tablet. Each sender is then given a message to send, with the instruction that this message must be reliably sent to his opposite number, the receiver.

Whenever a sender or receiver wishes to send a message they put their hand up. A free slave will then come over – note crucially that it may not be the slave from their own team – and pick up the message before returning to the middle of the room. There, he/she picks up a card from a pile of Action Cards and follows the instruction given on the card. These cards introduce the unreliability into the system, instructing the slave to (a) deliver the message at once, or (b) not deliver this message until after he/she has delivered another one, or (c) lose the message altogether.

It is at this point that the pupils really begin to understand the true nature of the problem, if they hadn’t already grasped it. If all parties are in the same room, the sender can see the message being physically scrunched up by the slave when the action card so instructs. They can then see the absolute need for resends. If the parties can be placed out of sight of one another, and the losing of a message is not so obvious, then the need for an acknowledgement becomes apparent as they sit for long ages while nothing happens.
After 5-10 minutes of running the protocols, the activity can be halted, and the receivers asked to read what they’ve got, followed by the senders’ reading the original message. Often, classic problems of missing and out-of-order message parts can be identified at this stage.

If there is time, pupils can be allowed to rework their protocol in the light of experience. A second run can then be a competition to see who can get their message sent both first and correctly.

The workshop can be closed with the connection of this protocol with the networking protocols used all around them. For example, when they consider a poor mobile phone connection, they quickly see the packet-based nature of the communication, since whole chunks are dropped while others remain.

4. EVALUATION
4.1 Workshops
At the time of writing, we are one year into a three year project. In this initial phase, we have concentrated on using academics to present in schools, in order to ensure that the materials are thoroughly trialed before handing them over to teachers. Eleven workshops (scheduling, communication in unreliable networks, ranking and indexing in information retrieval, data compression, algorithm development, graph colouring, image recognition, interface design, parallel processing, and machine learning) have been produced of which 7 have now been used with pupils from ages 13-18 and are ready for wider circulation. The first of these was presented in schools in February 2006 and by December 2006, 24 schools had been visited and five events held at Glasgow University.

Five CS lecturers and one PhD student have presented a total 69 workshops involving 1430 pupils who have experienced one or more workshops. The majority of pupils were 13-14 year olds in ICT classes, or were older pupils studying on specific computing courses. Non-computing students were at 3 of the University events and at one school workshop.

The method of evaluation is based on Draper et al (1996). Observations and questionnaires recorded a positive response from teachers which was borne out by teachers immediately requesting workshop packs in order to run the workshops themselves. All teachers reported that they would like further presentations by academics and all but one were interested in using them themselves. Two teachers are known to have successfully run the scheduling workshop themselves. The requests for packs and the first teacher-run workshops are a measure of the initial success of the project. Feedback from teachers contributed to the further development of the workshops. (e.g. “Give more instruction for tasks and use simpler language in explanations.”) Their input was especially valuable regarding adaptations for pupils of different ages, presentation, time allocation etc. and resulted in the development of the Hints and Tips for Presenters document for each workshop, to cover presentations with classes of different ages and ability as well as situations where more or less time was available than expected.

Feedback from teachers indicated that pupils liked the “hands-on/interactive approach which made understanding the concepts easy for the pupils”. Also they reported that: “One or two of the weaker pupils made unexpected contributions showing insights that they had not managed before.” “Most of the students enjoyed this workshop. I feel the presenters were excellent and built up a good rapport with the students and gave them food for thought on a topic they take for granted in every day life.”

Several times, we have seen evidence of pupils working hard with the concepts during the workshop. For example, one teacher helping with the scheduling workshop commented: “While one student [a task] was waiting to be ‘processed’ he became frustrated by boredom and asked ‘how can I send a pop-up to the processor’ which made me realise that although he was bored waiting to take part he was actually thinking about the role of the processor and what could be done to get its time/attention.”

Pupils themselves varied in their response and this appeared to depend on several factors (the workshop, class etc) but as yet we cannot quantify these.

Pupils reported: “I liked the ‘hands-on’ approach”; “Predictive texting isn’t as bad as I thought”; “l lecturer makes it clear what he means”; “I found learning about different networking systems interesting and the first task in the Tablets of Stone workshop which really helped me understand communications more”; “Interesting about how activity ran and how complicated calculations are divided into very simple ones”; “Disliked the fact that we did not do anything that exciting”; “Got a bit boring towards the end with all the sheets”.

The variability of the responses from the pupils highlights one of the major aspects of this approach compared to some of the others outlined in the introduction. This intervention is applied to a wide range of pupils, in the earlier years, before the students have expressed particular interest in the subject. Just as some pupils find Biology uninteresting, so it is inevitable that not all of the pupils will enjoy these workshops. By contrast, many of the other styles of intervention are applied to a self-selecting group of pupils who are likely to have already had some exposure to the subject. Evidence that there is potential to influence the pupils is emerging, as these quotes suggest: “One very bright girl is now considering doing Computing at University on the strength of your presentation”, “I should have taken Computing” [from a 15 year old who had already made choices away from computing], “Very useful publicity for computing as a subject. I expect to have a greater intake next year.”

Positive feedback has also come from the 5 GU Academics and the one Ph.D. presenter. They reported that it was fun and worthwhile and that they were willing to continue to be involved.

At this early stage, we only have evaluation results from two teachers using the workshops themselves. However, with little to no training, they had successful results. Indeed, the second use resulted from a teacher sitting in on one of our presentations to 15 year olds, who then said it seemed just right for his 12 year olds, an age group that we’ve avoided thus far as we viewed the material, this workshop in particular, as too advanced. He came back all smiles an hour later, having had a great session. This story gives us hope that the workshops are well-enough designed to be used with minimal preparation, but also suggests that once teachers really engage with these materials, they’ll make much better use of them than academic presenters are able. Whilst we are used to long monologues to docile students, the teachers know
how to maintain the interest and concentration of the younger, more energetic, learners – and hence our concerns on age are unfounded. Indeed it had already surprised us that the same workshop can easily be used across the 13-18 age range with relatively little adjustment to the presentation.

4.2 Website
The website was launched in June 2006 and approximately 90 users have now registered, ranging from teachers, regional subject specialists and education authorities, to academics in other universities. Teachers can and are downloading the Workshop Packs directly from the website (55 teachers so far) but we have as yet no data on their use in the classroom.

4.3 CPD
In discussion with teachers and a thorough investigation of regional CPD regulations, a CPD scheme has been developed. Several teachers have expressed interest and we are in the process of launching the scheme. We have a series of “twilight” meetings planned, recommended by the teachers as the most likely mechanism for ensuring use of the workshops in their classrooms.

4.4 Longitudinal Evaluation
We are undertaking an evaluation of pupil views, expectations and subject choices across the duration of the project. We have signed up a number of schools who are willing to provide progression data from year to year, for years both prior to and during the use of the workshops, so that we can attempt to determine whether our intervention is having any effect.

5. NEXT STEPS AND CONCLUSIONS
The results from this first year of the project demonstrate the validity of the approach. Both teachers and pupils have broadly been supportive of our use of the workshops in schools, and our very small sample set of teacher presenters indicates that the workshop materials are at the right level for teachers.

We have found that the hardest aspect is both making contact with teachers on a wide scale and supporting them to use the workshops. Nonetheless our goal is to have more than just a handful of ‘tame’ schools nearby, we are looking to have a CPD mechanism for ensuring use of the workshops in their classrooms.

To the presenters who have been involved in this project, these workshops and the materials being developed by others, including those mentioned in the introduction, constitute the beginnings of a school-level computer science curriculum. Just as the various components of, say, a Biology curriculum, help a pupil understand better the working of themselves and other living things, without qualifying them to be a brain surgeon, so workshops such as these enable the pupils to appreciate the underpinnings and workings of the immense technological systems surrounding them. In so doing, it is to be hoped they will appreciate the opportunities and limitations of technology to the betterment of society. If they chose to extend this interest into further study/careers in computer science, then so much the better.

6. ACKNOWLEDGMENTS
This work was supported by Engineering and Physical Sciences Research Council grant EP/D507219/1, and our project partners, the SETPOINT Scotland and the Royal Society of Edinburgh. Our thanks are due to the academic staff and PhD and undergraduate students in Computing Science at Glasgow University who have delivered and supported the workshops, as well as those teachers and pupils in Scotland who have welcomed us into their classrooms. We are indebted to the Unplugged team who provided the spark for this project.

7. REFERENCES