cs4fn Final Evaluation Report

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1. Executive Summary

1.1 Introduction

Computer Science For Fun (cs4fn) is an innovative initiative in public engagement seeking to engage students in "serious fun". In so doing, it aims to help them to see computer science as intellectually compelling, multi-faceted, creative and a pathway to a range of interesting careers. At the end of a five-year span of significant funding (£661,645) for cs4fn from the Engineering and Physical Sciences Research Council, this Final Evaluation Report offers:
- a record of key accomplishments or outputs of cs4fn;
- analysis of a suite of different types of impacts of cs4fn; and
- a set of reflections on insights, issues and lessons learned.

cs4fn was initiated in 2005 as a joint effort between Professors Paul Curzon and Peter McOwan, who later became the Principal Investigators of the EPSRC grant awarded in 2008. Consisting of a magazine, a website (www.cs4fn.org) and live shows, cs4fn has sought to introduce the potential for fun in computer science to school students and to capture their imagination. It also aims to encourage school students to consider higher education and careers in computer science or indeed other physical sciences or engineering. By emphasising this sort of engagement, cs4fn has sought to complement more strictly pedagogical approaches to conveying information about computer science. Nonetheless, it has served as a resource for teachers, schools and other education-related initiatives, as well as for students.

To gain an idea of the way the parts of the project work together, imagine cs4fn as a growing tree: the trunk is the cs4fn magazine at its core. Robust branches growing from this have included:
- the cs4fn website;
- an extensive programme of school visits;
- a set of additional events (such as science festival presentations) and
- publications (from handbooks on the magic of computer science to academic articles).

The cs4fn tree has borne numerous fruits, or impacts, leading to a diversified legacy, with influences on:
- pupils,
- teachers and university colleagues (early career and established);
- other efforts in science communication;
- a zeitgeist change in views of computer science education and related policy changes;
- institutional change and spinouts;
- as well as sharing of lessons learned.

1.2 Accomplishments

Standing out among the accomplishments is the production of some ten issues of the cs4fn magazine, following earlier issues for a total of 16 by autumn 2013. In addition issues of other magazines with a similar flavour, ee4fn and Audio!, were produced as well as several special publications, in particular the books *Magic of Computer Science* and the *Magic of Computer Science 2*. Developed with high production values, and with writing that illuminates research and computer science topics through unusual angles, the cs4fn magazine is viewed very positively by both teachers and students. Now up to a print run of 31,000, it is distributed widely across the UK, and indeed also to subscribers in some 80

countries. The magazine seeks to reach diversified audiences, as exemplified by its extremely successful special issue in 2010, *The Women are Here*.

The magazine is presented on the cs4fn website, with additional elements; again the website places the characteristic cs4fn emphasis on fun. A variety of portals (e.g. magic, teachers) facilitate access for individuals with different interests. Between 2008 and the present, the website has received over a million visits (1,155,521 by mid June 2013) with over 890,000 pdfs downloaded. A website survey running since 2008 has generated very positive responses, not only as far as the website's quality, usefulness and enjoyable nature, but also as to its influences. Over two thirds of respondents:
- saw more ways in which computer science is used,
- think of computer science as more interesting and
- think of a variety of careers that would use computer science.

Since 2008, members of the cs4fn team have given talks to nearly 20,000 school students in some 270 visits to schools and universities and engaged with a further 10-15,000 at science festivals (such as the Royal Society Summer Exhibition). School talks reach a diversity of students, both in terms of ethnicity and in terms of reaching more girls than would be typical for computer science events. Feedback from both students and teachers is extremely positive. In a post-talk survey, 79% of teachers agreed that as a result of the lecture one or more students is now more likely to consider taking computer science at university.

cs4fn has provided teacher support, ranging from the magazines and the website's teachers' portal that includes descriptions of cs4fn classroom activities to invited talks at conferences and inset day workshops; the team contributes to continuing professional development (CPD) and is currently running CPD courses for ICT teachers shifting to computer science.

cs4fn contributes to colleagues in computer science and in public engagement, not only providing magazine copies for other universities to distribute, but also giving talks at other universities' engagement activities and giving advisory talks at other universities. The cs4fn team has continuously reflected throughout the grant period and has shared lessons learned, via vehicles including but not limited to academic presentations and articles.

1.3 Impacts

cs4fn has given rise to a rich portfolio of impacts, in different categories.

Conceptual impacts, changes in understanding or views, include:
- more positive perception of computer science (and studying computer science) among students;
- a deeper understanding of computer science and its potential among teachers; and
- contributions to a "zeitgeist" change, with educational policies now beginning to view computer science as more intellectual and creative than the past association simply with IT.

Instrumental impacts, more tangible, include:
- production of long-lasting publication and website resources;
- contributions to policy/curriculum changes,
- influence on teachers and teaching practices; and
- spinouts (a company developing cs4fn material into workshops and a text for teachers, and a creative new app, *Tunetrace*).

Capacity-building impacts include
- influences on teachers, brought about through a range of activities, CPD and presentations;
- teachers have picked up on both content and the cs4fn "style" of learning.
- Although primarily connecting with teachers in the UK, cs4fn has contributed to international capacity-building as well, for example sharing with individuals involved in the Genoa Science Festival and, most recently, leading to leadership by McOwan of a large EU-funded project to support science teachers in innovative enquiry-based teaching.
- Another dimension of capacity-building has been the cs4fn team's mentoring of next-generation researchers, introducing some 45 individuals to public engagement.

A significant **Attitude/Culture Change impact** has taken place in the home institution, Queen Mary University of London, which has elevated the status of public engagement, for example through establishment of a Centre for Public Engagement, a new Vice Principal post, and new academic promotion criteria that recognise public engagement.

While all of these impacts represent legacies of cs4fn, cs4fn's legacy of influence is perhaps especially clear to see in its **Enduring Connectivity impacts**, with various onward "ripple effects" occurring through continuing uptake of available cs4fn materials, approach and practice by: university colleagues, teachers/related organisations, and other outreach initiatives, along with the media. In this report itself, cs4fn team members have distilled highlights of their rich understanding of public engagement into succinct advice for: researchers becoming involved/ carrying out science outreach activities; leadership of public engagement initiatives; and funders.

1.4 Concluding Thoughts

Early on in the era of national bemoaning the lack of interest in computer science among bright young people, the cs4fn team decided to convey consistently but in often off-beat ways the message that computer science is/can be 'serious fun', that computer science is inherently interesting as a rich multi-faceted subject and that it underpins a wide range of attractive careers. This approach has worked. Vast numbers of students at UK schools, and abroad, have been exposed to the magazine, the website and/or presentations at school visits or festivals. Teachers too have used the various cs4fn deliverables (products or activities) as a resource; now more than ever as the curriculum shifts occur cs4fn is contributing directly to teachers through a website portal, workshops and CPD. Colleagues at various universities and different science outreach initiatives have made use not only of cs4fn materials but also its learning about good practice. The innovative juxtaposition of magic with computer science, in live presentations and in cs4fn publications, exemplifies the initiative's success in creativity. Through five years of EPSRC investment, and above-and-beyond effort by a deeply committed team, cs4fn has led to a diverse portfolio of important impacts on a full range of scales: from sparking excited interest in individual school students, to mentoring next generation researchers in science outreach, to supporting numerous teachers with accessible and distinctive resources, to helping to bring about a zeitgeist change as to how computer science can best be viewed and taught.

While full financial sustainability has not been achieved in the sense that the activity of cs4fn will not be able to continue at the same scale, the team have recently been awarded a major new grant from the Greater London Authority's London Schools Excellence Fund to continue the work. This will have a specific focus on supporting teachers in London. Although it is thus likely to produce 'fruits' that may be disseminated somewhat less widely, the cs4fn 'tree' has still sown multiple seeds that will continue to grow. With ongoing uptake of cs4fn

materials and practices by those who have come to have deep respect for the cs4fn brand, cs4fn will continue to have influence – a living legacy.

In summary, several key points emerge distinctly, in particular as seen through the evaluator's 5-year role as critical friend/evaluator:

- Accomplishments have effectively matched – and often surpassed – targets. In some cases, targets have evolved (e.g. producing special issues in place of an annual). Very often, additional deliverables have been generated.

- Satisfaction with cs4fn deliverables (publications, talks, etc.) seems in general to be very high – among teachers and students. Other colleagues and organisations have a high regard for cs4fn as well.

- cs4fn has successfully reached a diversity of students, from different sorts of schools and backgrounds. The issue *The Women are Here* is particularly commendable in tackling disparities in genders' interest in computer science.

- cs4fn has created a special brand, a "unique selling point", by emphasising the potential for fun – curiosity, puzzles, intellectual play – in computer science, a dimension that students might otherwise seldom encounter.

- The team members have remained alert to a wide-ranging arena of computer science and related interdisciplinary research, and interesting applications. For many, this has illuminated uniquely the multiplicity of careers related to computer science.

- With implementation of its early and distinctive vision made possible by EPSRC support, cs4fn has made a difference. While lines of causality between individual students and individual university subject choices are impossible to prove, the combination of indicators available convey a range of impacts generated by cs4fn, in a full portfolio including conceptual, instrumental, capacity-building, enduring connectivity/leverage and culture change impacts.

- Financial sustainability for cs4fn continues to be dependent on external funding. Its future through autumn 2015 has been guaranteed by the Greater London Authority's London Schools Excellence Fund. Reflecting the priorities of its funders, cs4fn's activities now include more direct teacher training in addition to resource production. As long as cs4fn is not self-sustaining, it will need to adapt to funders' desires. But already cs4fn has generated a rich and multi-faceted legacy, so that its influences will continue to ripple outward and be felt.

The members of the cs4fn team are notable not only for an unusual breadth of understanding of computer science but also for outstanding personal commitment and continuing creativity.

2. Introduction

2.1 Background, Objectives and Guiding Principles of cs4fn

The Computer Science for Fun initiative (cs4fn) began in 2005 as a joint effort between two individuals already deeply immersed in science outreach. Professor Peter McOwan and Professor Paul Curzon conducted "open house" events for school children visiting their department, then the Department of Computer Science at Queen Mary University of London (QMUL) and realised that they shared a vision for conveying their own enthusiasm for computer science as a dynamic, multi-faceted subject. Feedback was so positive that they went on to do more, particularly as McOwan's artificial intelligence research was selected for the Royal Society Summer Science Exhibition. To draw people further into the subject, they created a magazine and website, telling fun and accessible stories about diverse computer science research efforts that they themselves found exciting. Small amounts of funding from the EPSRC and the Royal Society helped in the early developmental stages of cs4fn.

Consisting of a magazine, a website (www.cs4fn.org) and live shows, cs4fn has been an outreach vehicle to introduce computer science research to children (primarily those aged 14+) in a fun, lively, accessible and exciting way, with the goal of enthusing the next generation of potential computer scientists. Articles and activities build on games and puzzles embodying computer science research, as well as conveying new understanding about the field, whether specific research projects or a core topic of computing. Computer Science is portrayed as contributing to not only the "obvious suspects" of fields such as robotics, human computer interaction or mathematics, but also to other domains such as the environment, health, sport, art or language. By conveying the potential for "fun" in computer science, the cs4fn initiative endeavours to capture the attention, imagination, curiosity and enjoyment of young people – and in this way to encourage them to consider higher education and careers in computer science or, indeed, other physical sciences or engineering. While the initiative's efforts and products do contribute to learning, emphasis throughout is on engagement. In this way cs4fn has sought deliberately to complement rather than directly feed into more strictly pedagogical approaches to conveying information about computer science.

The welcoming tone of the cs4fn website (www.cs4fn.org) reflects the guiding principle through which cs4fn seeks to engage young people:

> "*Welcome to the fun side of computer science! Explore how computer science is also about people, solving puzzles, creativity, changing the future and, most of all, having fun*."

cs4fn was successful even in its early years: for example, Curzon and McOwan were awarded the QMUL 2006 Drapers Prize for Teaching and Learning for the contribution cs4fn had made in enthusing students about and introducing them to computer science. The innovative approach they masterminded helped lead to an increase in applications to QMUL's Department of Computer Science of over 100% over two years, at a time when recruitment into computer science was viewed as a national challenge. In 2006, cs4fn was cited as an example of a successful CS education initiative in EPSRC's international review of computer science.

In 2008, the Engineering and Physical Sciences Research Council (EPSRC) awarded what appears to have been its largest-ever grant in science public engagement to Paul Curzon and Peter McOwan for the continuation and expansion of interlinked cs4fn features piloted in its first two years (physical magazine, webzine and high quality shows), creating a national

campaign focusing on interdisciplinary computer science. The team views this time as "a perfect storm bringing together people, opportunities, time, talent and the space to be creative". Over five years, the £661,645 EPSRC investment provided funding for: a research assistant / project manager (Jonathan Black); design, publication and distribution of the magazine; outreach visits; website development and formative evaluation activity. Objectives were to:

- Increase the readership of cs4fn, introducing computer science to new generations of school children
- Extend the range of topic portals covered, giving wide and deep coverage of major topic areas of computer science
- Extend the degree of interactivity on the site including additional methods of dialogue
- Extend the way multidisciplinary links between computer science and other research areas are covered.
- Encourage and mentor others to take part in CS public engagement
- Capture and share learning about effective approaches through a formal evaluation
- Create a sustainable governance framework to ensure the long-term stability of the campaign

The cs4fn management team describes cs4fn as follows:

- A global campaign to enthuse both students and others about inter-disciplinary computer science research.
- A unique channel for researchers to engage with the general public and communicate the excitement of their research.
- An opportunity for students, teachers and the public to get actively involved in learning more deeply about computer science research, and to have a dialogue with the researchers themselves at school events and festivals
- A project to investigate what works and what doesn't to enthuse people about computer science as well as science and engineering research more generally.

It consists of a free magazine sent twice yearly to schools, live interactive shows and a webzine that gained 14.9 million hits in the last year.

2.2 Metaphor for cs4fn and its portfolio

In thinking through with the evaluator how to describe cs4fn, members of the management team grappled with how to convey the multiple efforts, numerous outputs and diverse impacts of cs4fn. Various metaphors were considered, often emphasising a "web" of interactions or the growth of "ripple effects" over time and across arenas of impact. In the end, the organic metaphor selected as best suited to the way cs4fn has grown, changed and diversified over time was that of a tree composed of a foundational 'trunk', several branches and various fruits.

The habitat or ecosystem within which this tree has taken root is the context of a recognised and growing need for computer science expertise in numerous sectors, and the development of significant research discoveries, combined with a disappointingly low level of interest among school pupils going on to university. The "soil" from which the cs4fn tree grows is composed of not only computer science, but also other disciplines and indeed

interdisciplinarity. EPSRC's funding provided the essential fertilizer, with additional key nutrients supplied by Google in particular. The energising sap that flows continuously throughout the tree is cs4fn's distinctive philosophy and commitment to engaging young people through the fun of computer science.

Structurally, the trunk of the tree, at the core of the initiative, is the cs4fn magazine. Several robust branches have grown from this:
- the cs4fn website
- the extensive programme of school visits
- a set of additional events and
- publications (from handbooks on the magic of computer science to academic articles)

The cs4fn tree has borne numerous fruits, or impacts, leading to its legacy:
- Influences on pupils
- Influences on teachers
- Influences on other colleagues (early career and established)
- Institutional change
- Spinouts – activities and influences on other fields
- Influence on broader science communication
- Zeitgeist change/policy changes
- Lessons learned/good practice

2.3 Evaluation

From the beginning, formative evaluation was incorporated into the initiative, to facilitate ongoing reflection/informed evolution of cs4fn; gather key information; and capture insights and "lessons learned" for others undertaking similar challenges in the future. With the help of an external "critical friend" evaluator working with the senior management team, a Framework of Core Questions (Annex A) was generated to guide evaluation by identifying key aims (many deliberately ambitious). This was expanded into an initial working plan for the evaluation, considering various possible indicators and audiences. Just as cs4fn evolved, so did this plan. Evaluative methods used over the lifetime of cs4fn have included: semi-structured interviews; focus groups; surveys; website analysis; retreats; observation; logs and document analysis. The evaluation approach recognised the infeasibility of capturing step-by-step causality, (e.g. one particular teacher reading the magazine – inviting the team for a school visit – one particular child attending – that child later applying to study computer science because of that visit) – in part but not solely due to confidentiality laws prohibiting longitudinal studies. Instead, a portfolio of individual "steps" or categories of cs4fn effort have been examined for accomplishments and impacts in their own right and for their implications regarding overall, sometimes intangible, impacts of cs4fn.

2.4 Purpose and Content of this Report

The purpose of this report is to integrate multiple strands of data and evaluation input into one document which both accounts for return on investment and shares learning as to issues and good practice. This analysis will present:
1) Key accomplishments and outputs;
2) Impacts;
3) Reflection on insights, issues and lessons learned.

3. Key Accomplishments and Outputs

3.1 cs4fn Magazine

Principles, quality, writing

As stated in the original bid, "the magazine provides a tangible entity. It is an outreach vehicle in its own right." Development of each issue of the magazine is shaped by several key principles:
- It should look exciting – people should want to open it to read more;
- It should be enjoyable and thought-provoking to read;
- Readers should learn about underlying concepts about computer science and other subjects;
- Articles should include a sense of fun, whether in the research described or by the metaphors used;
- Articles should have a sense of narrative rather than just being factual;
- Articles should convey the links between subjects across the whole STEM spectrum – and that such links is where exciting research often happens;
- It should present a positive role model to women and minority groups.

The team's article "cs4fn.org: Enthusing Students about Computer Science" (Curzon, 2009), articulates key messages of the magazine specifically and cs4fn overall:
- 'Computer science is fun';
- Computer science is not ICT';
- Modern science is interdisciplinary';
- Computer science is about people'; and
- Computer science is for everyone'.

The cs4fn magazine combines very high production values with a distinctive style melding a quirky irreverence and genuine fascination with the subject matter. Story topics (whether from specific research projects or based on core computing concepts) are chosen to engage a range of readers by showing that computing can be used in multiple fields or sectors, tackling problems from robotics to art. Illustrations are selected carefully and layout is designed deliberately; in short the magazines are professionally published to a high standard. QMUL's graphics design team work closely with cs4fn, particularly its project manager, to achieve the "look" of the magazine, and they deserve recognition for the part they have played in the success of the project. Text is clearly written and titles and content of articles include "hooks" for engaging the reader. Nearly all of the actual writing of magazine text is done by experienced PI Curzon along with project manager Black, who is trained in science communication, and Col McOwan. At 20 pages, each issue, oriented toward an area of computer science or its links to other areas, consists of a mixture of long and short articles, serious topics (addressed from a "fun" angle) and more "off-the-wall" topics, interviews, games and puzzles drawing on computer science. While each magazine is different, as are the annuals and other special booklets, they all share distinctive: style of the design, "flavour" of the magazine's content, "take" on subject matter and deliberate diversity of subject matter, gender and culture incorporated within an issue. (Annex B provides an illustrative table of contents.)

History of issues produced, distribution

cs4fn magazines

As stated in the bid to EPSRC, the initial annual targets were to produce 2 themed magazines plus one annual issue drawing upon these and website articles as a resource for school libraries and so on. While year-by-year production varied and some different types of issues were substituted, overall the number of magazine issues (10 during the lifetime of the EPSRC grant) matched the expectation of ten, although not always two equally spaced per year, and the plan for recapping in annual issues evolved somewhat, moving toward specials with new content. For example, while the first annual compendium collected the first three issues, the second was shaped into a special 60-page booklet on women in computing and electronic engineering. In addition, validating the cs4fn approach, two magazines (electronic engineering for fun, *ee4fn*) were produced on electronic engineering and four on audio-engineering (*Audio!*, spun out of the cs4fn subject portal on Music and Audio Systems Engineering in 2008). In total, fifteen issues of the cs4fn magazine have been produced at the time of writing, with #16, the tenth EPSRC-funded issue, due to appear in autumn 2013. Overall, the cs4fn team exceeded its target of 6 articles per month for 5 years (360 articles) as it had produced 389 articles by end of December 2012. The team also produced a booklet on interdisciplinary developments, *Biology loves technology* (2013), and two magic books: *The Magic of Computer Science, Card Tricks Special* (print run of 5000, with reprint of 5000) and *The Magic of Computer Science II: Now we have your attention* (print run of 2,400 with two reprints of 3,000 each). A member of the team recently co-authored another book (with guidance for teachers), *Maths Made Magic*. Several publications have been translated and/or reprinted due to demand. (Annex C lists cs4fn publications.)

Issues/publications per year

	Magazines	Specials	Translations (T) Reprints (R) Videos
2008	cs4fn issue 7 cs4fn issue 8 Audio issue 1	The Magic of Computer Science, Artificial Intelligence book	
2009	cs4fn issue 9 cs4fn issue 10 Audio issue 2	The magic of computer science 2	The Magic of Computer Science (**T**-Welsh)
2010	cs4fn issue 11 cs4fn issue 12	"The women are here"	Magic Book 1 (**T**-German) Magic Book 2 (**T**-Italian) (activities on website-also **T** Portuguese, Slovenian) Artificial intelligence Book (**R**) Magic Book 2 (**R**)
2011	cs4fn issue 13 Audio issue 3 ee4fn issue 1	Artificial intelligence leaflet	**VIDEOS**: Why Faces are Special; Will Robots Take Over the World
2012	cs4fn issue 14 cs4fn issue 15 ee4fn issue 2	Artificial intelligence poster The Women are Here poster	AI leaflet (**T**-Italian) The Women are Here (**R**) Magic Book 2 (**R**)
2013	cs4fn issue 16 (tbd) Audio issue 4	Biology Loves Technology	Teacher activity pdfs (**T**-French, German, Russian)

Interest in the magazine has increased. To meet growth in demand, the magazine print run has increased from fewer than 5,000 for Issue 3 to 15,000 for Issue 7 in 2008 to 31,000 today. In addition, magazines are frequently downloaded from the website. In total, over 890,000 copies of cs4fn pdfs (magazines, specials and other resources) have been downloaded from the cs4fn website since 2008. (Downloads of pdfs are discussed in the next section; see Annex K for full details.)

The magazine is distributed (free) to 5,400 secondary schools in the UK and also to over 2,000 subscribers in the UK. Recipients include ICT teachers, as well as teachers of other subjects, school librarians and careers teachers. In addition to 'automatic' distribution to schools, copies are mailed in response to individuals' requests and particularly to teachers asking for class sets. Indication of demand for the magazine can be seen in these individual self-initiated requests in three issues across time, for example:

Issue	#Teachers/#Copies	#Students/#Copies
Issue 9	262 teachers/4,275 copies	228 students/279 copies
Issue 11	411 teachers/7,207 copies	458 students/503 copies
Issue 15	785teachers/10,970 copies	209 students/324 copies*

*Number of students went down since cs4fn put people on 2-year rather than indefinite subscriptions. In the final year before that policy, 643 students asked for 711 copies.

University partners also distribute the magazine directly; for example, 3,040 copies of Issue 15 were sent to 17 universities for their own distribution. In addition to the global reach of magazines available on the website, the physical magazine has been sent to subscribers in some 80 countries.

Publications were engaging and timely. For instance, even within just the first 24 hours after mailing of the May 2013 cs4fn special on computer science meeting biology research (*Biology Loves Technology*), 288 schools requested additional copies, adding up to approximately 9,800 extra copies to be used both in science and computing lessons (and art), for clubs and in libraries, across age groups from KS3 to KS% level. Early comments included: "*It's bound to create an interest in the subject area!*" and some observations pertaining to cs4fn publications more generally:

> "*Both IT and Science departments love the cs4fn magazines. They are very popular with pupils who always ask when the next one is due. This is undoubtedly because the articles are interesting and engaging – targeted very well at their target audience. The recent book on women in computing was very well received by staff and pupils. We look forward to your next publication!*"

> "*This book reflects the way our digitally native pupils learn: snapshots of information with a direct link to further detail via smart phones. The images contained within the book are fascinating and will no doubt be of interest to the art department as well. I have asked for enough copies to have a class set, so they can be of use to whole class teaching in the science department.*"

Reader Satisfaction

Teachers are enthusiastic about the magazine. (Annex D provides samples of teacher comments.) In a survey of teachers conducted in 2012, for example, 98% rated the cs4fn magazine as either "excellent" or "good". 77% agreed that they could use articles or ideas from cs4fn in their lessons.

> "*This has to be THE most inspired bit of literature/content for getting youngsters switched on to computer science!*"

> "*The magazines provide a fun, but informative way of putting Computing into perspective with real life.*"

Interestingly, comments from teachers about the magazines tend to be positive not just in relation to Computer Science, but to broader interdisciplinary learning and even general literacy as well.

- *"I came across issue 7 for the first time and I am very impressed by the content and context. I think this would be of great interest to our computing, multimedia and art students."*

- *"I am teaching some first year student the basics of ethics and IT so these would make a great workshop activity"*

- *(Copies will be used) "in order to offer our students an alternative to fiction/non-fiction books … They will also be used in English when studying a range of text types."*

- *An interesting resource to promote literacy within subject area (more reading required)"*

Not only do teachers themselves see students reading and enjoying the magazines, comments received from students consistently show their appreciation. A sample of student feedback comments includes:

- *"I'm interested in a career in Software Engineering, and when I picked up your magazine in our library my mind went into overdrive. Everything is so exciting and fun! The magazine also has a great layout and is a pleasure to read."*

- *I have recently read your first annual and was captivated by the subjects that were covered and I would like a few other issues to build on the knowledge and read more about Sodarace and the advances being made in AI."*

- *"It was recommended by my ICT teacher as I have a big focus on computer science for a career."*

- *"This magazine … It's simply awesome."*

Vignette: An Issue dedicated to Women in Computer Science

Curzon, P., Black, J., Myketiak, C., McOwan, P.W. & Shoop, K (Eds.) (2010) *The Women are Here*, cs4fn: Computer Science for Fun Annual, 2, Queen Mary, University of London.

In 2010 cs4fn focused its efforts to engage diverse students by developing a special 60-page booklet capturing stories of roles played by historical and contemporary women including current students in a variety of areas of computer science. This booklet collected stories from across past issues of cs4fn and included new purpose-written stories, with the intent of reaching female students at a formative age with role models demonstrating various attractive career options in computer science. With 60 glossy, full-colour A4 pages bound in paperback style, the book's sheer size and weight underscored the calibre and range of women's (current and potential) contributions to computer science. Initially, 11,774 copies were distributed as: two copies to each UK secondary school (one to the ICT subject leader and one to the library), local schools' career teachers, and then copies to teachers in the UK who had subscribed to the magazine via the cs4fn website (from 1-50 copies each). Three times the usual number of teachers contacted cs4fn to request more copies. Some planned to keep several copies in the library; some gave out sets to students in a class or even an entire year group; some planned to use the booklet in workshops or themed days planned as part of larger recruitment strategies for girls in computing. Some teacher comments referred to girls' interest in the booklet; hopes that the booklet would counter girls' view of computing as a male field; and usefulness of the booklet in reinforcing girls' interest and self-confidence. The mailing also generated some 30 expressions of interest specifically for a "women in computing" talk. In addition, the cs4fn team gave away copies during school visits and events; the booklet works as a complement to outreach events and also as a stand-alone resource. The first printing, supported by both the cs4fn grant and the Westfield Trust affiliated with QMUL, generated 15,000 copies; the high demand led to cs4fn supporting a second printing of 4,000 copies. In 2010 alone, the year of publication, the online pdf version was downloaded 52,680 times and overall has now been downloaded over 75,000 times. Analysis of the usefulness of providing role model examples in a free print publication has been published by the team (Black et al., 2011).

3.2 Website

Content

The cs4fn website www.cs4fn.org contains hundreds of articles, the pdfs of the magazine, numerous articles and more. It also embodies cs4fn's characteristic emphasis on "fun" with, for example, interactive elements, a maze created out of links between articles and competitions. Articles on the website have been structured so that they can be accessed via "portals" acting as entry points for people with different interests; some portals are based on computer science topics (e.g. computer vision www.cs4fn.org/vision/), some are based on subjects (e.g. audio engineering at www.cs4fn.org/music/), regional portals and "fun" portals (e.g. games www.cs4fn.org/games/). The team more than met its target in terms of numbers of portals, albeit the kind of portal developed evolved slightly differently than envisaged at the start, with fewer topic portals and more regional and other portals (e.g. Women in Computing, Teachers, Scotland, Magic, Mathematical Magic, German magic, etc.). An emphasis was placed on interaction, for example with new interactive applets (e.g. The Face www.cs4fn.org/programming/face/) and some articles with interactive elements (e.g. Hampton Court maze www.cs4fn.org/maze.html). Support has also been added for social media, including an RSS news feed, a Twitter account with nearly 800 followers and easy links for sharing pages via various social networking sites. cs4fn audience members can also engage via do-it-at-home computer science magic tricks, a Teleporting Robot Jigsaw, and so on.

Use

Between 2008 and the present, the website has received over a million visits (1,155,521 as of mid-June 2013). Visits peaked in 2010-11 (for a variety of reasons including the extreme popularity of *The Women are Here* booklet published in 2010 and available on the website, exhibits at major science shows and a push to do a large number of school shows). They were at their lowest in 2011-12, and have climbed a little in 2012-13, although not quite as high as the first year. Interestingly, engagement of visitors in the site appears to be getting deeper. In 2008, 8% of visitors stayed on the site for three minutes or more; now 12% do so, one and a half times as many. Return visits have more than doubled, from 6% in 2008 to 13% today.

Website use

YEAR	# Visits	Some Engagement % of Visits	Deep Engagement % of Visits	Returning Visitors #/ % of Visits
2008-9	205,392	11	8	12,917 /6%
2009-10	279,392	11	9	29,081 /10%
2010-11	306,316	10	8	25,837 /8%
2011-12	175,161	11	11	22,541 /13%
2012-13	189,260	11	12	24,275 /13%

No Engagement: 30 seconds or less on site;
Some Engagement: 30 seconds to 3 minutes on site;
Deep Engagement: three minutes or more on site

pdf downloads: Clearly, deeper interest is indicated when individuals take the trouble to actively download something from the website. Full details of downloads are given in Annex

K. Overall, since 2008, pdfs have been downloaded 890,000 times. In 2012 alone, the last full year of the project, 138,000 pdfs were downloaded.

Downloads of magazines tend to peak in the year they are published but downloads continue to be strong thereafter. The original issue of the magazine from 2005 has, for example, been downloaded 48,500 times since 2008. As other examples, between April 2008 and April 2012, the average monthly download of Issue 8 (on Space) was 293 and that of Issue 9 (Environment) was 297.

Magazines focusing explicitly on interdisciplinary topics have been particularly strong. Apart from Issue 1, the two issues with most downloads in the period have been Issue 7 (*CS and Art*) with 40,200 downloads and cs4fn Issue 8 (*CS and Space*) with 45,800 downloads. This would seem to validate the emphasis on interdisciplinary computing by the team rather than restricting the project to pure computer science.

The specials have also been extremely popular in terms of downloads with the *Women are Here* booklet having 75,600 downloads, *Magic Book 1* having 245,000 downloads and *Magic Book 2*, 92,000 downloads. Three thousand people downloaded the pdf of the second Magic of Computer Science book in just the first three months after it was put on the website in February 2009. This also extends to the translations of specials. For example, *Magic Book 1* in German has had 24,000 downloads and *Magic Book 2* in Italian, 17,000 downloads.

The online resources specifically for teachers rather than students have similarly been popular, if on a smaller scale. In particular, the sheets describing activities done in shows for teachers to try have thousands of downloads each, especially: the *Intelligent Paper* activity (9,400 downloads); the *Create a Face* activity (8,000 downloads) and *Brain in A Bag* (5,000 downloads).

Impact of website: A website questionnaire running since 2008 has generated between 1,234 and 1,261 answers to each of seven questions; all questions were answered in strongly positive ways. (Annex E) The website is well-liked: half (50%) think the cs4fn website is excellent, with another 37% seeing it as good; similarly 85% of respondents either strongly agreed (47%) or agreed (38%) that they found the website useful / relevant / informative and 85% enjoyed the cs4fn website (50% strongly agreeing, 35% agreeing). Slightly fewer (80%) found the cs4fn website simple and easy to use. Particularly interesting is the majority of positive responses to questions about influences felt relative to cs4fn's particular aims:

Perceived Use and Influence of cs4fn Website

Question	Total % Positive	Strongly Agree	Agree	N
The website has helped me see more ways in which CS is applied or used in the real world	77%	47%	30%	1242
I think of CS as more interesting than I did before coming to the cs4fn website	59%	24%	35%	1243
The website has helped me think of a variety of careers that would use computer science.	59%	22%	37%	1236

Responses to the last question are especially interesting given that cs4fn articles do not directly describe careers in computing. Clearly people see the possibilities, even though the magazine instead focuses on research and presenting topics in fun ways.

3.3 School Visits / Events

Description, School Visits

The cs4fn team has given talks to nearly 20,000 school students in some 270 visits to schools and universities, with some repeat talks given on schools' requests, and has reached a further 10-15,000 at various science festivals. Audiences are a mixture of ages ranging from 10 to 18 years, including primary and secondary school and sixth form; students have been ethnically diverse and the visits have reached more female students than would typically attend a computer science talk.

cs4fn School Talks

Year	People	Talks	Schools/events
2008-2009	2441	38	36
2009-2010	3351	50	40
2010-2011	6368	81	57
2011-2012	3946	49	38
2012-1013	3838	53	46
Total	19,944	271	217

Various indicators show that school visits/shows are popular. Team members' logs reflect on what worked well and what didn't, with most noting real enthusiasm in many audience members. Post-event questionnaires, observations by teacher-hosts and comments from pupils all indicate enthusiasm for the style and content of talks/visits. Clearly, some students have been genuinely influenced by these visits:

> *"I was part of the year 9's that you lectured about artificial intelligence a couple of months ago. Would just like to say that I love your work, and that you're an inspiration to me. Thank you for coming into the school, Professor."*
>
> (An unsolicited email received by Paul Curzon on 4 May 2013)

Feedback from students of all ages has been very positive about these events. Student enthusiasm is indicated by just a few examples of comments on artificial intelligence talks.

Artificial Intelligence Workshop for Primary Schools – post-event student feedback

"The best day at school ever!!! p.s. SUPER COOL!!!"

"I really like how you explained it and I thoroughly enjoyed it and I hope you come again"

"I enjoyed making the brain out of wire and toilet roll and how we made the face"

"The thing that I enjoyed (about) is learning about the brain"

**Artificial Intelligence show for Gifted and Talented Students
– post-event student feedback**

"…not just thinking out of the box - tearing it up"

http://www.cs4fn.org/project/feedback/

Teachers, too, appreciate the visits. 100% of teachers surveyed after cs4fn visits to their schools said that the talk had met their needs and 100% said they would recommend cs4fn to other teachers. A more recent issue with the advent of new computing courses in schools is the need for teachers to attract students to them. This has been a common reason for teachers engaging with cs4fn and teacher feedback suggests cs4fn does support them in this: 71*%* of teachers responding to the survey agreed that as a result of a cs4fn lecture one or more students is now likely to consider taking computer subjects further at school. (Of course, some groups had already chosen their subjects before the visits.) More than half (59%) agreed that one or more students became more interested in taking science and engineering more generally, an influence beyond Computer Science alone. Given that an original driver of EPSRC funding was the UK's need for more students, it is worth noting that 79% of teachers agreed that as a result of the lecture one or more students is now more likely to consider taking computer science at university; indeed 29% strongly agreed. Only one teacher disagreed. Annex F provides more detail on results of the post-visit teacher surveys 2010-2012.

> *"I am sorting the Sixth Form options for next academic year at the moment and there has been an explosion of interest"* (a teacher after a cs4fn school talk)

Other events

The cs4fn team has presented at a variety of Science Festivals (28 during the EPSRC funding period), including the Royal Society Summer Exhibition (twice), the British Science Festival (four times), the Brighton Science Festival (five times), and the Manchester Science Festival (twice), as well as contributing internationally to the Genoa Science Festival (three times). (Annex G gives an illustrative though not exhaustive list.) The team has also given numerous other major workshops and shows around the UK, many in collaboration with local universities or the National "Computing at Schools" group. Pictures and positive comments appear in attendees' blogs, a good sign that even more individuals are struck by the fun nature of cs4fn presentations.

3.4 Teacher Support

Despite its focus on students, cs4fn has also provided support directly to teachers. These include the magazines as resources; since stories are based on contemporary research, teachers as well as students can learn from them. A special teachers' portal was created on the website in 2010 www.cs4fn.org/teachers/ . The portal is clearly being used: in the last year the portal page had 3054 page views and the page listing cs4fn teacher resources specifically for teachers www.cs4fn.org/teachers/activities/index.php had 2392 page views. As noted already, downloads of activity sheets for teachers is strong, with 7 sheets being downloaded over 44,000 times in total.

When the team gives shows and lectures to students, teachers normally attend and feedback suggests that they too can benefit, even though they might be presumed to be a critical audience. For example, one teacher commented on a post-talk questionnaire:

> *"After the lecture, one member of staff said that his teaching method was inspiring"*.

The team also gives invited talks at conferences and inset day workshops specifically for teachers. These invitations have been largely as a result of word-of-mouth and due to teachers' seeing cs4fn talks – invitations have come not only from computing / ICT teachers but also, more broadly, science and mathematics teachers, e.g. Head of Science workshops. Feedback has been very positive throughout. (An illustrative but not exhaustive list of over 20 talks is provided in Annex H.*)*

In spring 2013, QMUL awarded an Innovation grant to the cs4fn team to conduct CPD short courses (Programming and more: CPD for GCSE Computing) for teachers who are participating in the national shift from IT to Computer Science teaching. This led to the team being awarded a major grant to support computing teachers in London over the next 2 years from the Greater London Authority.

3.5 Reach of cs4fn

UK Breadth

Through its magazines, school visits, festivals/events and teacher training efforts, cs4fn has developed a UK-wide reach. One view of this breadth of access can be seen through distribution of the magazine across UK postcodes. (Annex I)

International Reach

The reach of cs4fn is international, not only through subscribers from more than 80 countries receiving physical copies of the magazine, but of course particularly through its website:

Top ten sources of website hits

1.	United States	353,052
2.	United Kingdom	257,016
3.	India	82,763
4.	Canada	45,914
5.	Germany	27,095
6.	Australia	26,428
7.	Philippines	23,130
8.	Brazil	15,716
9.	Italy	14,304
10.	Poland	13,303

Compiled between 1 April 2008 and 4 October 2013

Also, since 1 April 2008, Google Analytics counts: 1,227,662 total visits; 1,102,741 unique visitors; and 2,456,855 page views.

Various resources have been translated into French, German, Russian, Italian, Welsh, Portuguese and Slovenian. Some of this was specifically funded by external organisations. For example, in 2013 and 2014, Google sponsored the translation of four of cs4fn's teacher activities into French, German and Russian, enabling teachers elsewhere in Europe to teach the fundamentals of CS using resources already proven to be successful, in line with Google's goal of connecting students and teachers with the best in CS resources, across borders. Through "Teaching Enquiry with Mysteries Incorporated" (TEMI), a new EU grant led by Peter McOwan, the general cs4fn approach will continue to influence teachers in eleven countries (described further as Enduring Connectivity impact, below.)

Diversity Reached by Visits

The team has given talks to year groups, to primary school groups (Year 5 and 6) and secondary school groups (Y7 to Y13). Groups reached have ranged from "gifted" to "difficult" students, and in between. Schools have ranged from fee-paying schools to state schools in underprivileged areas. Estimating ethnic composition of groups visited was not an exact science for very busy presenters, who only did so for about half of their visits; and quick descriptors, e.g. "mainly" or "mostly" make precise tallying impossible. However, even erring

on the side of underestimation, it is clear the cs4fn talks reached an ethnically diverse audience. So, for example, in the set of 152 visit audiences for which there was a description, 47% (62) were described simply as "Mixed". Of the remaining 90 audiences, over a third (37%, or 33) were described as being at least a third (sometimes far more) non-white. Only 16% of the 90 audiences were described definitely as nearly all white, meaning that, in the rest of the audiences, some unknown but significant percentages of students were non-white. While, similarly, busy presenters did not conduct precise counts of audience members of either gender, data on 185 visits indicate that girls as well as boys were reached by cs4fn. Of all the audiences, 32 were made up of 'all boys' and another thirty or so audiences were mixed but weighted toward boys. By contrast, some 37 classes were 'all girls', with one other talk's audience consisting of two-thirds girls. Nearly two-thirds (63%) of all the audiences were described as 'mixed' in gender (92 classes) or 'mixed 50%' (24 classes). Thus, a significant proportion of audiences for cs4fn talks has been female - much closer to an even split than typical participation rates in computing.

3.6 Partnerships and Leverage

From 2008, the year in which EPSRC funding began for cs4fn, through 2013, Google has provided financial support to cs4fn as part of its CS4HS (Computer Science for High School) programme for Europe, the Middle East and Africa. Google awards have, for example, supported distribution of full class sets, travel for activities around the UK and translation. From 2008 to the present, Google has provided £120,580. Although donation amounts have decreased significantly since the original "bumper" year of 2008, in which Google provided £37,983 (the largest such donation they made that year), the consistency with which Google has provided support each year suggests sustained appreciation of cs4fn's efforts. Across years 2010-2012, the Genoa Science Festival has provided over £10,000 to support cs4fn participation in the festival. In addition, a number of schools have given voluntary donations and some other universities or organisations have paid for cs4fn providing local talks. For example, in the summer of 2013 Newcastle and Teesside universities covered costs for a cs4fn's teacher CPD talk at events they organised. In addition, the cs4fn grant led to leveraging of some additional funding from internal QMUL schemes, notably the Westfield Trust for the Women in Computing Special and initiating the ee4fn magazine series (£15,000) and the Innovation Fund to support Teacher CPD (£10,000). Furthermore, a series of EPSRC research grants have included funds for public engagement activities through the cs4fn framework, as a part of the department's recent public engagement strategy.

Consistent with cs4fn's focus on public engagement for the subject of computer science, rather than institutional recruitment specific to one institution, the EPSRC-funded phase of cs4fn allowed it to spread its reach, in part through expanding partnerships with other universities and bodies. While one of its original targets, to significantly increase magazine materials submitted by researchers in other institutions, was not fully achieved (although some colleagues did submit ideas and occasionally draft articles that were then edited by the cs4fn team), and only a small number submitted articles in a suitable format needing only minor editing, nonetheless cs4fn did contribute to others' outreach strategy, another target. Contributions took the form of:
• Increasing numbers of computing-related departments using cs4fn material in their own public engagement programmes (e.g. partner universities of: Birmingham, Bristol, Dundee, Edinburgh, Essex, Glasgow, Hull, Manchester, Oxford, Swansea). Overseas universities also use the materials (e.g. Siena College, Calvin College, Auburn University and Purdue University in the US, Universitat Passau and Universitat Erlangen-Nurnberg in Germany, University of Calgary in Canada, and Universitetet i Bergen in Norway).

- Talks given by the cs4fn team to support local engagement activity of other universities (e.g. Universities of Aberystwyth, Bangor, Cardiff, Dundee, Glamorgan, Glasgow, Leeds, Manchester, Swansea, Newcastle, Teesside).
- Invited talks to academics about the cs4fn approach to public engagement (e.g. at the Open University and the Universities of Durham, Glasgow, Kent, Newcastle and Manchester).

3.7 Sharing of Lessons Learned

The cs4fn team has continuously reflected upon and shared lessons learned about public engagement in computer science. In some cases this has taken the form of peer-reviewed academic presentations, workshops and articles related to international computer science education, including papers and workshops at "the ACM International Conference on Innovation and Technology in Computer Science Education (ITiCSE)" where Paul Curzon also gave an invited keynote in 2007, "Informatics Education Europe" and "The ACM Technical Symposium on Computer Science Education (SIGCSE)". This sort of sharing is complemented by the team's many presentations to educators regarding lessons learned as to novel good practices. Annex J provides a list of presentations to educators and related academic publications.

4. Impacts

4.1 Overview of Impacts and Impact Identification

Even beyond accomplishments, it is possible to identify a sheaf of impacts that can be harvested from cs4fn. Because impacts, and impacts-in-progress, can vary widely, it is useful to think in terms of a portfolio of different categories of impacts that an initiative can generate. For example, three conventionally recognised categories of non-academic impacts of research are: conceptual impacts (influences on knowledge, understanding, attitudes), instrumental impacts (more tangible "use") and capacity-building impacts (developing abilities) (Nutley et al. 2007, p.36); to these in other impact evaluation work the evaluator has added "enduring connectivity" (when individuals stay in touch beyond the funded project) and "attitude/culture change" (the latter usually in relation to knowledge exchange). (Meagher et al, 2008) As a parallel to impact categories generated by research, here we will consider the science outreach impacts identified by the team and the evaluator, and group these impacts under similar categories. (Team members discussed impacts both in focus groups as part of retreats facilitated by the evaluator and in individual semi-structured interviews conducted by the evaluator, who also conducted this analysis, in conjunction with other interviews, case studies and document analysis.) While any placement of entries into categories is inherently a matter of judgement, and often any one impact could fit into more than one category, this framework makes it relatively straightforward to capture and convey diverse, often subtle impacts.

Portfolio of cs4fn Impacts, by Category
(C=Conceptual, I=Instrumental, CB=Capacity-building,
EC=Enduring Connectivity, A/C=Attitude/Culture Change)

Impact	C	I	CB	EC	A/C
Primarily Conceptual Impacts					
More positive perception of CS, CS studies by students	X				
"Zeitgeist" change to recognition of fun, intellectual side of CS	X			(X)	
Primarily Instrumental Impacts					
Resources used by teachers/students (magazine, web, books)		X	(X)	(X)	
Contributions to policy/curriculum changes	(X)	X			
Influence on teachers/teaching practice		X	(X)		
Spinouts		X			
Primarily Capacity-building Impacts					
Influence on teachers, e.g. enhancement of teachers' learning through magazines, website, visits	(X)		X		
International sharing with teachers, science outreach efforts			X	(X)	
Mentoring Next-generation researchers			X	(X)	
Primarily Enduring Connectivity (Onward effects)					
Sharing with university colleagues		(X)	(X)	X	
Sharing with teachers, related organisations		(X)	(X)	X	
Sharing with other PE/outreach efforts		(X)	(X)	X	
Distinctive Dissemination	(X)	(X)		X	
Primarily Attitude/Culture Change (toward science outreach)					
Institutional change, QMUL					X

Each of these kinds of project impacts is explored in detail in the following sections.

4.2 Conceptual Impacts

Indicators of Impacts on Students: Conceptual impacts, in which new ideas, new possibilities and new ways of viewing a topic are absorbed internally by individuals, are inevitably subtle and elusive; while deeply significant, they are difficult if not impossible to capture in tangible ways. Yet, conceptual (sometimes called 'enlightenment') impacts are key aims of cs4fn, as it hopes to change students' ways of viewing computer science/natural sciences and potential careers. Unfortunately, the obvious 'ideal' way to capture long-term influences of cs4fn on students – following from school days through university choices those individual students who interacted with the magazine, the website or class visits – was not possible. Data confidentiality laws preclude longitudinal studies of individual students, or indeed even targeted follow-up inquiries. Neither could schools/teachers provide us with such information. As is often the case with analysis of conceptual impacts, we instead consider several different relevant "indicators", giving us confidence through triangulation:

1) retrospectively, influence of early cs4fn on QMUL recruitment in CS;
2) a survey of a sample of students who did choose to study CS (at QMUL);
3) a post-lecture survey of teachers and
4) UK-wide student and teacher comments regarding influence or impact, derived from multiple sources.

The first two indicators of necessity are based in data which could be obtained from the host university, QMUL. While these indicators may be elevated by students' engagement with the QMUL-based academic leads for cs4fn, they may well still suggest the direction of travel of cs4fn influence more generally. The last, broad-based category of indicators arises from several surveys, teacher interviews, unsolicited comments from pupils and their teachers, and team members' logs of comments/reactions (just a few examples will be given here).

While primarily occurring before the EPSRC support of cs4fn, it is worth noting that, in a time of general UK-wide concern over low numbers of applications to study computer science, cs4fn appeared to contribute significantly to success of recruitment efforts for QMUL's Department of Computer Science. This is a specific case of impact on student interest in pursuing computer science, which might be illustrative of a more general conceptual impact among students more generally, albeit one too elusive to capture given inability to follow individual pupils longitudinally.

As a 'tracing-backward' method, a survey was conducted (December 2010) of first-year undergraduates studying computer science-related courses at QMUL, during a break in a lecture for the required first year programming module. About a fifth (18 students, or 19%) of those 94 students completing the survey (in a class of 167) had heard of cs4fn before coming to QMUL. Over half had enjoyed reading articles from the magazine and over half had enjoyed reading articles from the website. Of the students who had heard of cs4fn before university, 61% felt that "cs4fn has to some extent led to me being more positive about computer science" and indeed 44% (8 students) agreed that "cs4fn encouraged me in some way in my decision to take a computer science related course at University". Thus, at the least, 5% of the whole first-year intake at QMUL were encouraged by cs4fn to take computer science. This suggests that some other students elsewhere who experienced cs4fn were similarly influenced, although proving this would have been intractable.

Arguably, teachers are the best sources of informed overviews as to what captures multiple students' imagination and changes their view of a subject. So, for example, interviews of teachers who had hosted school visits by cs4fn provoked observations such as

> "Paul's visits are fantastic! They have opened up opportunities for the students that they didn't know existed. … I've got a lot more pupils who are interested now in talking about it (CS) and asking more questions …. I would estimate that 5-6% of the students are looking in that direction (after the school visit)… Students are asking questions. For example, on Options Evening, pupils are now asking 'How about if I want to do Computer Science?' I never got that before! They now realise that that option exists".

Another teacher, when interviewed, reflected:

> "We as teachers try to give something beyond, and stretch the pupil. cs4fn really does that. It enthuses kids, a lot more than could be done in a regular classroom. It focuses them on certain aspects of ICT they could get interested in, maybe at University and beyond. It seems to tie all the possibilities together with the students."

This teacher cited an example:

> "During Paul's first visit, he mentioned the computer animation competition at the University of Manchester. Our school submitted three entries and won in two categories! So, three students went from having not much interest in IT to winning a national competition – a direct result of Paul's visit."

In a relatively small (n=30) survey of teachers' views following cs4fn visits, all (with most strongly agreeing rather than just agreeing) felt that 'the students enjoyed the lecture'; 'the students found the lecture interesting'; and 'the lecture improved the understanding of the students'. While not surprisingly seen by fewer teachers and with the number of those agreeing almost equal to those strongly agreeing, nonetheless 25/30 host teachers saw the more subtle and potentially far-reaching impact of 'some students have changed their view of computer science in a positive way'. Indeed, in terms of follow-on influence, 22 teachers felt that, as a result of the lecture, one or more students is now more likely to take Computer Science at university. (And in addition a broader influence is suggested by the fact that 20 teachers feel that one or more would be more likely to pursue Science, Engineering or Maths at university.) In free text feedback regarding the 'best things' about the lecture, comments were extremely complimentary. One teacher's favourite thing was

> "just the fact that it opened their eyes to computing as being something that they should consider".

Another reflected,

> "With this approach students become inspired to look at a new area of potential study. In schools we are constantly trying to broaden the students' understanding and appreciation of the many routes they can take into higher education. The computer science talk model is the best way I have come across so far".

While positive comments were received from teachers (in interviews, the post-event survey, etc.) regarding the applicability of visits to multiple grade levels, suggesting a wide-ranging relevance of cs4fn, some tactical issues were raised as to timing relative to key exams and choice of university subjects. (School visits to 6th formers come too late to influence subject choice, for example.)

Indicators of impacts on teachers as well as students: A web-based survey of users of the cs4fn website has been running since 2008, with a total of 1,261 respondents (ANNEX E). While some questions had to do with the website *per se* (usefulness, etc.), three in particular shed light on conceptual impacts of cs4fn:

1) seeing more ways in which computer science is applied or used;
2) thinking of computer science as more interesting;
3) thinking of a variety of careers that would use computer science.

Whether considering all respondents, pre-university students, or primary/secondary teachers, the cs4fn website has clearly contributed to new understanding and ways of viewing computer science. Across type of respondent and for all questions, more than half responded positively. The highest percentages of agreement were found with "the website has helped me see more ways in which computer science is applied or used in the real world"; interestingly 80% of teachers, as well as 73% of students felt this, suggesting that the website (and magazine articles posted thereon) provided teachers as well as students with new understanding. Similarly, well over half of both teachers (60%) and students (64%) were enlightened as to the range of possible computer science-based careers that exist. Given that individuals coming to the site were likely to have some degree of interest in computer science already, it is noteworthy that the website enhanced the interest level of over half the respondents (55% teachers, 61% students).

Percentages Strongly Agreeing or Agreeing

Question	Total (N=1236-1243)	Pre-University students (N=217-223)	Primary/secondary Teachers (N=249-250)
A-more ways used	77%	73%	80%
B-more interesting	59%	61%	55%
C-varied careers	59%	64%	60%

Question A: The website has helped me see more ways in which computer science is applied or used in the real world.
Question B: I think of computer science as more interesting than I did before coming to the cs4fn website.
Question C: The website has helped me think of a variety of careers that would use computer science.
(Detailed analysis of the first few months of this survey can be found in Curzon et al., 2009.)

Other aspects of changes in teachers' own professional views of computer science and how it can best be appreciated are captured under Capacity-building Impacts, discussed below. However, it is worth noting here that some teacher comments from post-talk surveys are suggestive in terms of influence on teaching *approaches*, even though most ICT teacher respondents felt knowledgeable about computer science themselves. For example, one commented

"*It has made me more enthusiastic toward delivering ICT*"

and another, self-described as "a previous convert" still noted that

"*Other staff in my department (non-specialists) now have a deeper understanding of what CS is*".

Clearly changes of this sort within teachers could have follow-on influences on their students.

"Zeitgeist": Reshaping Views of Computer Science and its Teaching: Perhaps the most elusive of conceptual impacts is that of influence on emergence of a new 'zeitgeist', or broad

conceptual change, yet clearly this can be of far-reaching importance. An expert focus group considering this challenge at the end of a formal evaluation of non-academic impacts of a large research programme suggested several aspects to consider, even though absolute attribution of causality would be impossible, for example:

"1) Timing and dynamics – if a 'wave' is already cresting, an initiative can probably ride it whereas if the initiative is there at the beginning you can probably say it contributed the greater influence;

2) Evidence of engagement with key people – either face to face or via ideas, to show there is influence, looking at activities and relationship to a zeitgeist

3) What stakeholders themselves think – if there is a consensus that someone or some work is a source of influence, you probably have to rely on that.…"

(Meagher, Laura. 2012. *Societal and Economic Impact Evaluation Relu, Part Two.* Report to ESRC, www.esrc.ac.uk).

Even prior to their launch of cs4fn in 2005, PIs Curzon and McOwan had been actively working for some time toward a re-shaping of the perception of what computer science is, spotting early on the need for innovative approaches to interesting students in the subject. (To underscore this timing relative to the emergence of a zeitgeist change in terms of how the teaching of computer science was being viewed, cs4fn was one of just three outreach examples noted (and commended) by reviewers in *International Perceptions of the UK Research Base in Information and Communications Technologies* (December 2006) (http://www.epsrc.ac.uk/SiteCollectionDocuments/Publications/reports/ICTIntReviewReportV2.pdf)**,** and it wasn't until August 2008 that a "Computing for the Next Generation" group developed a *Rationale for a GCSE in Computing* (http://www.computingatschool.org.uk/data/uploads/GCSERationale.pdf). In November 2009, the report of the Computing at School Working Group, in *Computing at School, the state of the nation*, cited cs4fn as "a major activity", an example of "exciting and innovative work going on" under the subtitle "Guerilla outreach" (p.13 http://www.computingatschool.org.uk/data/uploads/CAS_UKCRC_report.pdf) In April 2010, EPSRC held a national workshop "ExICTe-Igniting enthusiasm for ICT" as "a valuable means of sharing first hand experiences and a necessary preliminary activity in raising the profile of ICT"; cs4fn PI Curzon was an invited speaker. (http://www.epsrc.ac.uk/SiteCollectionDocuments/Publications/reports/ICTIntReviewReportV2.pdf)

Thus cs4fn began early to act as a "brand" exemplifying a vision of computer science as multi-faceted and intellectually fun or compelling, and encouraging engagement with it as a dynamic subject with multiple opportunities for application. This vision and approach have been shared consistently over the years, not only through cs4fn's widely available magazines and website, but also through a wide range of events (e.g. shows, workshops, teacher education events as noted in Annexes F, G, H, J) at which key individuals including teachers, academics and policymakers became familiar with cs4fn's underlying message. As one of the cs4fn PIs describes it, there has been a significant change in views of computer science to seeing it as having intellectual depth and potential for creativity – "Moving beyond 'it's just about the technology and the programming' to 'it's about the creativity'" – and that cs4fn has contributed:

"It's a fairly strong thing we've been able to do; it ties in with the magic … and telling stories about computer science … real people doing really cool stuff. … I think that was actually a pretty useful thing cs4fn gave the world, in a way that we constantly reinforced, so people are paying attention to those sorts of things in a way they hadn't previously."

In addition, the team (in particular McOwan, and Curzon, both founding members) contributed to the development of Computing at Schools, an organisation supporting teachers of Computer Science. The recent shift in educational policy such that Computer

Science is differentiated clearly from ICT classes is certainly aligned with the messages of cs4fn over these years.

Outside of the cs4fn team, interviewees with deep experience and informed overviews reflected on the difficult question of intangible contribution by cs4fn to the change in zeitgeist that has occurred. So, for example, a now-retired teacher/head of department observed that

> "*My take on cs4fn is that it actually provides a foundation that with other things has actually moved the subject to where it needs to be, in an innovative and attractive and fun way – part of the jigsaw putting pieces together to move the subject to where it needs to be in the 21st century*". "*What (the) material did, was that it came along at the right time when people were beginning to question if the IT curriculum had run its course and it was time to rebalance the curriculum so that it included three strands – IT, digital literacy and computer science. … So it sort of was part of the momentum … illustrating that you could do a lot of Computer Science unplugged from the computer, that there was more to it than programming or keyboard skills or office software. … It (cs4fn) was part of the mosaic, part of the background one needed to be able to say that the IT curriculum was not right (because) it didn't actually show that Computer Science is broader.*" … (cs4fn provided) "*accessibility to the richness of the discipline*" … "*So, cs4fn definitely contributed to the tapestry, the background ending in change to the national curriculum, rebalancing the curriculum so that Computer Science features in the 5-16 curriculum which it hadn't done until this recent change.*"

Another individual with an overview, an academic with high-level input into curriculum policy changes, when asked about zeitgeist changes, acknowledging that it is a "complicated and fuzzy picture" with multiple strands, described the time in which

> "*teaching under the auspices of the national curriculum was seen as increasingly disengaging to pupils. ICT over ten years was seen as the use of technology and general skills rather than anything you'd describe as Computer Science. … There was a multi-pronged response. cs4fn was one of the more visible and best-known responses … (it) was the most visible of the university-led activities in this space*". "*It is fair to say that cs4fn was one of the threads helping to bring about change. It was certainly a significant component of a process raising awareness in schools of the desirability of a change.*" …. *You can see (that awareness) in the growth of membership of the grassroots organisation CAS. … cs4fn magazines will have had a significant role in preparing the ground. … At the time it was around, it was important for it to be around. And it was one of the first University-led initiatives to try to do something to help computer science at schools.*" The interviewee followed praise for the cs4fn magazines and live talks by saying: "*My sense is that there is enormous respect across the UK computing community … I personally have a lot of respect for what they've done. And them doing it has caused a lot of people to say 'that's great; what can we do?' --- a kind of zeitgeist influence. .. cs4fn does what it does. There is no point in anyone trying to improve on it, but it has given motivation to others to think what they could do alongside that.*" This interviewee noted that, as the context for computer science education appears to be in the process of changing very significantly, "*therefore the future of cs4fn will have to accommodate that in some way. But they played a huge role in the process to date*".

4.3 Instrumental Impacts

Instrumental impacts of cs4fn take different forms, including: development of widely used products; contribution to policy change; influence on teachers/teaching practice; development of widely used magazines/other publications/website; and spinouts.

Production of Resources: As noted earlier, cs4fn has generated numerous tangible outputs (16 cs4fn magazines, 4 Audio magazines, 2 ee4fn magazines, five additional products including magic books, and a comprehensive website) which remain available as physical and electronic resources for students, teachers and others to generate continuing impacts.

Policy/curriculum change: Even though cs4fn was deliberately created so as to, in a fun and engaging way, *complement* classroom teaching, rather than serve as a formal component, it still appears to have made a contribution to the recent significant policy (and practice) shift toward re-conceptualising the way in which computer science is taught within the curriculum. So, for example, in the policy document generated by the Computing at School Working Group in March 2012, "Computer Science as a school subject: Seizing the Opportunity", cs4fn was cited to allay potential fears that teachers would be unable to teach the subject: noting that "fantastic free teaching resources are available", within which "The cs4fn site is a treasure trove of puzzles and stories all with a computer science theme.") (p.15 http://www.computingatschool.org.uk/data/uploads/Case%20for%20Computing.pdf) In terms of influencing teaching practice related to this shift, a copy of the cs4fn magazine was included in a "Strategic Information pack" sent by CAS in March 2012 to every head teacher of state-maintained English secondary schools as a reassuring example of "the wealth of high-quality material that is available to support computer science teaching". (http://www.computingatschool.org.uk/index.php?id=headteachers) CAS refers and links to cs4fn in its newsletters and invites the cs4fn team to give talks at its annual conferences. A 2010 report of the Computing at School Working Group for the UK Computing Research Committee cites cs4fn as an example of "exciting and innovative" work. (http://www.ukcrc.org.uk/resources/briefings/computing.cfm?type=pdf)

The "human vector" of instrumental influence should not be discounted; as noted above, both the cs4fn PI's, were founding members of the pro-active Computing at School organisation, (http://www.computingatschool.org.uk/) which as a "grassroots organisation" including teachers, governors, industry and university members, parents and professional societies), has become a vital force in shaping teaching practice and related policy. McOwan also served as a member of the BCS (The Chartered Institute for IT) Expert Panel generating the document "The case for Computer Science as an option in the English Baccalaureate" (2012) which continued the consolidation of a case for Computer Science to be considered a rigorous and vitally important discipline alongside, for example, Physics and History. (And cs4fn was cited in this report as creating "inspirational computer science related material" and thus helping to demonstrate "the breadth of support from the computing community" (p.25, 26 http://academy.bcs.org/sites/academy.bcs.org/files/Case%20for%20Computer%20Science%20as%20an%20EBacc%20option.pdf) McOwan was also a member of the BCS/Royal Academy of Engineering group generating the second draft of an ICT Programme of Study, November 2012 (http://www.computingatschool.org.uk/index.php?id=draft-ict-programme-of-study)

Influence on teachers/teaching practice: Through survey comments and post-event observations, numerous teachers have recognised an added value provided by cs4fn. Repeat invitations for school visits form one indicator of teachers' willingness to incorporate cs4fn into their offerings; another indicator is repeated requests for copies of the magazine and another indicator lies in the many visits to the teachers' portal on the cs4fn website. Informal comments following teacher CPD events suggest that teachers intend to try the activity in class themselves. Indeed, cs4fn was cited in a discussion of the importance of "enhancement and enrichment activities", or non-formal learning, in the Royal Society's 2012 report, Shut down or restart? The way forward for computing in UK schools (p.40, 47 http://royalsociety.org/uploadedFiles/Royal_Society_Content/education/policy/computing-in-schools/2012-01-12-Computing-in-Schools.pdf).

As an example of influence on teaching practice, an interviewed teacher was not only aware of himself and other schools using cs4fn activities such as the card method of demonstrating parity checking, magic and the demonstration of noughts and crosses algorithm ("*It certainly inspired me to make more use of props, cards and so on*"), but also used the magazines to

"*get students to engage in the subject and think of Computer Science as a career, with more possibilities*". Furthermore, cs4fn's ideas and "*huge amount of materials*" formed a foundation for informing a new stage of syllabus specifications. "*It would have taken me a lot longer to pull materials together.*" cs4fn was seen as providing teachers with "*a rich patchwork of connection with the academic world of Computer Science, but in a fun way*". An observation born of long experience affirms the cs4fn premise:

> "*One of the things that I've noticed over the years – I taught 14-16 and 16-18 year olds – is that enjoyment of the lessons' content and style of learning has a huge impact (on what the student goes on to do)*".

Insights into use of the magazine were gained by an analysis conducted on (optional) comments left by 167 teachers in online forms requesting subscription to the magazine. Uses for the magazine included: leaving copies in computing labs/ICT suites; giving copies to all students in a class; leaving a copy in the library; studying in home schools. Teachers also used the magazine for specific activities addressing particular classroom objectives, with many giving open-ended assignments allowing students to explore the magazine's computer science topics for themselves. Overall purposes for use of the magazine included not only enthusing others and generating interest, but also personal benefit and serving as a resource for teachers themselves. Diverse educational targets were cited, ranging from gifted and talented classes to "at risk"/behavioural problem classes. (Myketiak et al. 2012) As discussed under capacity-building impacts below, teachers and teacher groups continue to seek input from cs4fn.

Spinouts: The cs4fn initiative has generated spinout activity. The Scottish company Flummix is developing cs4fn material into workshops and a text, *The Conjurer's Classroom*, as resources for teachers. Another spinout has been the development of a creative new app.

In addition, other initiatives have taken up and shared cs4fn materials, captured below under "Enduring Connectivity" impacts. For example, cs4fn's "Intelligent Piece of Paper" activity has been included on the highly influential New Zealand CS Unplugged website and as a result was also later translated into Slovenian.

Vignette: A fun – and educational – app

"Tunetrace" is an innovative app arising from the cs4fn team and supported by ImpactQM (also funded by EPSRC), via QApps, QMUL's app development venture. Brainstorming by cs4fn's PI Peter McOwan and project manager Jonathan Black, along with BAFTA-winning collaborator Ed Burton, led to a new app created for iPhones and iPads, and free to download: Tunetrace turns photographs of real drawings into music. Supported with fun, easy classroom resources, the app (in addition to simple enjoyment) gives insight into computer programming. cs4fn PI and co-founder of QApps McOwan says "The drawing gives … instructions, the app applies its rules, and the music happens. Using this app you can easily explore the ideas behind computer programming by adding more to the drawing to change the tune". (www.qmul.ac.uk/media/news/items/se/99519.html) The development of the app was well-received. For instance, in naming it one of the week's best 20 iPhone and iPad apps, the Guardian recognised its educational value: "The serious aim here is to get children interested in coding".
(http://www.theguardian.com/technology/appsblog/2013/may/20/best-iphone-ipad-apps-beethoven-hangout) The app was featured on the Canadian version of the Discovery Channel and there have already been over 30,000 downloads of the app.
(video and download at http://www.qappsonline.com/apps/tunetrace/).

Vignette: A cs4fn spinout in progress

cs4fn contributed original content and impetus to a startup, Flummix (www.flummix.co.uk), which is about to publish *The Conjurer's Classroom*, "a collection of workshops that combines ideas in magic to explain principles of computer science and computational thinking". With a curriculum focus, Flummix will also offer related workshops and video support for teachers. Scotland-based founder Jody Greig has been a magician for a dozen years. After starting to teach computer science at the secondary school level in 2008, he began to introduce magic into his classes. At the end of 2010 a colleague showed him a school copy of the cs4fn magazine which contained a magic trick and in June 2012, Greig contacted Peter McOwan and visited the entire cs4fn team in London. With this visit, "it started to become clearer that there was an opportunity to take the material they (cs4fn team) had developed and published – and develop it into a curriculum-relevant book, making it more accessible to teachers".

Greig refers to the cs4fn team's "fantastic work, taking magic tricks and creating a clear association with computer science". Through an intellectual property agreement with Queen Mary University of London, he is taking a commercial route, building upon that original work to develop a resource for which teachers or schools would pay. There is an acknowledgement of cs4fn on the opening page, with a link to their free resources; and the flummix website also has a link to cs4fn. In writing *the Conjurer's Classroom* text, Greig's added value is "bolting it all together in a way that is structured and a good resource", making it explicitly clear to teachers just how they could use the workshops in their classrooms to address curriculum specifications. In Scotland's Curriculum for Excellence, for example, the exercises represent "rich tasks" with experiences and outcomes that are cross-curricular in nature, addressing not only computer science but also numeracy, literacy, health and well-being and the arts. Through Flummix, Greig is also trialling additional magic-based workshops for more generic learning skills for life; yet another "ripple effect" of interaction with cs4fn. Greig has received excellent feedback from school workshops conducted so far and hopes that the online ebook will become a global resource. This will extend yet further the "reach" of cs4fn's impact on computer science.

A "small world" note: Jody Greig won a Magician of the Year award from the Forth Valley Magic Circle, which was the branch of the Magic Circle Peter McOwan helped to found when a teenager in Scotland!

4.4 Capacity-building Impacts

Influences on Teachers: As noted above, despite its primary vision of complementing rather than constituting classroom education, the cs4fn team has contributed both informally and formally to capacity-building in teachers with responsibility for computer science. Certainly, the magazine, the website and school visits have all provided teachers with content and examples of activities which they could themselves develop with students, as well as a way of seeing connections between computer science and other areas. As one teacher who had hosted a cs4fn visit reflected in a survey response to a question asking if the teacher's view of computer science had changed as a result of the lecture, *"I hope to (during holidays) try and learn some of the tricks and practice them to be able to teach-entertain pupils and hopefully interest them enough to explore Computer Science".* A teacher in a different field noted seeing it "as a far more valuable discipline …that can be used for modelling and simulation, in my lessons as well as others". Responding perhaps more to the cs4fn style displayed, another stated, *"I am going to try to be a more creative and inspiring teacher";* another said *"It has inspired me to think of creative ways to deliver the content";* and another observed *"It has changed the way in which I would think about delivering some topics – building a more interactive element into lessons".*

The cs4fn team has presented more formally at numerous workshops and conferences attended by teachers. (Annex H) Most recently, QMUL has provided support to the cs4fn team to conduct Continuing Professional Development classes for teachers preparing for the shift to a new sort of Computer Science class, "Programming and More: CPD for GCSE Computing". As well as positive individual comments, attendance at workshops and CPD events as well as recurring invitations for the cs4fn team to speak suggest that teachers do indeed find their experiences valuable. Some degree of a capacity-building impact (and often, presumably, related conceptual impacts) on teachers seems likely.

Recently, for example, following a presentation at a teacher CPD workshop in Teesside, reception was positive on several levels. Curzon was thanked for "*an excellent and engaging presentation*" and was told that "*the audience were talking about it across the weekend and those who only came on Sunday were clearly jealous of the people who'd attended both days*". In addition, a university leader was described as "*really keen on getting more of this thought into our undergraduates. I believe he's found some of your work on your website that he's going to point at for our first years, to get them up to speed in this form of unplugged thinking before they arrive. So you came for teachers but your impact is much wider and I hope you know that's the difference you make. Thank you.*"

Vignette: Teacher CPD

Recently, PI Curzon gave a 2-hour CPD talk on Computational Thinking as part of activities put on by Newcastle University for its local teachers. Organizer Dr Nick Cook, responsible for schools outreach and widening participation in the School of Computing Science at Newcastle University, observes: *"Paul gave sessions to staff at Newcastle and to local teachers. Both were received very enthusiastically. CS4Fn is an excellent source of inspiration, expertise and resources for our own engagement with local schools. We are very happy to be institutional partners."*

Not only has Newcastle University now joined as cs4fn's newest partner, its online evaluation of participant teachers (20 of the 48 responded) showed enthusiasm for cs4fn-style CPD from the 'coalface'. Curzon's session received nearly all 4s or 5s. (Responses were on a scale from 1=definitely disagree to 4=mostly agree to 5=definitely agree.)

Externally-conducted assessment of a cs4fn CPD session

Question	Rating	% 4/5 ratings
Overall satisfied	4.9	100%
Useful ideas for the classroom	4.8	100%
Speaker was well prepared	5	100%
Speaker was approachable	4.9	100%
Speaker responded to questions well	4.8	95%

Teacher comments included the following indications not only of satisfaction and enthusiasm, but of likely uptake of some activities clearly communicated on a practical level:
- "Engaging and informative! Fun and thought provoking. Relevant to the curriculum and to classroom engagement. Refreshments."
- "the practical nature of the presentation"
- "Practical activities, Suggested links with Magic and computational thinking"
- "The use of real examples for the classroom, well-rounded explanation"
- "The speaker, easy to listen to. The content, so easy to adapt. Appropriateness of the resources to teaching. The relaxed and fun approach. Hands on with audience participation.
- "Speaker expertise and style. Practical nature of teaching CS. Good reference back to objectives after each section."
- "I think the initiative is a really good way to get teachers involved in delivering what is for most an alien concept."
- "Excellent speaker, had a very informative evening in a relaxed atmosphere."
- "Brilliant CPD really enjoyed it"
- "Many thanks … loved it!"

International sharing: cs4fn has led to capacity-building internationally as well, with some examples discussed below under "Enduring Connectivity Impacts". In some cases, this has been facilitated by Google support for translations of several cs4fn teacher activities. One specific example of sharing has been the Genoa Science Festival.

Vignette: An International Science Festival

The Genoa Science Festival (Festival della scienza) is an established event in Italian science outreach. (http://www.festivalscienza.it/site/home.html) For four years beginning in 2010, it has provided support for participation by the cs4fn team. Not only has cs4fn presented directly to children, families and others attending the festival, it has also effectively provided mentoring, leaving behind a lasting footprint. In each case local science ambassadors were trained up by the cs4fn team to deliver the activities. A "math fitness" centre in Genoa (for dissemination of mathematics) now uses some of the cs4fn activities in its workshops on computer science applied math.

As a venture, work with the Genoa Science Festival has in turn provided professional growth opportunities in the UK. cs4fn project manager Black reflects that his development of interaction with the Festival was a point of personal pride, as it was a new idea in 2010 that he had to run with even though he "had no idea how I would do it". He organised the presentation, fitting the needs of a festival in another country, and built a good working relationship. The international partnership has endured and has been handed over to an Italian colleague based at QMUL, a lecturer who will now gain additional experience in science outreach.

On a broader scale, cs4fn helped lead to a new £3M EU-funded project awarded to PI Peter McOwan, with teacher training seminars due to begin in January 2014. TEMI, or "Teaching Enquiry with Mysteries Incorporated" (http://teachingmysteries.eu/) will involve thirteen partners in eleven countries -- teaching institutions and networks across Europe. The overall goal is to transform they way that science, technology, engineering and maths subjects are taught; TEMI will develop new teaching methods and support science teachers, for example through innovative training programmes called "enquiry labs" that will mentor teachers through the transition to use enquiry to teach science. Clearly continuing the cs4fn ethos, McOwan says about TEMI:

> "*People love solving mysteries – the popularity of TV shows, books and films where the plot unfolds revealing new and previously unknown facts have universal appeal. Our project aims to harness the power of magic tricks, myths and mystery to allow teachers and pupils across Europe to develop their investigative skills and explore some fascinating hidden science. … The project hopes to create a range of new teaching materials and classroom training resources for science teachers, such as Smartphone apps, videos and printed materials. We will work closely with established teaching networks to develop activities that use local myths and mysteries to explain and hopefully get students excited about STEM subjects.*"
> http://www.qmul.ac.uk/media/news/items/se/104121.html (press release 17/7/13)

The magic part of TEMI was a clear extension from the magic of cs4fn through to illusioneering, in McOwan's view, with both initiatives credited in a recent article about TEMI (http://www.scienceomega.com/article/1237/a-kind-of-magic-3m-project-will-teach-science-through-mystery)

Mentoring Next-generation Researchers: Another sort of cs4fn capacity-building has taken place among next-generation researchers, laying the groundwork for computer science outreach in the future. Roughly 45 undergraduates, postgraduates and postdoctoral researchers have been involved with cs4fn over the years of the project.

A mid-course focus group was held with several next-generation researchers (postdoctoral, late postgraduate) who had been involved with cs4fn and/or one of its spinoff magazines. The focus group was designed to encourage reflection on challenges and opportunities posed by involvement in science outreach, and also possible relationships between research and public engagement in future careers; some key points made are captured below.

Various thoughts offered by next-generation researchers on interaction between research careers and public engagement

*Learning how to describe what you and other researchers do, in so many ways, helps even in your 'ordinary' academic teaching role; and you get to know how to pitch your research at various levels, such as introduction or summary of thesis."

*Public engagement experience helps you when talking with fellow researchers, even across disciplines".

*You can get new ideas from it; if you're interesting enough, people will have interesting ideas about what you do." (An example was given of a conference paper that initiated in a conversation with a BBC producer.)

*Public engagement gets you away from the desk of normal work, recharges your batteries and makes you think outside of the box. It can be quite inspirational".

*Sometimes you need to just break away and have fun…. And still something in your mind might click, with an indirect benefit of fresh new ways of thinking".

*As a researcher, you can get too focused … public engagement gives a sense of reality, perspective and/or potential use of the research. It can verify your thought processes or help you see problems".

*Not all researchers should do public engagement, as genuine motivation is necessary. Such motivation could be made the most of by: some training during the PhD, encouragement from senior individuals and opportunity to build a public engagement community with informal sharing of lessons learned".

Mentoring leads to ongoing impacts. Another individual mentored by the cs4fn team, a lecturer, has just returned enthusiastically from presenting an interactive installation to over 1700 visitors at the Royal Society Summer Science Exhibition, as a collaboration between computer science and biology (zebrafish genomics); the cs4fn product *Biology loves Technology* was distributed to some 700 students there. "Ripples" of influence continue to be launched through personal interactions with the team; for example PI Curzon gave an informal magic show to next generation researchers in the evening of an EPSRC-funded research initiative in which he is a lead investigator (CHI+MED); some of those individuals have now helped out at cs4fn events and public engagement has been embedded as a core part of that project*.

Following one individual from selection of university to current PhD work provides a tangible example of the impact of cs4fn mentoring in public engagement (see Vignette below).

Vignette: cs4fn Impact on Next Generation Researchers:
One Example of a Legacy

When James Snee was a school student planning to go to university, he heard a lively talk by Peter McOwan; he applied to QMUL Computer Science in part because he was 'quite taken with the people'. In 2007-8 Peter was one of James' first year lecturers; then in James's latter two undergraduate years he helped out at QM open days, and got to know Peter and Paul as they did cs4fn-style talks. When they invited him to help out at science fairs, James helped run the cs4fn stand, learning to do magic tricks and explain things about computer science to fair attendees. Looking back on the experience, James remembers "I had a lot of fun!" He notes that "a lot of people don't get involved with outreach because they think it will have a negative impact on their work—but I graduated with a first class degree – So the cs4fn experience made it better".

Stating that "Peter and Paul were definitely very influential on my academic career", James is now a PhD student in the Digital Technology Group of the Computer Laboratory at Cambridge University. He comments that "I am very into education, specifically technology and mathematics education, and I think that has all come out of being involved with cs4fn". Along with his studies, and a little freelance software development, James takes part in lab and college open days. James is also working on a Code Club for 8-9 year olds at a local primary school: "a lot of the cs4fn stuff translates very well into that, because it is so visual". And, he still does the occasional magic trick at the pub.

Encouraged to reflect on his experiences, James commented that the cs4fn experience gave him "a good head-start" in terms of confidence when standing in front of a group of people, and the unpredictability of questions asked at science fairs prepared him for dealing with colleagues throwing "curve ball questions" at conferences. More generally, he feels that "doing the cs4fn thing made me realise how much you really need to think about getting your ideas across to people … that communicating research really is quite difficult and you have to think carefully about how to communicate—it is important that you do it well, and not give a wrong impression or wrong ideas to the public". In fact, he observes that being able to explain principles to people in simple ways, and ways that they enjoy, "definitely helped my research, as what I am doing now is quite hard to explain". "The main thing cs4fn made me do is step back from my own research and ask how does this look in the broader picture, to try to explain my work in a way that makes sense to the person on the street and try to explain how it affects them". Since James' research is on smartphones, it would be possible to stay focused only on how they work rather than their possible uses, but when "you are not afraid to talk to other people about it", he finds that "you can get a whole different perspective on where the work should be going". James would agree that there can be strong parallels between public engagement and knowledge exchange; and that he is much more able to do this, and more willing, as a result of working with cs4fn.

Looking ahead, in terms of public engagement, James is "very interested in communicating science to people. People pay taxes and the government pays for research, so they should understand what they are paying for." In the future he sees himself taking the same approach as cs4fn: "finding the core aspects of my field and finding interesting ways of communicating it… Magic is very good." If projects like cs4fn were around in his future, he would definitely like to be involved. Along with public engagement and research, James envisions education at a university level as part of his future career. He has clearly internalised the cs4fn ethos: "I never want to give a boring lecture in my life!"

4.5 Enduring connectivity (Onward effects)

Onward Effects: In evaluations of the impact of research beyond academia, Meagher has found "Enduring Connectivity" to be a useful process-based indicator, suggesting that impacts could still be developing, in that case through ongoing knowledge exchange interactions between researchers and particular stakeholders/groups with whom they had worked. To examine processes likely to continue to generate impacts from cs4fn as a science outreach initiative, perhaps the most useful analogue would be to consider ongoing, onward "ripple effects" as mediated through connections with other individual and organisational partners. In effect a "legacy" of influence may be created through continuing uptake of available cs4fn materials approach and practice by: university colleagues, teachers/related organisations, and other outreach initiatives, along with the media.

Sharing with University Colleagues: New university partnerships still develop: Newcastle University just became a partner, for example. Various university partners of cs4fn (from five partners at the beginning of the grant to 18 currently) have distributed multiple copies of the cs4fn magazine as part of their own public engagement outreach efforts (such as open days or visits to schools) to encourage young people to consider computer science studies and careers. The magazine is generally well-regarded as a "useful resource" by other institutions. For example, one university partner, when interviewed in 2009, spoke of cs4fn's "*high quality website and fabulous high quality of the magazine*", going on to praise the research foundation of the magazine:

> "*a very positive thing cs4fn does is to help blur (a) distinction between people who do research and people who do outreach, a dreadful distinction. By blurring the overlap cs4fn makes a contribution --- outreach articles based on research are very much like 'research-informed teaching'. … (the magazine helps the partner university) "let pupils, parents, teachers see that Computer Science is not what they think of as 'IT'; it broadens student awareness*".

When asked for recommendations as to what cs4fn could do in the future, another partner, also praising cs4fn highly, referred to the large-scale transformational change needed in views of computer science, saying that cs4fn should "*do what it currently does and keep doing it. Five years is not enough. This is going to be a large problem to turn around. cs4fn is just one cog.*"

cs4fn team members have contributed their time and effort to make presentations at other universities' outreach events (e.g. Universities of Aberystwyth, Bangor, Cardiff, Dundee, Glamorgan, Glasgow, Leeds, Manchester, Swansea, Newcastle, Teesside). In addition, cs4fn team members visit other universities to share their practices, effectively acting in a mentoring role. For example, one major university in a strategic partnership with cs4fn is currently sending people to cs4fn to work on its public engagement strategy, and hopes that cs4fn will come to its location and mentor its academics in outreach. An email from a colleague at another university, Auburn University in the US, paints a picture of uptake of cs4fn:

> "*I just wanted to let you know that I will be using your cs4fn project starting this summer. In July I have 2 camps just for girls. … I already included "The Women are Here!" as a resource and topic for related discussions in the campus blog. … I am also working on including other cs4fn activities. In Fall 2013 I will teach 2 "introduction to CS" courses for grade 7 and 8. I am working on selecting some of your cs4fn projects especially for the eighth grade students. I will keep you posted.*"

Additional cs4fn activities used at Auburn include cs4fn: Kakuro, Logic and Computer Science; and cs4fn: the FUNdamentals of Algorithms. (The summer programme is described at cs4allg.eng.auburn.edu/).

More formally, as described earlier and in Annexes H, J, the cs4fn team has on a variety of occasions shared good practice through presenting at CS education conferences, sometimes "infiltrating" conventional science-based conferences with rallying presentations about outreach practices. For example, in July 2013, in St Petersburg, Russia, PI Curzon gave a paper, "Teaching Formal Methods Using Magic Tricks" at the Fun with Formal Methods Workshop, part of the 25th International Conference on Computer Aided Verification. (As immediate feedback on uptake, a member of the workshop organising committee, Nikolay Shilov, thanked Curzon, saying that he had read the paper beforehand and had already used the cs4fn Magic Trick examples in place of more traditional lectures twice after the paper had been selected. He gave a lecture, "Fun with Formal Methods: making formal methods understandable", for 1st and 2nd year students of Novosibirsk State University and Novosibirsk State Technical University who attended a Summer School on Parallel Programming. He then gave an adapted version for middle and high school pupils enrolled on the Novosibirsk regional Summer School for Young Programmers. (See https://twitter.com/LSHUP, and a photo of students gathered watching the magic is at http://vk.com/lshup?w=wall-361592_726.) He said he was delighted by the students' reception of the tricks.

In addition, as noted earlier, the cs4fn team has captured insights and lessons learned in a set of academic publications (See Annex J). As just one example of additional influence in this arena, Curzon's work on cs4fn has led to him being invited on to the programme committee of the International Workshop in Primary and Secondary Computing Education (WIPSCE) and refereeing papers related to school education for the International Journal, Transactions on Computing Education. Curzon has been invited to present a keynote address on cs4fn at WIPSCE 2013 in Denmark in November (http://www.wipsce.org/).

cs4fn influence is not limited to connection only with academics who are computer scientists. Indeed, cs4fn has supplied its overarching funder, EPSRC, with examples and stories. The hallmark magic theme of cs4fn has been extended beyond computer science to mathematics; Peter McOwan has recently produced a book, the *Manual of Mathematical Magic* (http://www.mathematicalmagic.com/docs/mathsmagic_full.pdf). He presents this to mathematical audiences such as the Institute of Mathematics and its Applications, and to the British Science Festival 2012, when he and a colleague presented the Maths and Computing Magic Show, and plan to do so again in 2013; for the 2014 festival he has been selected as president of the maths element. A recent Royal Society education special podcast includes McOwan discussing "Maths made Magic" http://blogs.royalsociety.org/rscience/2013/08/29/august-2013-education-special-what-will-you-learn/). McOwan also extended this theme to "Illusioneering", magic to engage with science more generally.

Sharing with Teachers, Related Organisations: As described earlier, the cs4fn team has shared not only its materials but also its approaches with teachers (and teacher-related organisations such as CAS) – through the magazine, website and school visits, but also to presentations and workshops for teachers, including CPD, (Annex H) helping teachers develop innovative approaches to teaching Computer Science (as distinct from IT). It is likely that word will continue to be spread to teachers. For example, cs4fn is noted several times on the website of the Royal Academy of Engineering, including in its advanced activity developed for teachers on "The Engineer's Brain", which: acknowledges the cs4fn brain-in-a-bag resource inspiring the activity, profiles PI McOwan and lists the cs4fn website as the first of its 'next steps'.

As teachers take up elements of cs4fn's "fun" approach, enhancing student views of what computer science can be, they are spreading further the impact of cs4fn. One example is the work of Mark Dorling, a teacher playing a leadership role in developing teaching materials for broad use by other teachers (See Vignette: Sharing with Teachers below).

Another aspect of "onward influences" lies in use of the cs4fn magazine by school careers teachers, as they can play an important role in pointing out future options to students. So, for example, comments by careers teachers seeking copies of cs4fn publications, *Audio!, ee4fn*, or *Biology loves Technology* include:

> "*Many of our pupils do not go into STEM related careers so by providing them with resources that demystify aspects of science and computer research this may help to raise aspirations.*"

> "*Perfect for the browsing student. I would like to display the books along with the careers literature and hand out to any students who show an interest.*"

> "*As a result of recent media coverage, an increasing number of students are expressing an interest in engineering and it would be useful to have a well presented, interesting resource to springboard conversation and research into careers in this area. Ten copies would allow small groups to be invited to discuss and review the contents in detail with the intention of feeding back to peers.*"

Vignette: Sharing with Teachers

Now moving into the role of national CPD coordinator for CAS (Computing at School), teacher Mark Dorling has since 2008 been the coordinator of the Digital Schoolhouse (www.**digitalschoolhouse**.org.uk). Based at Langley Grammar School in Slough, the Digital Schoolhouse reaches out to primary as well as secondary students (and their teachers), providing resources for learning about computer science, hosting student visits and providing teacher training. Well over 50 other schools have visited; between December 2008 and July 2011 some 4000 students visited; and its website makes a point of having hundreds of how-to-teach resources, ready-to-use activities and materials for teachers. Mark himself has a computing degree and has been influenced by the cs4fn approach. He says of the cs4fn magazine "*I read the magazine; it gives me ideas as a teacher as to what to teach and how*". He has passed along magazine copies to students – articles may be a step away from the younger ones, but are "*interesting and written in a child-friendly way*." He encourages primary school teachers and others to use the cs4fn website:

> "*Non-specialists can struggle locating the best resources. The DSH has encouraged them to use the cs4fn website. It provides excellent examples of how computer science links to other subjects, providing inspiration for adapting existing schemes of work*"
>
> (http://www.computingatschool.org.uk/data/uploads/newsletter-spring-2013.pdf)

With his efforts at the Digital Schoolhouse selected in the Royal Society report of 2012 as an example of outstanding teaching in computing, Mark graciously acknowledges inspiration from others;

> "*That's why I was mentioned – I tried to learn lessons from Technocamps and cs4fn*".

Dorling was particularly impressed by the cs4fn magic tricks as a practical element for teaching. In fact, he and Curzon together created a magic trick for elementary school, on following algorithm-based instructions and continuous loops. Later they worked together on an activity about human-computer interaction (HCI); although the relevant industry contact moved on so it was not completed, Dorling hopes that HCI and usability will feature in the new school curriculum, and that their idea will develop into something that might be included by CAS as a resource.

> "*Taking one thread from first talking to Paul and reading the magazines through to something that did not quite happen but it highlighted to me the importance of HCI and usability, to pupils' overall computing educational development; I have been lobbying ever since for inclusion of HCI in the curriculum.*"

Another jointly developed idea was a literacy algorithm referring to Harry Potter; Dorling has found that years 5 and 6 in primary love it. Dorling describes the shared roles of knowledge exchange: "*The main point – the link between a teacher and an academic, the teaching pedagogy and the subject knowledge – is that I understand his world and he understands mine; that produced a nice set of ideas.*" Yet, the transformation from cs4fn material into actual lessons a – for example those captured on the Digital Schoolhouse website – can be challenging for teachers and constitutes a crucial step: Mark observes that through his own effort he has "*taken cs4fn material and turned it into great lessons, probably the most popular ones on the (Digital Schoolhouse) website*".

Dorling has built on cs4fn to develop teaching activities: for example, he got the idea of the Hampton Court maze as a way to teach 'nested-if statements', then went on to develop that for actually teaching primary school children. He has also used other elements of the cs4fn

website including its treatment of the Fibonacci sequence, getting students to draw and spot patterns, and has since done links to art.

> "*I wouldn't have come up with that idea if I hadn't read the website. … I teach patterns and fractals and all that stuff. Using the cs4fn website I was able to create schemes of work which suddenly became very cross-curricular which are therefore more relevant and useful to students, and particularly great for engaging girls*".

Dorling observed that the unexpected range of topics woven into computer science teaching at his school appeared to open Education Secretary Michael Gove's eyes, helping him to see CS as more than programming, during his 19 October 2012 visit to the school. (http://www.youtube.com/watch?feature=player_embedded&v=JgrXNc_7qEM)

In fact, during that visit a statement by Dorling on the importance of computational thinking was agreed with by Gove and other visitors; the Department of Education tweeted that "*Mark Dorling ICT teacher says computational thinking underpins all other subjects*" and several newspaper articles referred to the school and to computational thinking.

> "*So, lessons we have come up with were based on those cs4fn ideas that have influenced me and I've used them to influence others.*"

Sharing with Other Outreach Efforts: cs4fn interacts with and/or contributes material to a number of other science outreach initiatives, thus leveraging its work and expanding its scope for ongoing impact. For example, Manchester University, an early partner of cs4fn, runs an annual UK Schools Competition for Computer Animation and a linked Animation Festival. The cs4fn team has run its magic stall at the Festival and promotes the animation competition on its website and in magazines (which in turn are still distributed to school students at the Manchester event. cs4fn activities have been adopted by a range of other projects, including, for example, the Digital Schoolhouse (see Vignette), EU-funded Technocamps in Wales (http://www.technocamps.com/) and CS Unplugged, a well-regarded initiative operating from New Zealand.

Vignette: Contribution to Computer Science Outreach Worldwide

Based in New Zealand, *CS Unplugged* (csunplugged.org/) has become a key website resource for teachers, with an emphasis on developing teacher-ready material. Its founder, Tim Bell, has high praise for the contributions made worldwide by cs4fn, which it views as a sister project in the same sort of space acting as "*a source of inspiration and ideas*". The increase in computer science recruitment at QMUL brought about by cs4fn against all national trends made a real impression on Bell at a critical stage in developing his own initiative.

> "*For me, that was incredibly encouraging and influential as we went about trying to make changes in New Zealand. … It was inspiring that a programme or approach had such a big impact. … Someone actually proved that it could be done at a time when it was very depressing and most interventions seemed to be ineffective. Since then, a whole lot of things have been going on but its existence, certainly for people like myself, provided the back-up and inspiration to jump into doing this sort of thing.*"

In Bell's view, cs4fn

> "*was helpful in bringing about a change in view of computer science but it was especially helpful when people wanted to change what they were teaching, as it provided resources … something they could change to.*"

Bell observes, "*cs4fn would have to be the richest computer science site for school students in existence, covering so many topics from so many angles*". Over the years, Bell has searched on line for every resource on every topic relevant to high school; not only do cs4fn articles come up frequently, but also

> "*it covered so many things and covered them well … it is a reliable collection … a curated collection that you can depend on pointing people to.*"

There is a "*consistency of quality*"; other than his own initiative, cs4fn and Quintin Cutts' "CS Inside" work in Scotland, Bell notes that

> "*nothing else springs to mind where we would go for consistently laid out teacher resources*".

CS Unplugged and cs4fn have been in touch for a long time, citing and using each other's work. cs4fn "*really puts meat on the bones… (it) provides us with the opportunity to provide a better story*" and "*hands it to us on a plate*"; links to cs4fn stories make it easy for CSUnplugged to complement technical learning. With its stories, "*targeted very well and not too long*", cs4fn contributes in different ways. For example, Bell reflects

> "*You can't underestimate the value of a lot of these resources for adults; a lot is for teachers, parents, grandparents, advisors and so on. Often they find computer science a little harder to understand than students do, so it has a valuable role there. If you can influence a parent, and especially a teacher, then you can influence several students*".

At a time when teachers may feel threatened by demands to change their teaching of computer science,

> "*there aren't many resources as good as cs4fn – and it gives teachers confidence*".

In Bell's upcoming *CS Field Guide*, a comprehensive on-line text accessible for high school students and designed for use worldwide, there will be a reference to cs4fn in almost every chapter. So, the ripple effect of cs4fn will continue internationally.

Sharing through Distinctive Dissemination: As mentioned earlier, cs4fn has put on presentations at a many large-scale events designed to stimulate interest in science, with the Royal Society Summer Science Exhibition and the British Science Festival just two examples. (Often such presentations are picked up on in blogs and social media.) Other sorts of media dissemination have arisen as well. So, for example, cs4fn and/or McOwan have been mentioned in credits or acknowledged/thanked in science television shows, including *Breaking Magic* discovery science series (for which McOwan was a scientific consultant), that builds on Illusioneering (http://www.illusioneering.org/) and mathematics of magic, and a mini-series documentary on *Super Senses* (2012). He also appeared on Radio 4's *Material World* programme. (A podcast features McOwan: http://www.bbc.co.uk/programmes/b012wzpb). McOwan ran an "are you human" test for a Secret Cinema screening of Blade Runner in 2010 – once again bringing out a quirky, fun side to engage the public. (http://guerillascience.co.uk/contributor/peter-mcowan) Not only is magic making its way via cs4fn into computer science dissemination, but the reverse is also true: cs4fn's two magic books and the Illusioneering book have been accepted for inclusion in the Magic Circle Library in London.

4.6 Attitude/Culture Change (toward science outreach)

Institutional Change: Changing a university culture is recognised as a genuine challenge, yet cs4fn has helped to bring about significant change in institutional support for outreach and public engagement at its home institution. cs4fn became known in the physical sciences and then more broadly in the university, which gladly cited cs4fn efforts and accomplishments. At a 2011 university-wide meeting of an outreach committee, McOwan reported an "awed silence" following Curzon's presentation of the reach of cs4fn. McOwan worked extensively with university leadership to secure institutionalisation of a commitment to public outreach, using cs4fn as one of several strong success stories to make a persuasive case. Indeed, cs4fn is mentioned by name in the University's Strategic Plan. (http://www.qmul.ac.uk/docs/about/32329.pdf) "*cs4fn fingerprints are all across the new outreach agenda.*" In April of 2011, after sustained efforts by McOwan and other PE champions drawn from across the insitution, the university agreed to establish a Centre for Public Engagement (CPE). It immediately started work and was formally launched in autumn of that year (http://www.qmul.ac.uk/publicengagement/). The Centre for Public Engagement performs many functions, including fundraising, offering awards, mentoring and facilitated sharing of good practice, producing guides and training activities, and holding public engagement surgeries, as well as continuing to raise the profile of outreach and generate respect for that activity as an integral part of the university and an academic's remit; in fact there is a link to the CPE on the front page of the University's website. The CPE is developing a new Masters in Public Engagement, and the Centre's executive officer is doing a PhD in public engagement. It should be noted that McOwan also had input into the UK Research Councils' Concordat for Public Engagement, so that, through this 'human vector', it seems likely that the cs4fn vision and approach had some influence on funding policy.

Indeed, successes in the career paths of both PIs reflect culture change at QMUL. Early on, each received teaching and outreach-related awards, including QMUL's own Draper Prizes but also others: McOwan was elected a National Teaching Fellow by the Higher Education Academy in 2008 and was awarded the 2011 IET Mountbatten Medal for his work in promoting computer science to diverse audiences; Curzon was made a Higher Education Academy National Teaching Fellow in 2010, was shortlisted for the 2009 Times Higher Education Most Innovative Teacher of the Year and won the EPSRC's "New Computer Science Writer of the Year" award in 2007. UK-wide recognition of the team members translated into QMUL recognition of public engagement a little later. Curzon was made a Professor in 2013, with particular recognition of his innovative and successful cs4fn role. A new post, Vice-Principal for External Relations and Public Engagement (now, "Vice Principal

for Public Engagement and Student Enterprise) was created for McOwan in 2011 and began in 2012. From this post, McOwan secured an RCUK Catalyst award of £300K in April 2012 to (further) grow a culture of public engagement at QMUL, embedding it within policies, procedures and practices.

More recently, the Principal has announced allocation of significant HEIF funding to support public engagement projects, with more set aside for the future and at a recent meeting of the NCCPE, hosted at Queen Mary, introduced the compelling concept of public engagement-led research, where Public Engagement comes first to help inform relevant questions and methods for academic study. A specific, and telling, example of the process of embedding is that public engagement activities now appears as an entry in the College statements for promotion, at the heart of the academic value system, with the VP for External Relations and Public Engagement sitting on the promotions panel.
http://www.hr.qmul.ac.uk/acadreview/staffcareerprogress/. Over the past two years, staff in all faculties at QMUL have been promoted when public engagement activity was a clear factor in their promotion. And, very recently, QMUL provided support for cs4fn-influenced CPD for teachers of computer science. As McOwan noted about the award (and thus about the university generally), the aim is that QMUL will be able to "*move towards achieving an environment in which (public engagement) is a naturally integral part of what we do*". There is of course a hope that QMUL and other successful role models will act to spread culture change more widely across other institutions.
(http://www.qmul.ac.uk/media/news/items/71379.html)

5. Reflection: Insights, Issues and Lessons Learned

5.1 Evaluator Reflections

Key Insights from the Evaluator

As captured in the Executive Summary, some key points emerge distinctly, in particular through the evaluator's 5-year role as critical friend/evaluator.

1) Accomplishments have effectively matched – and often surpassed – targets. In some cases, targets have evolved (e.g. producing special issues in place of an annual). Very often, additional deliverables have been generated.

2) Satisfaction with cs4fn deliverables (publications, talks, etc.) seems in general to be very high – among teachers and students. Other colleagues and organisations have a high regard for cs4fn as well.

3) cs4fn has successfully reached a diversity of students, from different sorts of schools and backgrounds. The issue *The Women are Here* is particularly commendable in tackling disparities in genders' interest in computer science.

4) cs4fn has created a special brand, a "unique selling point", by emphasising the potential for fun – curiosity, puzzles, intellectual "play" – in computer science, a dimension that students might otherwise seldom encounter.

5) The team members have remained alert to a wide-ranging arena of computer science and related interdisciplinary research, and interesting applications. For many, this has illuminated uniquely the multiplicity of careers related to computer science.

6) With implementation of its early and distinctive vision made possible by EPSRC support, cs4fn has made a difference. While lines of causality between individual students and individual university subject choices are impossible to prove, the combination of indicators available convey a range of impacts generated by cs4fn, in a full portfolio including conceptual, instrumental, capacity-building, enduring connectivity/leverage and culture change impacts.

7) Achieving a broad definition of sustainability, cs4fn has generated a rich and multi-faceted legacy, so that its influences will continue to ripple outward and be felt. While full financial sustainability has not been achieved, so that cs4fn activity cannot continue at its current level, nonetheless future funding has been won from the Greater London Authority's London Schools Excellence Fund.

8) The members of the cs4fn team are notable not only for an unusual breadth of understanding of computer science but also for outstanding personal commitment and continuing creativity.

Meeting Targets and Goals

Targets have been met, or surpassed, although sometimes the targets themselves have evolved. (The last expected magazine is projected to appear within or just after the formal end of the grant, but additional unexpected publications have been added to cs4fn accomplishments.) cs4fn deliverables (e.g. magazines, other publications, website, school visits, other events) appear to be very positively received, by teachers and by diverse students (including girls, and students from a wide range of types of schools).

cs4fn has met its key goals. Cs4fn team members had a variety of motivations, such as:
• "rebranding the subject, widening the definition of the subject and including interdisciplinary understanding";
• "removing the stigma" of the subject;
• increasing the pipeline of entrants into the subject, across the UK;
• helping students to learn about fairly deep topics;
• providing "serious fun";
• interesting different students through a mix of articles; inspiring others;
• "doing something that makes us feel we've had an impact, to make the world a better place";
• and the team "having a good time doing it" –because then they will do it well!

The first three motivations (rebranding, removing the stigma and enhancing recruitment UK-wide) were ambitious, large-scale goals; however these appear to have acted as clear continuing messages throughout all of cs4fn efforts with evidence suggesting that individuals directly engaged with cs4fn products and activities were, at the very least, certainly exposed to these views and it does appear that some young people broadened their study/career options accordingly. Furthermore, as discussed earlier, cs4fn was among those contributing toward a related 'zeitgeist change' in how computer science is to be framed as a curriculum subject. The second three motivations (helping students learn, providing serious fun, inspiring others) have been achieved directly through cs4fn products (magazines, website and other publications) and activities ranging from school visits to science fairs to mentoring of next generation researchers in science outreach. Finally, the team members are passionately committed to making a real contribution to the world through their efforts, and – often in the form of informal testimonials and expressions of enjoyment or gratitude from students or teachers – they receive personal feedback suggesting that they are doing so. When the administrative burdens of academia and stresses about sustainability fade temporarily into a dim background, and team members are in the limelight writing or presenting about what they love – they clearly are themselves having serious fun.

Scale: It is worth noting that current explorations of how impacts of research can best be evaluated have raised the issue of "scale" of impact (e.g. Meagher, 2013). Many times, for example, an impact narrative or case study arises from a close relationship between individuals at one university and at one or very few stakeholder organisations. While such impacts are genuine and well worth capturing, they do sometimes beg the question of how they could be scaled up to benefit far more stakeholders. When considering impact of public engagement efforts in regard to this question, cs4fn is notable in the extensive scale of influence it has achieved. While committed cs4fn team members do strike up localised impacts through school visits, most of the cs4fn effort reaches many, many individuals, whether through the printed magazine, the website or through follow-on activity of individuals (teachers, academic colleagues or next generation researchers) mentored by cs4fn. cs4fn has achieved an unusually significant reach and scale of impact.

Evolution: Every effort needs to evolve, particularly initiatives like cs4fn that are predicated on creativity. Even within the finite 5-year timeframe of the EPSRC funding, the cs4fn project

has adapted to a changing context in several ways. For example, with policy shifts facilitating curricular changes, the team has begun to work more directly with teachers: with a teachers' portal on the website, with demonstrations at workshops and most recently with CPD courses that have led to combined CPD courses and cs4fn resources in the newly awarded grant, which will involve teachers even more centrally. Although the team's original (and continuing) motivation and commitment was to use its "fun" approach to enhance rather than constitute an element of teachers' work, this evolution of activity seems to be 'infiltrating' pedagogical effort with the cs4fn approach. Indeed, cs4fn's contribution to policymaking was unexpected. In addition, the team was deliberately – and commendably – opportunistic, applying its vision and approach to previously unexpected niches as they arose, for example developing the *Audio!* and *ee4fn* magazines, and building on interdisciplinary areas, for example the recent *Biology loves Technology* publication. International use of the magazine and website has grown more than predicted at the start, and the team has made use of social networking media just emerging at the time of cs4fn's start. An Advisory Group interviewee made an apt recommendation in the early days: "*Think of cs4fn not as a magazine but as a campaign, which you would expect to change over time*".

Creativity and Entrepreneurship

Observing the team over the lifespan of the grant makes one thing perfectly clear: cs4fn is shaped not only by vision but also, fundamentally, by the passion of the PIs. They love the field of computer science and perhaps more than that they love sharing their passion for it with others. When cs4fn efforts generate a "spark" of interest in students in particular, or indeed in teachers or university colleagues, team members receive a corresponding "charge". They get great satisfaction when groups or even one individual share their sense of fun, enjoying quirky views of issues, odd juxtapositions of thoughts, or the surprisingly apt correlation of magic to computer science. They are not prescriptive as to what counts as computer science, rather they want to share the fun of solving problems and looking at things in new ways, much as both of them enjoyed the Martin Gardner books of mathematical puzzles when they were young. They are certainly what would in an art context be called "creatives"; there is a lively infectiousness in the room when they play with ideas and come up with new ones.

In many ways the PIs are entrepreneurs who have created cs4fn as their 'baby'. Like many entrepreneurs, they have poured above-and-beyond energy, effort and time into their creation. An important element added by the EPSRC funding was the project manager trained in science communication, who not only was able to learn how to write articles and give presentations in the "cs4fn style", enhancing the reach of cs4fn, but was also key in handling what turned out to be quite extensive administrative matters of the initiative, thus helping to free up the creative energies of the PIs. As with many entrepreneurial ventures, cs4fn has not given up control, whether through allowing sponsors to advertise or by trying to instigate regional franchising. This may lead to cs4fn staying small (and potentially vulnerable) in the future, rather than seeking to be "bought out" by the outreach equivalent of a multi-national corporation. However, the high regard in which cs4fn is held in so many quarters has already led to a major new grant from the Greater London Authority's London Schools Excellence Fund. Furthermore, the many sorts of legacies generated by cs4fn should continue to create opportunities for the PIs and other colleagues to contribute in creative ways to computer science outreach.

5.2 Issues

Financial sustainability

From the beginning, and throughout team retreats and advisory committee meetings, a goal of cs4fn was to achieve some level of long-lived stability; the team sought a model of sustainability that would not compromise their values. (For example, support through

commercial advertisements were deemed inappropriate by the team, given that the focus is on children.)

To achieve full financial sustainability would mean having sufficient resources that allow the same high level of activity as the team have achieved at the end of the grant. This currently involves producing 3 magazine series with print runs in excess of 20-30,000 copies, as well as specials each year, sending them free to all schools across the UK and free to subscribers worldwide. This is a far greater level of activity than at the start of the project due to the mixture of increasing demand, the success of pilot initiatives and the team managing to use the EPSRC grant to help leverage further resources to do more than that envisioned originally. Continuation at this level would be seen as ideal.

At this point, full financial sustainability has not been achieved. However, steps towards it have been made, and a more limited form of stability has been achieved that means that the core magazine will continue to be produced for at least two years beyond the end of the grant, as discussed below.

The team believes that the most likely way to achieve financial sustainability is through a smorgasbord of different funding approaches. Consequently, the team has gradually experimented with some changes and other approaches, with varying degrees of success. For example it tried to alter its 'everything-free" policy recently by charging fee-paying schools a modest fee for visits; but the number of invitations dropped significantly. Some early possibilities for attaining financial sustainability suggested by Advisory Group members and team members themselves have not transpired. Some would have called for either or both significant fundraising or organisational partnering activity (at the expense of actual public engagement activity) or ready availability of resources (not characteristic of these last few years of recession). For example, the idea of acquiring small sums of ongoing philanthropic support from many companies would have entailed very significant effort and time, quite possibly to no avail in this economic climate. More likely perhaps might have been partnerships with educational establishments such as the Teacher Development Agency, but as noted early on these were the sorts of organisations with which Computing at Schools was working directly. CPD for teachers was raised as another moneymaking activity, and the team is in fact doing some of this, but so are many other universities and organisations, and teachers and schools do not have the resources to pay for this as a profit-making activity; it is unlikely to become a major money-spinner for cs4fn. Rather, these activities have become an offshoot aiming to meet financial sustainability itself. And of course, the change in funding strategy evidenced by EPSRC away from large-scale outreach initiatives and toward incorporation of outreach into individual grants has changed the funding landscape. (In response to this change, QMUL is experimenting with a somewhat formal expectation that electronic engineering and computer science research proposals would each include as a small percentage a public engagement line item for cs4fn to generate public engagement content related to the bid, but in practice this expectation is not systematically followed. Nonetheless involvement in three grants means that grant funding has been secured for three issues, already.) In short, without support for a project manager or help with a breadth of visits and other activities, it has become clear that with the end of the EPSRC grant, the level of cs4fn activity is likely to decrease by an order of magnitude, down to perhaps an occasional magazine produced almost as an avocation by Curzon.

While in theory there could be follow-up to some leads of varying likelihood of materialising into funding, the two PIs are so busy that it is hard for them to find time even to actually do the outreach they are excited about, let alone to explore leads which might or might not pan out. This seems to underscore the utility of a Centre for Public Engagement with infrastructure/staff to help pursue various types of support.

At the time of writing several of the initiatives have paid off. Most notably, the initiatives exploring cs4fn-based teacher CPD have led to the team being awarded a major 2-year grant from the Greater London Authority. The project, called "*Teaching London Computing*", is in collaboration with King's College London and is worth £450,000 over 2 years to provide support for teachers across London in the form of both CPD classes and cs4fn resources. This alone will ensure that the magazine and other specials focused on school-linked topics will be produced until at least July 2015.

As noted above, the policy of the School of Electronic Engineering and Computer Science that all RCUK grants will include public engagement activity, with the default activity being cs4fn, has led to three successful grants so far including some funding for cs4fn resources. This will allow for some other specials to be produced. The team will also apply for additional funding through Queen Mary schemes.

Finally, the team is hopeful that it will receive further major industrial funding, though given the past pattern this is likely to be on an annual basis. The current Google support continues into 2014, and the team will continue to apply for such funding, as well as exploring other avenues.

Thus the immediate future is secure, and particularly within London. However, full long-term financial stability across the UK has not at this point been achieved. This is particularly unfortunate given that demand for cs4fn printed magazines and visits has increased across the country.

Recognition of outreach

Even as early as 2009, Advisory Group members (who were extremely complimentary about the work of cs4fn – "*hugely successful*", "*sterling work*", "*a fantastic job*", "*absolutely wonderful*") raised the issue of potential lack of recognition by the host university (QMUL) for science public engagement, even an initiative of this scope. Among the ideas floated was the establishment of an institutionalised Computer Science Public Engagement Centre. It is notable that QMUL did go on to establish a broad centre for public engagement, although not with this specific focus on computer science. As important an achievement in culture change as this and other important steps at QMUL represent, however, it does not translate into financial sustainability for cs4fn *per se*.

Challenge of capturing outcomes and impacts

The inability to capture longitudinal information equates with an inability to "prove" causality of cs4fn impacts on particular individuals' university and career paths. So much of the fundamental goal of cs4fn is to generate conceptual impacts, invisible and famously impossible to quantify, that impact evaluation needs to use a suite of indicators. Since teachers and students are numerous, widespread, busy and not necessarily geared to answering surveys or filling out feedback forms (during time-constrained visits for example), we do not have one monolithic dataset. Instead we have made use of a variety of sets of indicators, gathered from different individuals in different contexts, and have used those in the evaluation. Although data on the indicators have been gathered at different times and in different contexts, they were all gathered in relation to the foundational Framework of Core Questions (Annex A). In other words, templates for surveys, interviews, focus groups, and logs all referred to questions on this same integrative framework, making it possible to draw the data together in this summary report.

Challenges in educational context

Often, teachers of computer science in secondary schools are moved about in terms of responsibilities so that it can be difficult to build continuing links with them. Often they have "drawn the short straw"; all are not in that position by virtue of knowing about or loving the

subject. Often, ICT courses are seen as vocational (by students, staff and school management) and are thus not taken by the sort of leading students who might actually be well-suited to studying computer science at university. (This reality and perception may change in light of new curriculum policy.) This makes provision of supportive and accessible materials for teachers particularly important, along with opportunities for the brightest of students to learn about computer science as a subject before making university selections. At the same time, cs4fn is committed to avoidance of duplication with bodies and efforts targeting the formal curriculum per se; thus it attempts to weight its own work toward enhancement or enrichment.

Effort and Time

A notable feature of cs4fn is the sheer amount of personal effort put into making it happen – such an extensive burden that it can really only be seen as a labour of love, far beyond the level supported by any university or EPSRC funding. Occasional master-classes have been given by the team but generally other people are still not writing in the style needed for the magazine. A particularly huge burden is posed by school visits and events. For example, even in 2008, PI Curzon was often conducting 2-3 workshops per week, with more requests than he could handle. While he has not always kept up that level, he has made numerous visits continuously through the school year, across the whole grant period. Black, the project manager, grew into the role of conducting many visits, thus extending cs4fn's school coverage; an associate for a brief time also conducted some visits. McOwan "keeps his hand in" with magic shows for various groups, despite his workload as a vice principal. It should be noted that, depending on location, any one school visit could, with travel, take up a full day. The team has shifted strategically to accepting those invitations that allow them to reach as large a number of students as possible, but since this does not equate to fewer talks, the toll on individuals is still very high.

Developing partnerships/community

Although individual researchers at QMUL and partner universities were encouraged throughout to submit ideas or articles, few were submitted and the cs4fn team ended up significantly revising or actually writing most of even these submissions. The cs4fn team did however watch out for examples of exciting research from these partner universities (and elsewhere) to use as content for magazine stories. As one interviewee from a partner university noted in 2009, "*although cs4fn overall had the QMUL stamp, the various universities are involved and benefit by osmosis*."

A somewhat similar result occurred relative to early cs4fn aims of stimulating a 'community' or network of regional champions at different universities. Again, this was beyond cs4fn's gift, as it required willingness on the part of other universities. Early thoughts (e.g. at a cs4fn team meeting May 2009) included possibilities such as: a workshop for exchange of good practices between partners (even beyond the team running a master-class), a monthly newsletter and/or regional portals on the website. This last was trialled. It is not entirely clear that partners would have attended/been motivated to participate in an 'exchange' workshop on outreach practice, though the cs4fn team has responded to invitations to conduct several mentoring/practice seminars at other universities, individually. There does not appear to be a strong identity or sense of "community" across numerous university individuals involved in computer science public outreach, although perhaps events have overtaken a bit in that there is a small core of individuals who have been heavily involved in influencing/providing resources for curriculum change. (Indeed, Computing at School, CAS, has launched a network of excellence primarily for teachers but also including universities.) Also, on a practical level, computer science departments in different universities are, in a very real sense, competing with each other for the relatively few top quality students potentially interested in studying with them. cs4fn's avowed goal of increasing the number of such students overall, rather than advancing its own institution-specific recruitment, has always

been relatively altruistic within this context. And in most universities public engagement has not been fully recognised as "legitimate" activity, curtailing the time individuals can spend, particularly when (as is often the case) enthusiasts are quite junior and without internal political sway.

Sustainability as Legacy

It is important to note that "sustainability" does not equate only to financial security; it can be defined in various ways. cs4fn has clearly led to sustainability in the sense of "legacy", with numerous impacts and ripple effects spreading outward from its activities and enduring connections.

5.3 Lessons Learned

Although the cs4fn team members possess a rich, layered understanding of public engagement, they have offered here, a set of key lessons learned for: researchers involved in science outreach, leaders of public engagement initiatives, and funders. While the points here are in the form of brief bullets arising from comments during interviews and retreats, such lessons are shared at greater length in the team's talks, workshops and writings.

Advice for Researchers becoming involved/carrying out science outreach activities
- Employ various ways of making (any) academic subjects *interesting*:
    - Telling stories
    - "Hooks", ways of making subjects interesting
    - Relevance
    - Contemporary culture
    - People
    - Links to other subjects
    - Coming across as human!
- Recognise the importance of narrative as a hook, with relevance to contemporary culture, and humour … But do not patronize or dumb down the science. Make it *'serious fun'.*
- Make it *contemporary*. Talking about people and personalities is engaging and can help with issues of gender and ethnicity, etc.
- In writing, *find offbeat angles*; come up with metaphors; try controversial juxtapositioning; use a "grab" to entice them in with something surprising that is then resolved when you draw conclusions. Go through and ask what do we do and how, how can we make it interesting to the reader (versus thinking that the research itself is interesting enough).
- The *first couple of sentences* are important – the grab needs to be effective right at the start.
- *Titles* are important; they are all that some people will scan. They should be short and punchy. Think *Sun* headlines rather than academic paper titles!
- *Don't write/present down* to them just because the audience members are children. Treat teenagers as adults -- and primary school kids want to be treated as older, too.
- Older teenage audiences don't show emotions much – it doesn't mean they aren't enjoying it – it's just not cool to look engaged.
- The best writing is writing you do when you're *enjoying it*. You can't be creative when there is pressure on you. If you get bored writing it, it is probably better to leave it and come back to it when you're excited again.
- *Embed explanations of key concepts* of the subject in articles about research.
- Keep *jargon to a minimum*. Aim for only a couple of technical phrases and make explaining them an objective of the article or talk.
- *Know your audience* … but don't be slavish to them.
- Don't be afraid to be *quirky*; the quirkier the better (while not losing the science). But,

don't force humour or quirkiness if you're not happy with it…. It's got to be something you feel happy with.

- *Keep experimenting* in your talks – test something new each time (survival of the fittest as to what you then keep!). This keeps you and the talks fresh and sometimes you can even give rise to new talks as offshoots from trialling new things in existing talks. Give yourself "permission to fail".
- *Build interest* as you go when giving a talk. The best talks can have a roller coaster effect, with quieter points contrasting with something dynamic or a burst of controversy, so that overall you are building interest.
- Make talks *interactive* – get volunteers up in front to do demonstrations.
- Make talks constructivist – support the audience to *work things out for themselves*.
- *Make abstract ideas physical* and tangible.
- When you are doing events, always *be prepared*! Do count your cards, check your bluetack supplies, etc.
- You can do *research and public engagement hand in hand*, don't just see public engagement as something you can do at end of research.
- In public engagement you are putting yourself forward. It is really scary at times. Public engagement can *enhance your self-confidence*.
- Public engagement *makes you a better researcher*, since you have to think about the 'why', the rationale for doing certain things.
- And of course public engagement *makes you a better teacher*.

Advice for Leadership of public engagement initiatives
- *Creativity* is increasingly important in the world of today, especially if you want to reach young people you have to basically come up with an advertising campaign that is as compelling as the million and one other things out there catching their attention.
- By being creative you can help *spark creativity* in others.
- Have a reasonable idea of the strategy you want to follow but always be responsive to opportunities that arise. *"Agile development"* makes evolution possible.
- Being *flexible* in actions, as in writing, makes things more interesting. For instance, taking an interdisciplinary rather than a narrow view of what a subject is allows you to link to lots of subjects. Interdisciplinarity in school talks and magazine articles gets you to a wider audience. Versatility in use (of a magazine or a visit) enhances uptake.
- Think about *sustainability* from Day 1. But, even then, be sure to make something that is worth sustaining …. So you have hooks to hang sustainability onto.
- *"Do More; Do Better; Do Tell"*. (This is the motto of the QMUL Centre for Public Engagement.) This includes remembering to write up and find ways to promote your successes. Always have a couple of good stories to tell, and do so enthusiastically.
- Public engagement is a very strong way of doing *student recruitment*.
- Don't tell people you are good/your research is interesting … *show* them you are/it is.
- *Altruism* works. A free resource that fills their need rather than your desire may greatly encourage uptake, particularly if you want to reach students or teachers with limited/non-existent budgets.
- Try to reach *larger audiences* for each visit you do, for instance doing something teachers can see is of value to a whole year group. Try to do things that work across age groups and lots of ability ranges.
- Aim to do activities/talks with *younger students* – not just sixth formers, for example. The younger you go, the bigger the impact. Getting to a younger audience matters, before they are set in their subject choices.
- It takes real *time and effort* (it can be a full-time job) just to organise multiple school talks.
- The look and feel of a magazine (and talks and slides) has to embed the *qualities* you want. For instance, in a physical magazine the quality of paper matters – but it costs. Imagery makes a difference. Having a physical product such as a magazine is an important complement to a website and/or live talks, particularly as it can be used over

time; it gives people you engaged initially an immediate way to continue the engagement.

- *Science festivals* are a good place to introduce new people to public engagement, developing early career researchers and undergraduates in public engagement. (Be aware that people are not going to come up with whole talks on their own.) Getting students involved in public engagement enhances their employability and entails transferable skills. Responding to weird and wonderful questions at a festival can make people much better at their vivas!
- Recognise the need for *a mix of types of professionalism* when building a science outreach team. Someone with professional science communication skills can pick things up quickly and enhance the efforts of knowledgeable researchers, who ideally will themselves be suited to outreach.
- Seek out *"stakeholder" views* as to what would be helpful.
- Consider putting effort into *networking* with others who have similar aims, bearing in mind that that is a "soft investment" of time; while it may be very useful, you won't know that at the start.
- Publishing papers in and attending *education conferences in your field* is a strong way to spread the reach of a project as well as a general way to spread best practice and also a way of meeting prospective partners.
- Actively aim to link with and support *other public engagement projects*.
- Public engagement that goes beyond individual research projects is *very, very powerful*.

Advice for Funders
- *Support wide-ranging public engagement* projects, not just those linked to single pieces of research.
- Continue to recognise that public engagement can be especially important when there are concerns about level of interest in a subject for which *national capacity* is desired. (For example, at its start cs4fn was one of only a few "voices in the wilderness" when perception of computer science was as a deadly dull subject.)
- As new disciplines or technologies emerge, be prepared to help with quick *building of momentum* in extensive public engagement so that young people and teachers can keep pace.
- *Context* of new technologies in society needs to be understood, which often calls for interdisciplinarity.
- Public engagement can help *engender creativity and entrepreneurship* in others, but it can be scary for those undertaking it.
- Be flexible; allow individuals conducting public engagement to take *opportunities* that arise (as in Royal Society events or "guerrilla science" such as the Blade Runner event in which a cs4fn team member input reached thousands of people).
- *Allowing flexibility* can give a project the room to support other public engagement efforts' opportunities, synergistically.
- *Be wary of the REF's emphasis* on linearity and "bits" of public engagement being done on "bits" of research. In contrast a public engagement initiative can gain strength by having a broad portfolio, taking on anything that would be exciting for audiences.
- Recognise that there are some people who specialise in *science communication* or public engagement and may thus have skills, practices and understanding to offer that will complement researchers. These may be very important team members or advisors.
- *Mentoring* can be a good idea, even for experienced people,
- Including an *evaluator as a critical friend* in a long-term project can help with reflection and evolution.
- Recognise the frequent infeasibility of providing "proof" of causality of many changes contributed to by public engagement efforts; appreciate instead the *processes, multipliers, influences, indicators and case studies that, together, tell the story*.
- Recognise that academic researchers individually vary widely in their capability to both understand state-of-the-art research (and scout for good ideas) and conduct effective

public engagement, or even write accessible articles. *Not every researcher can do public engagement*.

- *Not all public engagement efforts will be equally successful*. (In the case of cs4fn, the two PIs realised they shared a vision, creativity and the ability to reach others; then the science communicator funded by the EPSRC award completed the team. In effect, there was a perfect storm – people, opportunities, time, talent, space to be creative. This is not always the case!)
- There are good ways to do public engagement and *good ways of investing in likely winners*. Find the right people, who can form creative teams and seize opportunities.
- Funders should *celebrate public engagement*. Tell positive stories on funder websites.
- Include more explicit sections on public engagement in *applications* and expect to assess it once projects are delivered.
- Watch for opportunities to contribute toward a *culture change* in the world of universities and research so that a more positive attitude toward public engagement becomes embedded.
- A message to funders from cs4fn: "*Thank you!* – for giving us a opportunity to do some wonderful stuff. It genuinely has been some of the most important parts of our lives."

5.4 Conclusion

The cs4fn team, and EPSRC as its funder, took a risk. Creativity is by definition risky, and cs4fn is predicated upon creativity. The spotting of interesting ideas and angles, the writing of each story, the development of each magazine, the design and varying presentations of live shows are all creative processes. Early on in the era of national bemoaning the lack of interest in computer science among bright young people, the cs4fn team decided to convey consistently but in often off-beat ways the message that computer science is/can be 'serious fun', that computer science is inherently interesting as a rich multi-faceted subject and that it underpins a wide range of attractive careers. This approach has worked. Vast numbers of students at UK schools, and abroad, have been exposed to the magazine, the website and/or presentations at school visits or festivals. Teachers too have used the various cs4fn deliverables (products or activities) as a resource; now more than ever as the curriculum shifts occur cs4fn is contributing directly to teachers through a website portal, workshops and CPD. Colleagues at various universities and different science outreach initiatives have made use not only of cs4fn materials but also its learning about good practice. The innovative juxtaposition of magic with computer science, in live presentations and in cs4fn publications, exemplifies the initiative's success in creativity.

Through five years of EPSRC investment, and above-and-beyond effort by a deeply committed team, cs4fn has led to a diverse portfolio of important impacts on a full range of scales: from sparking excited interest in individual school students, to mentoring next generation researchers in science outreach, to supporting numerous teachers with accessible and distinctive resources, to helping to bring about a zeitgeist change as to how computer science can best be viewed and taught.

At its final retreat in May 2013, the team noted with feeling that a fundamental irony exists in the fact that the EPSRC funding for cs4fn is coming to an end exactly at the time when the changes cs4fn helped to bring about nationally are moving ahead. Financial sustainability has not been achieved in the sense that the activity of cs4fn will not be able to continue at the same scale. However, the autumn 2013 Greater London Authority award focused on teachers, in London, was very positive news and should ensure that the core magazine and other specials will continue to be produced until July 2015. Public engagement line items from other QMUL grants will support additional specials. Although it is thus likely to produce fewer 'fruits', the cs4fn 'tree' itself will continue to survive. Furthermore, it has sown multiple

seeds. With ongoing uptake of cs4fn materials and practices by those who have come to have deep respect for the cs4fn brand, cs4fn will continue to have influence – a living legacy.

Acknowledgements

Annexes

A. Core Questions Framework: Evaluation of cs4fn

B. Illustrative Table of Contents, cs4fn Magazine

C. cs4fn Publications

D. Teacher/Librarian Comments, Sample of Feedback, cs4fn Magazine

E. Views of cs4fn Website

F. Survey of Teachers about cs4fn school talks, teacher feedback

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H. cs4fn team conference and workshop talks in support of teachers

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J. Presentations to Educators and Related Academic Publications

K. pdf Download Statistics

ANNEX A: Core Questions Framework: Evaluation of cs4fn

A common framework of core questions was devised to ensure that information gathered would, in the aggregate, address the full set of cs4fn project objectives. This common framework provided structure for various methods and tools capturing quantitative and qualitative, formal and informal information, and thus aided integration of analyses across methods. Key question categories are captured below.

I. Participation of students (including but not limited to girls, ethnically diverse students; full classes of different ages-not just IT classes)

II. Participation of teachers/schools

III. Satisfaction

IV. Enjoyment/fun of learning/enthusiasm

V. Later pursuit of computer science and/or science generally; recruitment by QMUL, partners and more generally.

VI. "Rebranding" of subject, changed perception, removal of stigma—CS becoming socially acceptable, awareness of diversity of people, problems, jobs. Understanding that CS can be socially useful, empowering to make the world a better place

VII. Recognition of value of outreach activity for the subject, perhaps also academic articles.

VIII. Spread of activity/mentoring re outreach etc/success of "mentees"; development of network of regional champions-maybe even internationally

IX. Interactions with/engagement of advisors, companies, others

X. Progress toward sustainability of cs4fn effort, some level of stability/longevity without compromise (range of types of sustainability)

XI. Contributions, Added Value (Influences, impacts)

XII. Lessons learned, good/best practice

ANNEX B: Illustrative Table of Contents, cs4fn Magazine

Does your computer understand you?
- **How user-friendly is a baby**
- **Making computers that treat you right**
- **Can emotions spread through Facebook?**
- **Will your next phone be a banana?**

ANNEX C: cs4fn Publications

cs4fn: Computer Science for Fun Magazine

1. Black, J. and Curzon, P. and McOwan, P.W. (Eds) (2013) cs4fn: Computer Science for Fun, Issue 16: Clean up your Language!, Queen Mary, University of London.
2. Black, J. and Curzon, P. and McOwan P.W. (Eds.) (2013) cs4fn: Computer Science for Fun, Issue 15: Does your computer understand you?, Queen Mary, University of London.
3. Black, J. and Curzon, P. and McOwan P.W. (2012) cs4fn: Computer Science for Fun, Issue 14: Alan Turing, Queen Mary, University of London.
4. Black, J. and Curzon, P. and McOwan P.W. (2011) cs4fn: Computer Science for Fun, Issue 13: Faces, Queen Mary, University of London.
5. Black, J. and Curzon, P. and McOwan P.W. (2010) cs4fn: Computer Science for Fun, Issue 12: Computing on the catwalk, Queen Mary, University of London.
6. Black, J. and Curzon, P. and McOwan P.W. (Eds.) (2010) cs4fn: Computer Science for Fun, Issue 11: Computer animation proudly presents..., Queen Mary, University of London.
7. Black, J. and Curzon, P. and McOwan P.W. (Eds.) (2009) cs4fn: Computer Science for Fun, Issue 10: computing goes mobile, Queen Mary, University of London.
8. Black, J. and Curzon, P. and McOwan P.W. (Eds.) (2009) cs4fn: Computer Science for Fun, Issue 9: programmed to save the world, Queen Mary, University of London.
9. Black, J. and Curzon, P. and McOwan P.W. (Eds.) (2008) cs4fn: Computer Science for Fun, Issue 8: computer science in space, Queen Mary, University of London.
10. Curzon, P and McOwan P.W. (Eds.) (2008) cs4fn: Computer Science for Fun, Issue 7: computer science and the image, Queen Mary, University of London.
11. Curzon, P and McOwan P.W. (Eds.) (2007) cs4fn: Computer Science for Fun, Issue 6: computer science everywhere, Queen Mary, University of London.
12. Curzon, P and McOwan P.W. (Eds.) (2007) cs4fn: Computer Science for Fun, Issue 5: the perception deception, Queen Mary, University of London.
13. Curzon, P and McOwan P.W. (Eds.) (2006) cs4fn: Computer Science for Fun, Issue 4: computer science and biolife, Queen Mary, University of London.
14. Curzon, P and McOwan P.W. (Eds.) (2006) cs4fn: Computer Science for Fun, Issue 3: computer science and entertainment, Queen Mary, University of London.
15. Curzon, P and McOwan P.W. (Eds.) (2005) cs4fn: Computer Science for Fun, Issue 2: magic of computer science, Queen Mary, University of London.
16. Curzon, P and McOwan P.W. (Eds.) (2005) cs4fn: Computer Science for Fun, Issue 1: Sodarace special, Queen Mary, University of London.

Audio!: Audio Engineering for Fun Magazine

1. Curzon, P and Dixon, S. (Eds.) (2013) Audio!, Issue 4, Queen Mary, University of London.
2. Curzon, P and Dixon, S. (Eds.) (2010) Audio!, Issue 3, Queen Mary, University of London.
3. Curzon, P and Dixon, S. (Eds.) (2010) Audio!, Issue 2, Queen Mary, University of London.
4. Curzon, P (Ed.) (2008) Audio!, Issue 1, Queen Mary, University of London.

ee4fn!: Electronic Engineering for Fun Magazine

1. Curzon, P and McOwan P.W. (Eds.) (2012) ee4fn, Issue 2, Queen Mary, University of London.
2. Curzon, P and McOwan P.W. (Eds.) (2011) ee4fn, Issue 1, Queen Mary, University of London.

Other booklets and Specials

1. Curzon, P and McOwan P.W. (Eds.) (2009) The Magic of Computer Science II, Book 2: now we have your attention, Queen Mary, University of London.
2. Curzon, P and McOwan P.W. (Eds.) (2008) The Magic of Computer Science, Book 1: card tricks special, Queen Mary, University of London.
3. Curzon, P., McOwan P.W. and Black, J. (Eds.) (2008) Artificial Intelligence...but where is the intelligence?, Queen Mary, University of London.
4. Curzon, P., Black, J., Myketiak, C., McOwan, P.W. & Shoop, K (Eds.) (2010) The Women are here, cs4fn: Computer Science for Fun Annual, 2, Queen Mary, University of London.
5. Curzon, P and McOwan P.W. (Eds.) (2007) cs4fn: Computer Science for Fun Annual, Issue 1, Queen Mary, University of London.

Puzzles

1. Curzon, P., Black, J. and McOwan. P.W. (2009) cs4fn Magic of Computer Science: The teleporting Robot. Queen Mary, University of London.
2. Curzon, P., McOwan, P.W. and Black, J. (2011) The robot dog illusion. Queen Mary, University of London.
3. Curzon, P., McOwan, P.W. and Black, J. (2011) The emotion machine. Queen Mary, University of London.

Posters

1. Curzon, P., Black, J. and McOwan. P.W. (2012) The women are here! Queen Mary, University of London.
2. Curzon, P., Black, J. and McOwan, P.W. (2012) Could your best friend be a robot? Queen Mary, University of London.

ANNEX D: Teacher/Librarian Comments, Sample of Feedback, cs4fn Magazine

We asked teachers asking for extra copies of the cs4fn magazine to tell us why they wanted them. Here is a sample.

- "Am previous bulk subscriber for Computing club at [a] Specialist Technology College, where magazines has inspired the club to seek opportunities to learn more about computing."
- "I came across issue 7 for the first time and I am very impressed by the content and context. I think this would be of great interest to our computing, multimedia and art students."
- "The magazines provide a fun, but informative way of putting Computing into perspective with real life."
- "We believe your magazines are highly informative, interesting and relates to topical ICT issues (Issue 6 was excellent). Additional issues would be an excellent resource for our students taking options in Year 9 who are interested in ICT and would benefit from seeing links between ICT, Science, Art and technology. This could enable them to make informed option choices based around areas of interest, links between subject areas and would also help them understand potential job opportunities."
- "This magazine is great! Please send 25 copies for me to use in my computer science technology class."
- "I am teaching some first year students the basics of ethics and IT so these would make a great workshop activity"

Feedback from Teachers around using magazines to support English/literacy

- "...copies in order to offer our students an alternative to fiction/non-fiction books. ... They will also be used in English when studying a range of text types."
- " technology teachers are both very impressed with the easy layout as we have a lot of pupils with not great literacy skills but plenty of enthusiasm and interest."
- "I would like sufficient copies for each of the English department staff. This magazine would be excellent for practise with extracting information from non-fiction texts, as students are required to do in their English Language exam, with subject matter that is interesting and articles that are not too long. "
- "would love extra copies to put into our Vertical Tutoring literacy boxes as a science/DT resource (literacy boxes tend to be very 'English Literature' in nature!). 85 copies would allow for one per box plus a couple of spare. The literacy boxes are used at least once a week during VT time to encourage the students to develop their reading skills and to impart the importance of reading around their subject areas."

Sample of Feedback from Teachers about ee4fn magazine

We asked teachers asking for extra copies of ee4fn to tell us why they wanted them.

- "Fantastic response to the first magazine-it has already been whisked away by our Head of ICT for use in lessons"
- "4 X class sets to give free to top set pupils (at a single sex [girls] school) in order to inspire, motivate and exemplify further study and career opportunity within STEM subjects"
- "AS AN EX-ELECTRONICS ENGINEER THIS MAGAZINE IS THE SORT OF ENCOURAGING PUBLICATION THAT HAS BEEN LACKING IN SCHOOLS"
- "I have just received a copy of EE4FN and am very impressed. "
- "...getting a personal copy would help enthuse the pupils even more."

- "It has had interest from pupils in our LRC. Therefore I am reqesting a class set in order to put more in the LRC for reading and also to give to our Computing dept for distribution in their clubs etc."
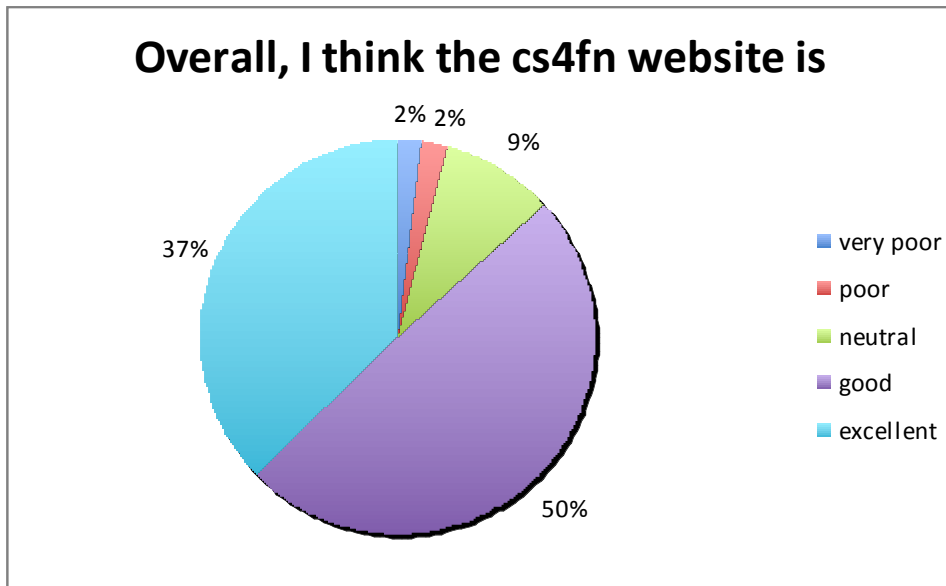
Sample of Comments from School Librarians about magazines and booklets

We asked librarians asking for extra copies of our magazines and booklets to tell us why they wanted them.
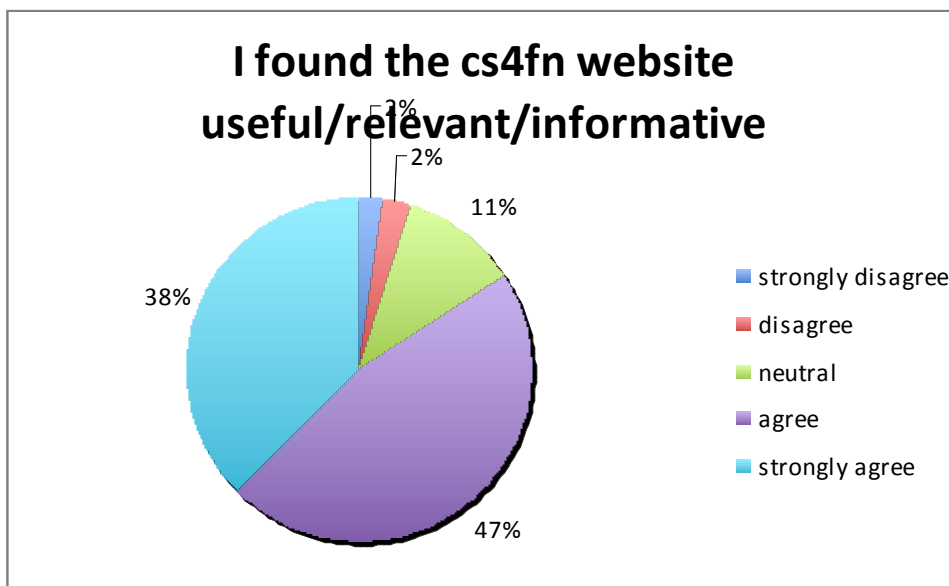
- "Your magazine is a popular read in our library. We are always trying to ensure our students have access to inspiring and thought-provoking resources, and there is a definite gap in our computing section for a book on women in the field."
- "I am currently setting up a new library in an Academy and your publication was recommended by colleagues as a good resource."
- "I would like to put copies in areas of the school other than the Library and students are more likely to pick up a magazine than a book. As I also act as Librarian to our co-located Special School I will put a copy or two there. There are students who would find the articles very interesting."
- "I received a free copy of your magazine and asked the I.T department to take a look- they were very impressed and asked if I could obtain multiple copoes for use throughout the I.T and sciences departments. I am not sure how many copies I can have but as many as possible would be fantastic."
- "Small university library wanting to provide computing resource options to students."
- Please send 16 copies for use in our library and can be passed on to the staff. I would like a copy of Women in computing also please."
- "As a former Women's Studies student I am interested in anything that celebrates women's contribution to science, history etc. Also, our school runs a girl's computer club and the publication would be a great resource for this."
- "I would like to put copies in all of our libraries and also give some to our ICT Department. Many thanks"
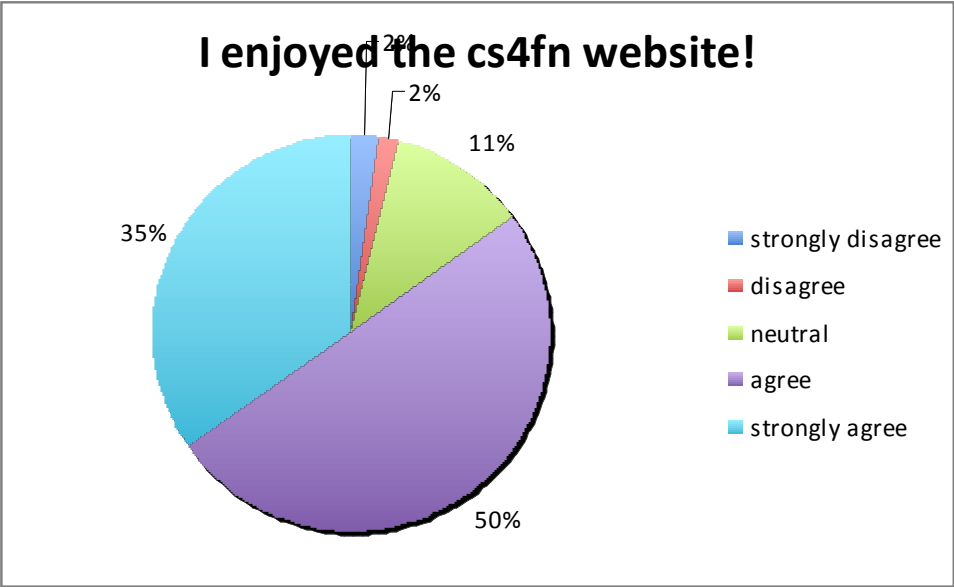
ANNEX E: Views of cs4fn Website

A questionnaire has been running on the cs4fn website since 2008. Responses (November 2008-July 2013) are captured here. Note: Total responses (N=between 1,234 and 1,261 per question) first, then pre-university students', then primary/secondary school teachers' responses.

Overall, I think the cs4fn website is

2% 2% 9%

37%

50%

- very poor
- poor
- neutral
- good
- excellent

Total responses
N=1261

I found the cs4fn website useful/relevant/informative

2% 2% 11%

38%

47%

- strongly disagree
- disagree
- neutral
- agree
- strongly agree

Total responses
N=1241

63

I enjoyed the cs4fn website!

- strongly disagree
- disagree
- neutral
- agree
- strongly agree

2% 2% 2%
11%
35%
50%

Total responses
N=1234

I found the cs4fn website simple and easy to use

- strongly disagree
- disagree
- neutral
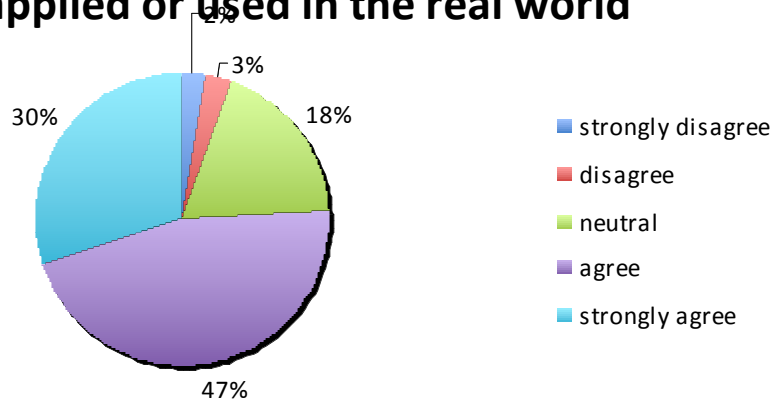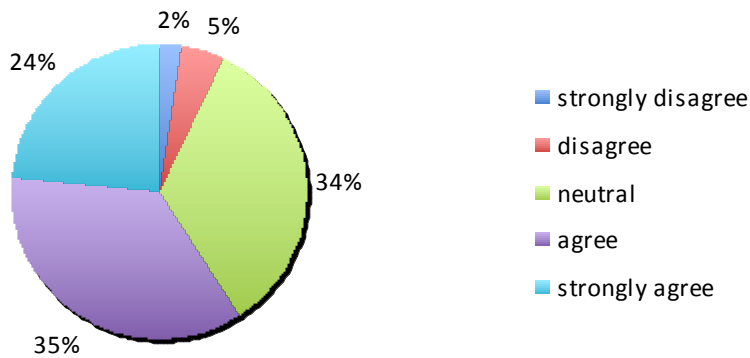- agree
- strongly agree

2% 3%
15%
34%
46%
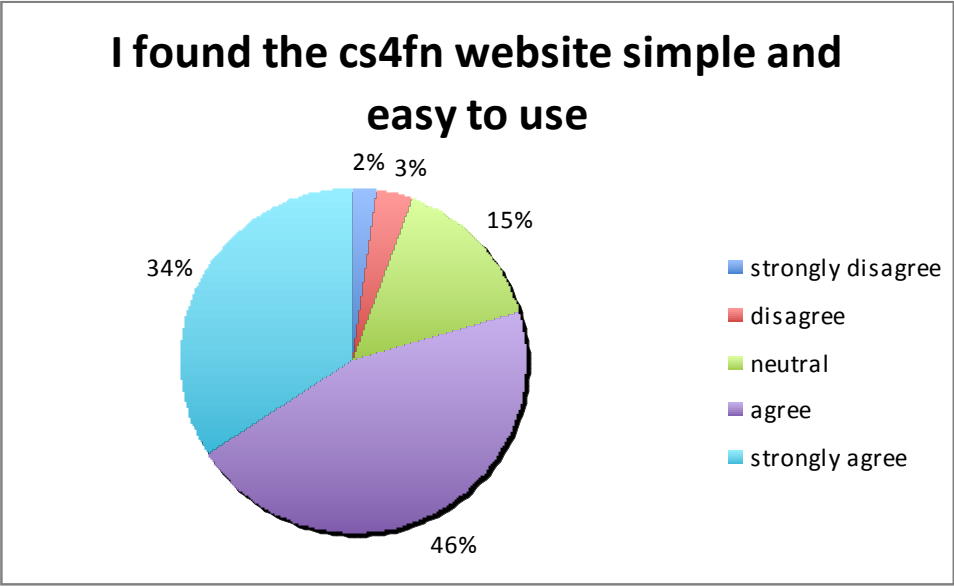
Total responses
N=1249

The website has helped me see more ways in which computer science is applied or used in the real world

- 2%
- 3%
- 18%
- 30%
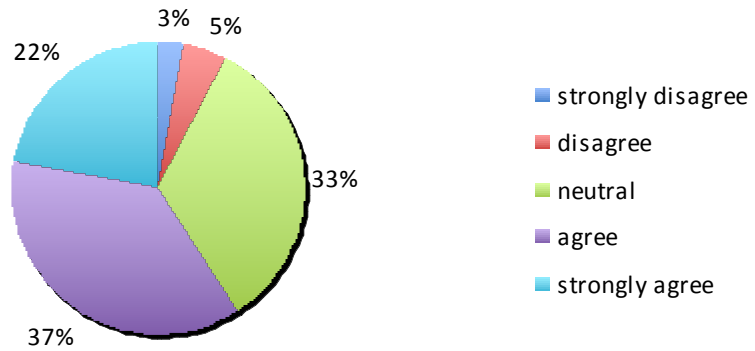- 47%

Legend:
- strongly disagree
- disagree
- neutral
- agree
- strongly agree

Total responses
N=1242

I think of computer science as more interesting than I did before coming to the cs4fn website

- 2%
- 5%
- 24%
- 34%
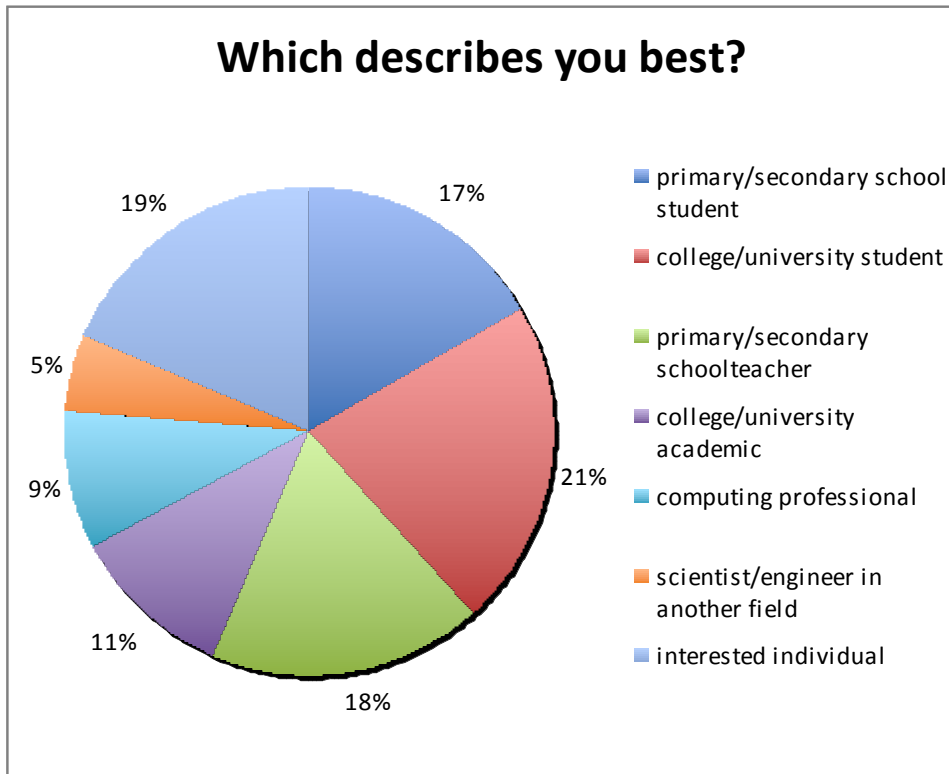- 35%

Legend:
- strongly disagree
- disagree
- neutral
- agree
- strongly agree

Total responses
N=1243

The website has helped me think of a variety of careers that would use computer science

3% — strongly disagree
5% — disagree
33% — neutral
37% — agree
22% — strongly agree

Total responses
N=1236

Which describes you best?

- primary/secondary school student — 17%
- college/university student — 21%
- primary/secondary schoolteacher — 18%
- college/university academic — 11%
- computing professional — 9%
- scientist/engineer in another field — 5%
- interested individual — 19%

Total responses
N=1287

Pre-University STUDENT responses

Overall, I think the cs4fn website is

- very poor
- poor
- neutral
- good
- excellent

4% 2%
11%
41%
42%

Students
N=232

I found the cs4fn website useful/relevant/informative

- strongly disagree
- disagree
- neutral
- agree
- strongly agree

4% 3%
12%
36%
45%
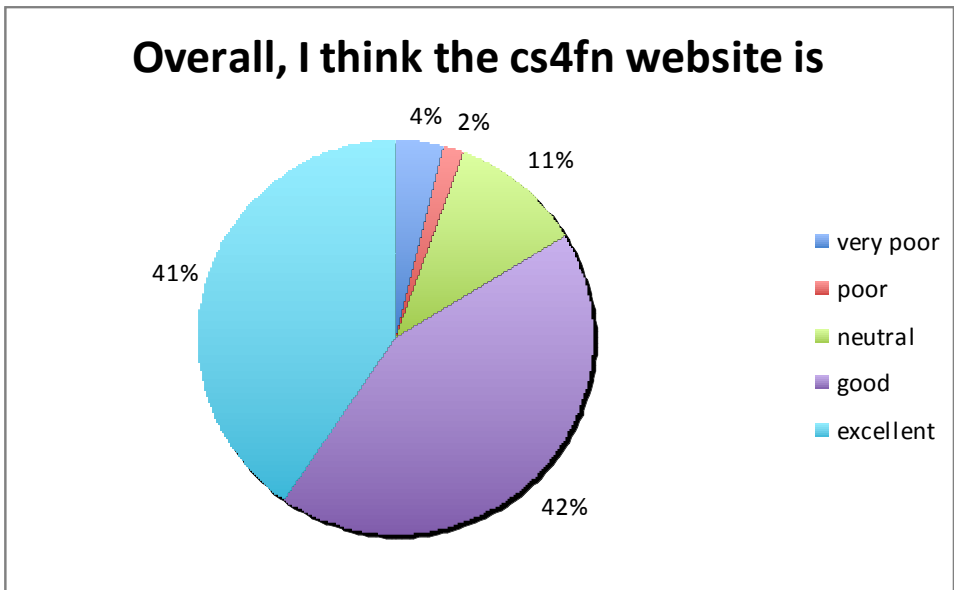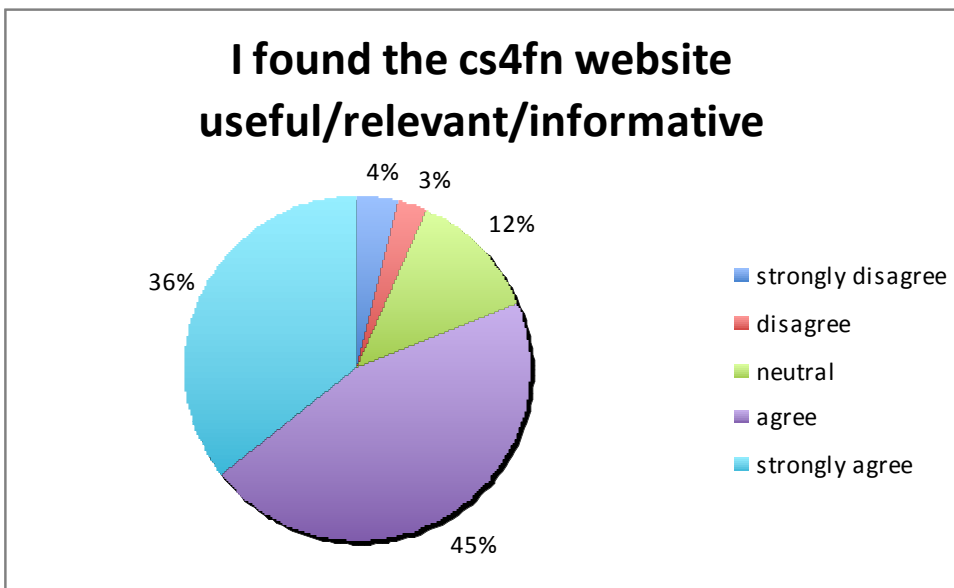
Students
N=227

I enjoyed the cs4fn website!

- strongly disagree
- disagree
- neutral
- agree
- strongly agree

4% 1% 14% 33% 48%
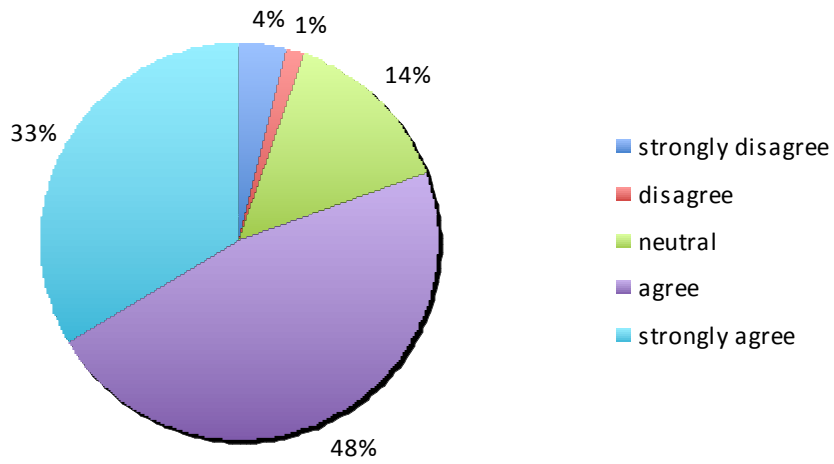
Students
N=227

I found the cs4fn website simple and easy to use

- strongly disagree
- disagree
- neutral
- agree
- strongly agree

5% 3% 15% 40% 37%
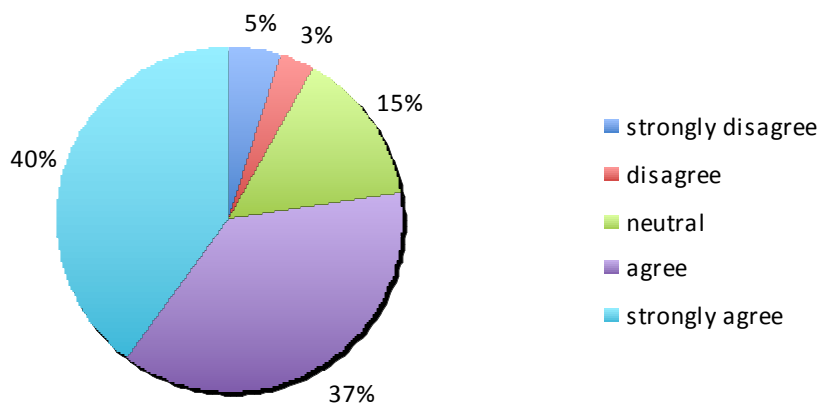
Students
N=227

The website has helped me see more ways in which computer science is applied or used in the real world
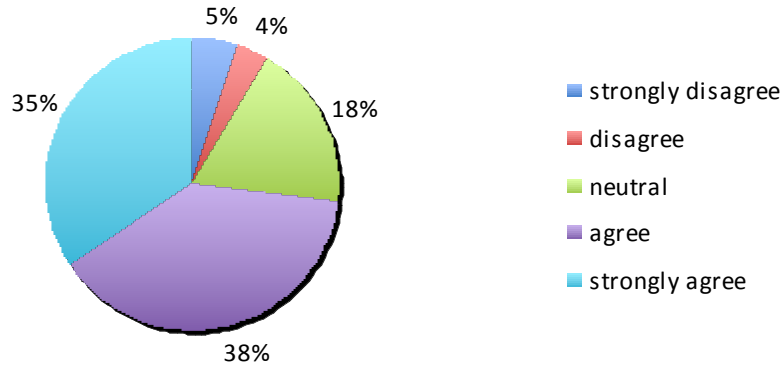
Students
N=223

I think of computer science as more interesting than I did before coming to the cs4fn website
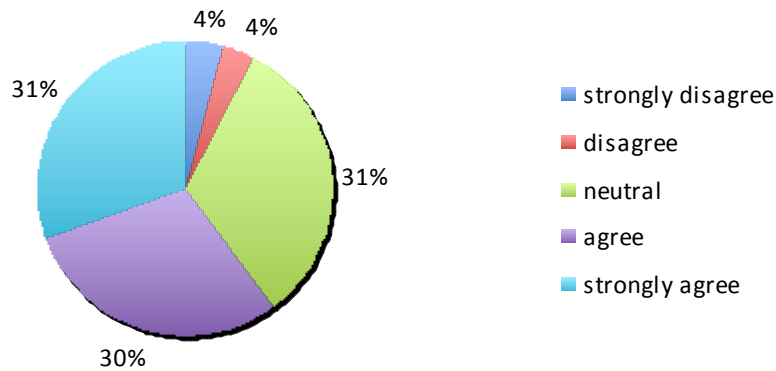
Students
N=219

The website has helped me think of a variety of careers that would use computer science

- strongly disagree
- disagree
- neutral
- agree
- strongly agree

5% 4% 28% 27% 36%
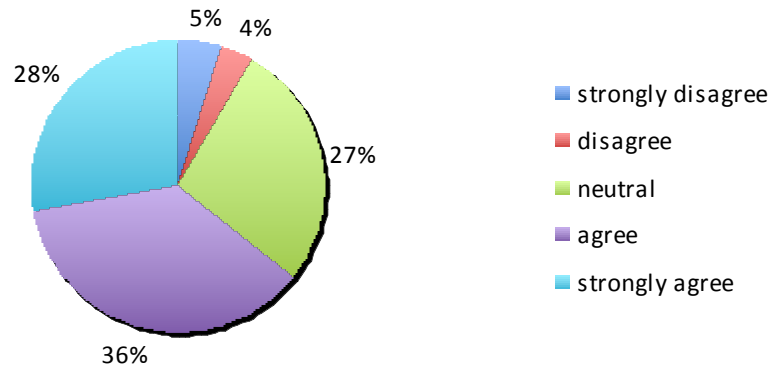
Students
N=217

Primary/Secondary Teachers' Responses

Overall, I think the cs4fn website is

■	very poor
■	poor
■	neutral
■	good
■	excellent

0% 2% 6%

45%

47%

Teachers
N=252

I found the cs4fn website useful/relevant/informative

■	strongly disagree
■	disagree
■	neutral
■	agree
■	strongly agree

0% 1% 7%

46%

45%
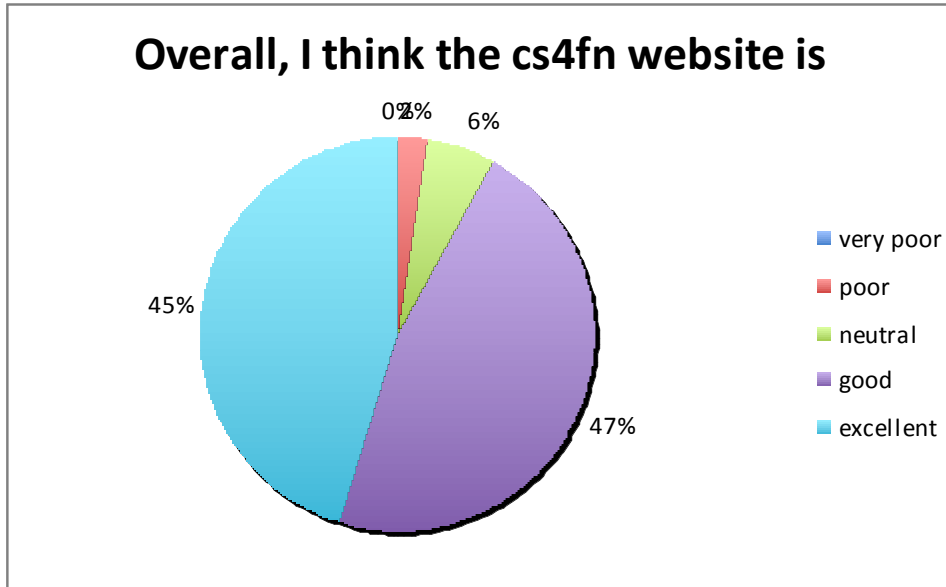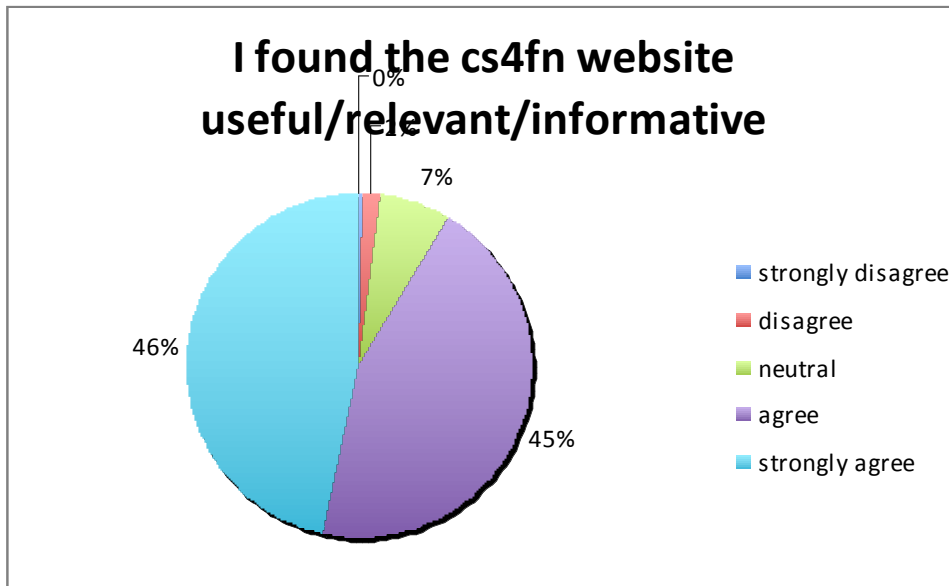
Teachers
N=245

I enjoyed the cs4fn website!

- strongly disagree
- disagree
- neutral
- agree
- strongly agree

1% 1% 5%
42%
51%

Teachers
N=252

I found the cs4fn website simple and easy to use

- strongly disagree
- disagree
- neutral
- agree
- strongly agree

0% 3% 14%
34%
49%
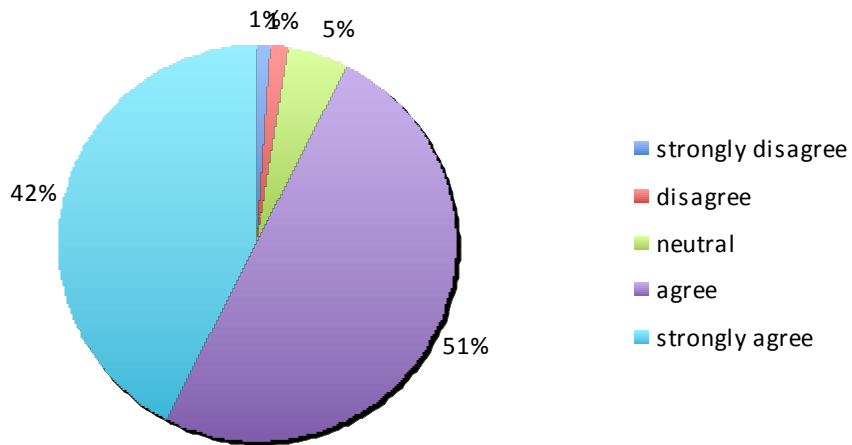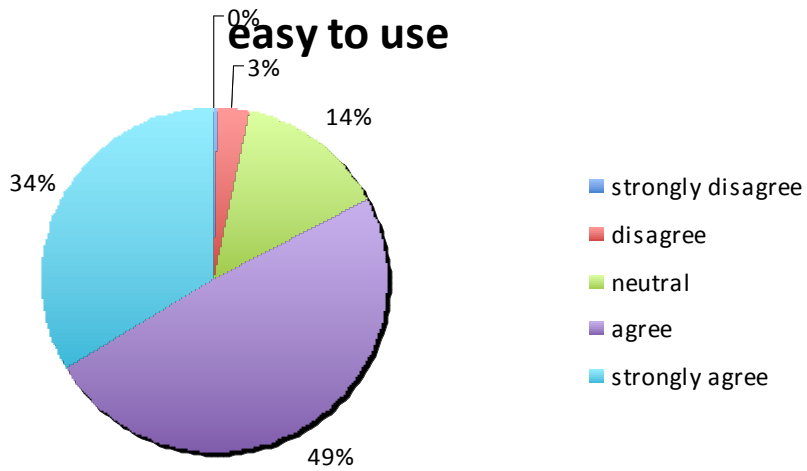
Teachers
N=250

The website has helped me see more ways in which computer science is applied or used in the real world

1%	strongly disagree
3%	disagree
16%	neutral
51%	agree
29%	strongly agree
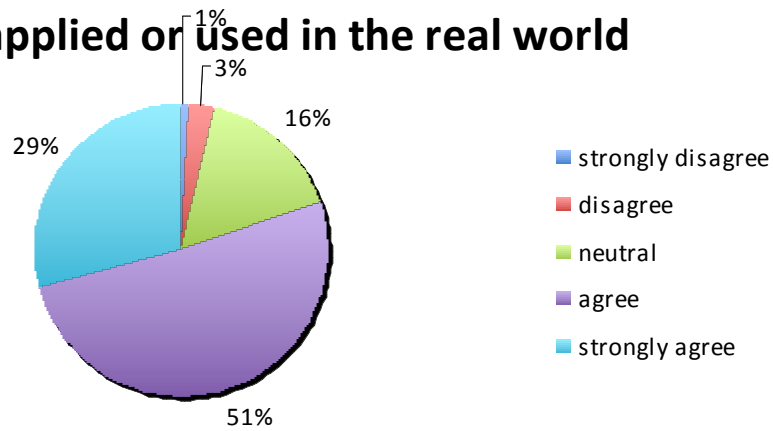
Teachers
N=250

I think of computer science as more interesting than I did before coming to the cs4fn website

1%	strongly disagree
4%	disagree
40%	neutral
36%	agree
19%	strongly agree
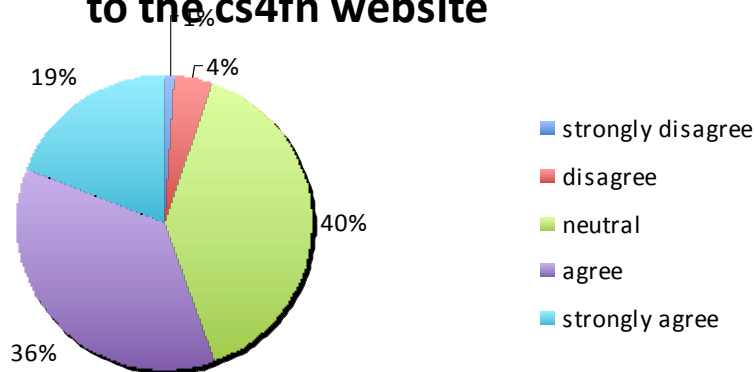
Teachers
N=249

The website has helped me think of a variety of careers that would use computer science

0%
3%
17%
37%
43%

- strongly disagree
- disagree
- neutral
- agree
- strongly agree
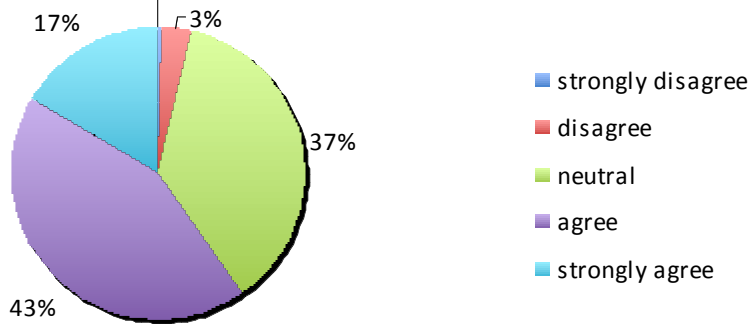
Teachers
N=250

ANNEX F: Survey of teachers about cs4fn school talks, teacher feedback

From December 2010 to December 2012 we conducted a survey of teachers who had organised talks we gave at their school. 30 teachers responded about 9 different talks given by 4 different presenters. Between them the talks covered students from Years 7 to 13. 27 percent were to male only audiences, 20 percent were to female only audiences and 53 percent to mixed audiences. 54 percent were to state schools and 46 percent to independent schools. 56 percent were selective and 44 percent non-selective.

- 83 percent of teachers surveyed said the talk was very good (the highest rating). All were positive (on the 5 point scale).
- 100 percent of teachers surveyed after we had visited their school said the talk had met their needs.
- 100 percent of teachers surveyed after we had visited their school said they would recommend us to other teachers.
- 100 percent agreed the students enjoyed the lecture.
- 100 percent agreed the students found the lecture interesting.
- 100 percent agreed the lecture had improved the understanding of the students of the subject.
- 83 percent agreed that some students have changed their view of computer science in a positive way.
- 71 percent agreed or strongly agreed that as a result of the lecture one or more students is now more likely to consider taking COMPUTING subjects further at SCHOOL. 25 percent strongly agreed. None disagreed.
- 58 percent agreed or strongly agreed that as a result of the lecture one or more students is now more likely to consider taking SCIENCE, ENGINEERING or MATHS further at SCHOOL. 25 percent strongly agreed. None disagreed.
- 79 percent agreed or strongly agreed that as a result of the lecture one or more students is now more likely to consider taking COMPUTER SCIENCE at UNIVERSITY. 29 percent strongly agreed. Only one teacher disagreed.
- 69 percent agreed or strongly agreed that as a result of the lecture one or more students is now more likely to consider pursuing SCIENCE, ENGINEERING or MATHS at UNIVERSITY. 17 percent strongly agreed. Only one teacher disagreed.

What did teachers think were the best things about the talk?

- "Aimed at the right level for the students Very interesting examples to support the lecture"
- "A unique way of grabbing the attention of the students and allowing them to learn without them realising it."
- "Visiting academic. Engaging, Freebies for kids"
- "The year 8 students enjoyed the noughts and crosses activity, the cleverbot video and the examples of artificial intelligence in everyday life"
- "It was very accessible- and extremely slick in the way it was put together."
- "The lecture was fast-paced, dynamic and really challenged the students. They engaged with it very well and several remained behind to ask questions afterwards. This was a very appealing way to promote the study of ICT."
- "[The lecturer's] delivery was excellent. He engaged his audience throughout. He made quite complex concepts accessible to our weakest students."
- "The start was a good introduction to the overall origins and theory - but the best bit really came with the interactive demonstrations and real-life modelling of computer functionality."

- "Just right level. Lecturer very sensitive to audience. Lecturer gained involvement of students."
- "Getting the students involved with activities such as building a brain. Opening the students minds to new concepts and new ways of thinking."
- "The mix of talking, video and practical examples."
- "Video animations + the noughts and crosses game + big [sic] blue went down well"
- "The more interactive parts of the lecture - where pupils could calculate and get more involved"
- "Practical hands on activities really engaged students - starting talk with 20Q which some had seen before, sweet computer to help build understanding of computer learning - and emphasis on drawing out students' own ideas"
- "The tasks/activities which the students undertook. These were very enjoyable and made their points well."
- "The lecture was well presented, relevant and made the students aware of many interesting issues."
- "The content actually matched the syllabus so students found it very relevant"
- "It was an exciting and fun approach to Computing and all the tricks worked (obviously)! [The lecturer] was on time and very kind and entertaining to the pupils. They were all thoroughly engaged! It was very interactive for everybody which was fantastic!"
- "The lecture was spot on for the age and enthusiasm of the audience. The pace was varied and the audience were involved."
- "[The lecturer] had a lovely style of delivery and managed to persuade a quiet and slightly shy group of girls to take a full part and really enjoy the process. I did not fill in the part about having changed the student's choice of subjects as they have already made their choices but the girls did say that next year we should involve the year 12s as some of the students in this session wished that they had known how interesting the subject could be! The squishy brains were a good incentive to volunteer!"
- "Enthusiastic, interesting, relevant, stimulating, overall an excellent lecture. Really really pleased with it, definitely going to ask for another one next year."
- "Just the fact that it opened their eyes to computing being something that they should consider."
- "Interactivity!"
- "Interaction with students, varied approach to delivering message, confident delivery, pitched correctly, interesting and relevant"
- "Student comments: Involvement of the audience Not just talking at you but showing you something as well Use of practical items to talk about computing"
- "Computer/user reliability, medical content and of course the maths in the tricks!"
- "The lecturer was able to engage the students with practical examples how computer science is used. Good delivery and he also used student participation. Students are still talking about!"
- "This is an innovative way of bringing course content to life through a presentation. Schools I am sure would welcome this approach from other university departments. This is much more interesting than departmental presentations about entry requirements and course content. With this approach students become inspired to look at a new area of potential study. In school we are constantly trying to broaden the students' understanding and appreaciation of the many routes they can take into higher education. The computer science talk model is the best way I have come across so far."
- ["The lecturer's] interaction with the students. He pitched the lecture to the students at the right level. After the lecture, one member of staff, said that his teaching method was inspiring."

Open feedback

- "Please can I organise another one for the school!!"
- "I look forward to arranging other lectures for our girls [...]"

- "We were delighted with the session and hope that [cs4fn] will be willing to come back and talk to our students again in the future. I am sorting the Sixth Form options for next academic year at the moment and there has been an explosion of interest in ICT (this year 2 students taking AS ICT; next year 12!), so his lectures are becoming ever more important to our students."
- "It was great to have a member of a university speaking in school. It is so good you run this outreach programme - but I had to search quite hard to find it. As school teachers we spend our days preparing our (fee paying) students for the "next step" so it was very helpful for everyone to meet someone who works at this level. The students were keen to ask questions about computing at uni both at the time and afterwards. I certainly hope Queen Mary will come and deliver another talk - I note you have many interesting topics on offer. Very many thanks for an excellent session."
- "If possible, how can I find out about all the lecturers and people that might be able to come to our school to deliver such talks? We're really interested in how technology and computing can relate to real-life relevant skills - especially the cool ones like making games and music!"
- "very well done!"
- "Thanks again for coming down and talking with our students."
- "Thanks for a very enjoyable and interesting afternoon!"
- "A very good lecture which I would like to be repeated again in the future. [The speaker] was very knowlegable and enthusiastic, gave the students and myself a lot to think about."
- "[The speaker] had a captive audience who responded very well to his presentation."
- "Thank you for speaking to our students the 5 schools involved all found it very useful."
- "Thank you very much. The students were thrilled to have you, the school was thrilled to have you and for what its worth, I think you did an amazing job and really got to the core of enrichment."
- "Please come again!"
- "Such a shame that more pupils did not attend... Would love to have more of the same in the future"
- "Pitched at the right level for the audience and good content students were very enthusiastic afterwards. Schools need to ensure students attend this type of talk in the lower 6th before they have made their ucas choices Some of our better upper 6th students who have elected to study electrical engineering feel it would have influenced their choice of course"

ANNEX G: cs4fn at Science Festivals

1. Animation13, Manchester, July 2013
2. Big Bang South East, Crawley, July 2013
3. The Brighton Science Festival, February 2013
4. Think Computer Science, Duxford, December 2012
5. Festival della scienza, Genoa, Italy, October 2012
6. The British Science Festival, Aberdeen, September 2012
7. The Big Bang London, July 2012
8. Digital Shoreditch, London, July 2012
9. The Big Bang Fair, Birmingham, March 2012
10. The Brighton Science Festival, February 2012
11. Think Computer Science, Duxford, December 2011
12. Festival della scienza, Genoa, Italy, October 2011
13. Manchester Science Festival, October 2011
14. The British Science Festival, University of Bradford, September 2011
15. Facial perception: Facing up to faces: perception from brains to robots The Royal Society Summer Exhibition The Royal Society, London, July 2011
16. Oxford Music Festival, May 2011
17. The Magic of Computer Science and Sodarace, The Brighton Science Festival Brighton, March 2011
18. BCS Academy, January 2011
19. Manchester Science Festival, October 2010
20. Festival della scienza, Genoa, Italy, October 2010
21. The British Science Festival, University of Birmingham, September 2010
22. The Big Bang Fair, Manchester, March 2010
23. The Magic of Computer Science and Sodarace, The Brighton Science Festival Brighton, February 2010
24. The magic of computer science Manchester Science Festival Museum of Science and Industry, Manchester, October 2009
25. The sweet computer, Brain in a bag and Sodarace Walking with Robots at the Manchester Science Festival Museum of Science and Industry, Manchester, October 2009
26. The magic of computer science and The mind of the machine: artificial intelligence, The British Science Festival University of Surrey, Guildford, September 2009
27. The magic of computer science: now we have your attention, The Royal Society Summer Exhibition The Royal Society, London, June 2009
28. Sodarace, The Brighton Science Festival Brighton, February 2009
29. Sodarace, The Brighton Science Festival Brighton, February 2008
30. The perception deception, The Royal Society Summer Exhibition The Royal Society, London, July 2007
31. Sodarace, The Royal Society Summer Exhibition, The Royal Society, London, July 2005

ANNEX H: Cs4fn team conference and workshop talks in support of teachers

1. Curzon P. (2013) "The magic of computer science: making medical devices safer", Sussex ICT Teachers Workshop, February
2. Curzon P. (2012) "Computational thinking: interdisciplinary thinking skills for science", Group 86 Independent School Heads of Science Teachers Workshop
3. Curzon P. (2012) "The Art in Making computational thinking skills physical", ESRC Festival of Social Science: Integrating computer science with art
4. Curzon P. (2012) "cs4fn, magic and mystery: interdisciplinary fun with computer science", 11th Hatter Technology Seminar: Integrated Approaches to STEM Education, World ORT, London, 2 November.
5. Curzon P. (2012) "Games and magic tricks to help teach computing", 4th Computing at School Annual Conference, Birmingham, July.
6. Curzon P. (2012) The Magic of Computer Science: making the abstract tangible Bromley ICT Teachers Inset Day, Cooper's School
7. Curzon P. (2011) "Computer science for fun: thinking skills for interdisciplinary science and engineering", Computing WOrkshop for teachers, Anglia Ruskin University, July
8. McOwan, P. (2011) "Magic of Computer Science" 3rd Computing at School Annual Conference, Birmingham, June.
9. McOwan, P. (2011) "cs4fn" 3rd Computing at School Annual Conference, Birmingham, June.
10. Curzon P. (2011) "Interdisciplinary Computing, fun and thinking skills for everyone", BASS (Leading Boy's State Schools) Maths and Computing Teachers Workshop
11. Curzon P. (2011) "Thinking skills for science: having fun with interdisciplinary computing", International Independent Boys School Conference
12. McOwan, P. (2010) "cs4fn" 2rd Computing at School Annual Conference, Birmingham, June.
13. Curzon P. (2010) "Computer Science for Fun", Trinity Group (Leading London Independent Schools) ICT Teachers, Alleyn's School
14. Curzon P. (2009) 1st Computing at School Annual Conference
15. Curzon P. (2009) Inter-disciplinary Computer Science, fun and thinking skills for Science, Pan Berkshire Science Subject Leaders' Conference, Reading.
16. Curzon P. (2009) Fun science the cs4fn way, West Midlands STEM Conference - STEM Subjects Working Together, Embracing the Big Picture, Science Learning Centre, Keele University, June.
17. Curzon P. (2009) CS is magic, First Computing at School Teacher Conference, Birmingham, June.
18. Curzon P. (2009) cs4fn: Computer Science for Fun, West Berkshire Head of ICT Teachers Workshop, March.
19. Curzon P. (2009) cs4fn and the Magic of Computer Science, Glasgow University Teachers Workshop March.

ANNEX I: UK Distribution of cs4fn Subscribers
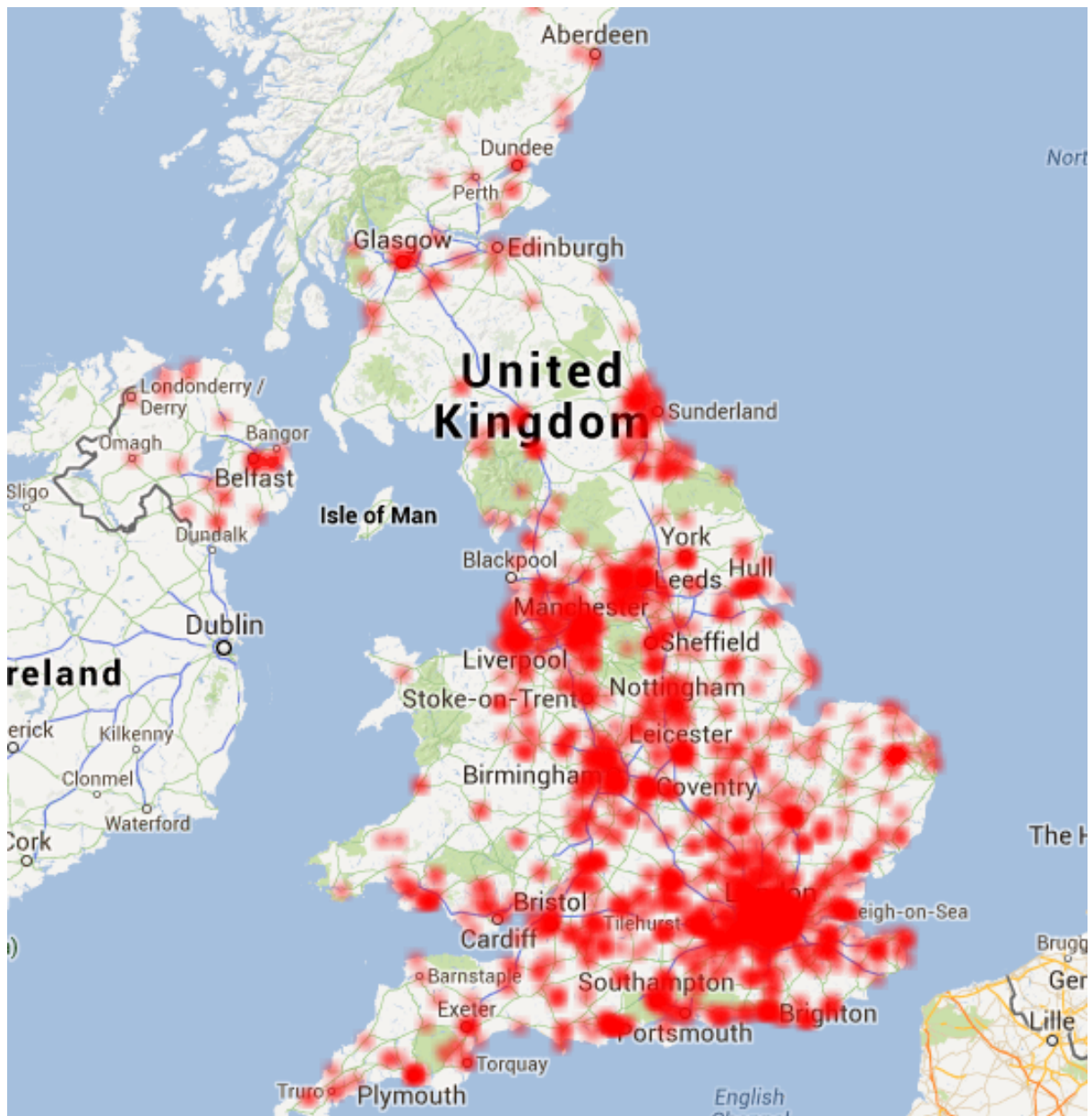
ANNEX J: Presentations to Educators and Related Academic Publications

1) J. Black, J. Brodie, P. Curzon, C. Myketiak, P. McOwan, L. Meagher (2013) "Making Computing Interesting to School Students: Teachers' Perspectives", ITiCSE '13, Innovation and Technology in Computer Science Education conference, J. Carter, I. Utting, A. Clear (Eds.), Pages 255-260, Canterbury, UK. DOI: 10.1145/2462476.2466519

2) Myketiak C, Curzon P, Black J, McOwan PW and Meagher LR (2012) cs4fn: a flexible model for computer science outreach. In Proceedings of ITiCSE '12 Proceedings of the 17th ACM annual conference on Innovation and technology in computer science education, Pages 297-302, ACM New York. DOI: 10.1145/2325296.2325366

3) P. Curzon, J. Black, L.R. Meagher and P.W. McOwan (2009) "cs4fn.org: Enthusing students about Computer Science", Proceedings of Informatics Education Europe IV, Christoph Hermann, Tobias Lauer, Thomas Ottmann and Martina Welte (Eds.), pp73-80, November.

4) Black, J., Curzon, P., Myketiak, C., and McOwan, P.W. (2011) A study in engaging female students in computer science using role models. In Proceedings of the 16th annual joint conference on Innovation and technology in computer science education (ITiCSE '11). ACM, New York, NY, USA, 63-67. DOI=10.1145/1999747. 1999768

5) Bell, T., Curzon, P., Cutts, Q., Dagiene, V., and Haberman, B. (2011) Introducing students to computer science with programmes that don't emphasise programming. In Proceedings of the 16th annual joint conference on Innovation and technology in computer science education (ITiCSE '11). ACM, New York, NY, USA, 391-391.DOI=10.1145/1999747. 1999904

6) Curzon, P., McOwan P.W., Cutts, Q. and Bell, T. (2009) "Enthusing & inspiring with reusable kinaesthetic activities", ITiCSE 2009, The 14th Annual Conference on Innovation and Technology in Computer Science Education, July, Paris. ACM SIGCSE Bulletin 41 (3), 94-98. DOI:10.1145/1595496.1562911

7) Curzon, P., Black, J., Meagher, L.R. and McOwan, P.W. (2009) cs4fn.org: Enthusing students about Computer Science, Proceedings of Informatics Education Europe IV, Eds. Christoph Hermann, Tobias Lauer, Thomas Ottmann and Martina Welte, pp73-80, November. preprint (pdf)

8) Curzon, P., McOwan P.W., and Black J. (2009) "The magic of HCI: Enthusing kids in playful ways to help solve the Computer Science recruitment problem". Invited Keynote at HCI Educators 2009 – Playing with our Education, Dundee, April 2009.

9) Curzon, P., Peckham, J., Taylor, H., Settle, A. and Roberts, E. (2009) Computational Thinking (CT): on weaving it in, ACM SIGCSE Bulletin 41 (3), 201-202. DOI: /10.1145/1595496.1562941

10) Curzon, P. and McOwan P.W. (2008) Engaging with Computer Science through Magic Shows, SIGCSE Bulletin 40 (3), pp179-183. ACM. ITiCSE 2008, The 13th Annual Conference on Innovation and Technology in Computer Science Education, DOI: 10.1145/1597849.1384320

11) Curzon, P., McOwan P.W. and Black, J. (2008) Securing the Future of Computer Science: Computer Science for Fun, Higher Education Academy Subject Centre for Information and Computer Sciences Annual Conference, Liverpool, August.

12) Curzon P.(2007) Serious Fun in Computer Science ACM SIGCSE Bulletin 39(3) p1, September. Invited Keynote at the 12th Annual Conference on Innovation and Technology in Computer Science Education, organised by the ACM Special Interest Group on Computer Science Education (SIGCSE) DOI: 10.1145/1269900.1268785

13) Curzon, P., McOwan P.W., Burton, E. and Gould, M. (2006), Engaging with Computer Science through Play and Performance, Presented at Designing the Not-Quite-Yet: Ideas and Methods for Engaging the Public in a Digital Future of their Choice, Workshop at HCI 2006: Engage, September.

14) Curzon, P. (2000) Learning Computer Science through Games and Puzzles. Interfaces 42, pp14, Spring.

ANNEX K: pdf Downloads

	2008	2009	2010	2011	2012	2013	Totals
Audio magazines							**12,877**
Audio Magazine Issue 1	64	3390	2223	1354	459	252	7,742
Audio Magazine Issue 2		846	1263	1177	559	194	4,039
Audio Magazine Issue 3				493	370	222	1,085
Audio Magazine Issue 4						11	11
cs4fn Magazines							**373,298**
cs4fn Magazine Issue 1	1720	10716	20361	9184	3763	2782	48,526
cs4fn Magazine Issue 2	2094	8576	15336	5279	2247	1460	34,992
cs4fn Magazine Issue 3	948	4602	8754	3107	1473	922	19,806
cs4fn Magazine Issue 4	1432	7670	13068	4561	1988	2057	30,776
cs4fn Magazine Issue 5	3078	8892	10500	3820	1722	874	28,886
cs4fn Magazine Issue 6	1220	5886	16062	2735	2827	1179	29,909
cs4fn Magazine Issue 7	4594	12682	15888	3832	1887	1333	40,216
cs4fn Magazine Issue 8	1210	11128	21258	6171	3786	2342	45,895
cs4fn Magazine Issue 9		11984	11880	3362	1373	898	29,497
cs4fn Magazine Issue 10			13002	2572	1280	806	17,660
cs4fn Magazine Issue 11			13326	7213	2495	1172	24,206
cs4fn Magazine Issue 12				5128	1843	1493	8,464
cs4fn Magazine Issue 13				3546	2282	1042	6,870
cs4fn Magazine Issue 14					3408	1590	4,998
cs4fn Magazine Issue 15					337	2260	2,597
cs4fn Annuals							**82,958**
cs4fn Annual 1	848	764	3168	1510	529	480	7,299
cs4fn Annual 2			52680	11516	5997	5466	75,659
ee4fn Magazines							**3,982**
ee4fn Magazine Issue 1				145	1295	1245	2,685
ee4fn Magazine Issue 2					317	980	1,297
Biology Loves Technology					189	490	**679**

	2008	2009	2010	2011	2012	2013	Totals
The Teleporting Robot		2,678	2,199	1,849	651	283	7,660
The Teleporting Robots (Italian)			249	266	91	44	650
The Robot Dot Illusion				1,767	1146	493	3,406
The Emotion Machine				1,099	653	239	1,991
The Emotion Machine (Italian)					38	61	99

Figure K.3 – Downloads of activity sheets for teachers

	2008	2009	2010	2011	2012	2013	Totals
1 The Intelligent Piece of Paper		1,402	2,487	2,842	1,417	1,246	9,394
2 Brain-in-a-bag: creating an artificial brain		892	1,566	1,857	770	536	5,621
3 Emotional robot video		776	1,746	2,103	640	481	5,746
4 Create a face: programming an emotional robot		1,546	2,823	2,422	788	496	8,075
5 Winning Games: the perfect Tic-tac-toe player		1,000	1,938	2,046	1,072	799	6,855
7a Sweet computer boards		320	1,095	1,210	463	282	3,370
7b The Sweet Computer: machines that learn		676	1,575	1,707	689	568	5,215
TuneTrace: a question of chance or a chance for a question?						145	145
TuneTrace and the rules of programming						171	171
Introducing Computational Thinking without Computers						18	18
STEM Conference - flyer		214	84	109	29	23	459
The Magic of Computer Science: Making Medical Devices Safer						21	21
Women in Computing [separate from the cs4fn annual]				114			114
Walkthrough Template for a Hotel Alarm	68	294	216	291	61	44	974

Figure K.4 – Other cs4fn activity sheets and posters

	2008	2009	2010	2011	2012	2013	Totals
Pixel picture: snake	162	536	1,044	439	143	28	2,352
cs4fn code breaking crossword	508	1,684	2,010	1,310	557	392	6,461
A cs4fn Kakuro to try	168	546	1,068	459	145	34	2,420
Leaflet Sudoku	358	1,498	2,280	1,055	318	175	5,684
brainacademysudoku	564	2,720	4,704	1,495	308	139	9,930
A cs4fn Kakuro to try	544	1,472	2,394	1,072	407	183	6,072
Pixel picture: snake	870	2,666	2,688	1,660	579	239	8,702
Perception deception: Maths made visual illusions (1)	96	524	642	680	228	160	2,330
Perception deception: Maths made visual illusions (2)	84	384	504	548	146	129	1,795
Perception deception: Maths made visual illusions (3)	94	608	504	572	184	132	2,094
Formal verification in human error modelling	34	88	144	220	11	4	501
Magic Eye Poster	94	440	591	547	169	132	1,973
Illusion Eye Poster	78	374	462	401	135	88	1,538
Sodarace Poster	94	512	594	682	199	143	2,224
The Physics Behind the Soda Constructor	558	1,768	4,380	1,242	997	1,788	10,733
Sodarace Tutorial	910	2,920	5,886	1,867	781	382	12,746

Figure K.5 – Downloads of *The Magic of Computer Science (1 and 2)*, and *The Mathematics of Mind*

The Magic of Computer Science 1 & 2	2008	2009	2010	2011	2012	2013	Totals
(1): Card Tricks Special	478	41,064	13,374	108,296	49,210	32,426	244,848
(1): Welsh / English			66	1,497	536	391	2,490
(1): German				12,711	8,127	31,00	23,938
(2): Now we have your attention		19,022	13,581	24,371	20,821	13,999	91,794
(2): Italian language			4,506	10,508	1,139	551	16,704
The Mathematics of Mind (Italian language)				387	438	270	1,095

Figure K.6 – Downloads of the front cover posters, used to advertise each cs4fn magazine

	2008	2009	2010	2011	2012	2013	Totals
cs4fn poster - cover for issue 1	88	394	501	535	187	128	1,833
cs4fn poster - cover for issue 2	74	388	402	267	134	85	1,350
cs4fn poster - cover for issue 3	80	334	426	257	89	113	1,299
cs4fn poster - cover for issue 4	84	360	402	255	83	86	1,270
cs4fn poster - cover for issue 5	114	444	510	506	126	88	1,788
cs4fn poster - cover for issue 6	74	364	432	289	82	73	1,314
cs4fn poster - cover for issue 7				180	102	123	405
cs4fn poster - cover for issue 8				183	101	99	383
cs4fn poster - cover for issue 9				185	104	113	402
cs4fn poster - cover for issue 10				186	109	74	369
cs4fn poster - cover for issue 11				176	115	77	368
cs4fn poster - cover for issue 12				212	122	95	429