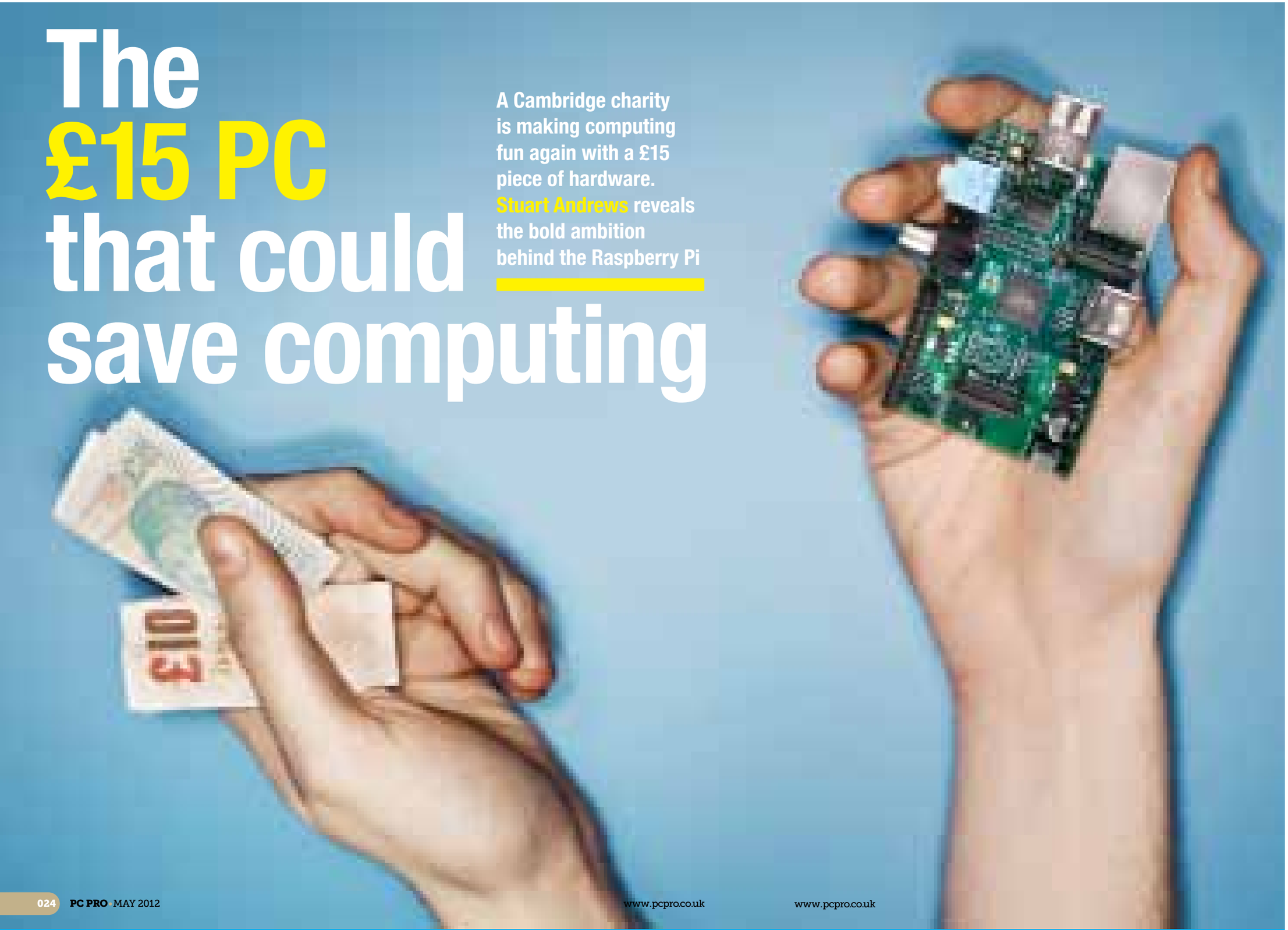
The £15 PC that could save computing

A Cambridge charity is making computing fun again with a £15 piece of hardware. Stuart Andrews reveals the bold ambition behind the Raspberry Pi



Photography: intro, Danny Bird; repro, Jan Cihak

Thirty years ago, Cambridge was the epicentre of a computing revolution. By releasing affordable computers into British homes and schools, companies such as Acorn Computers and Sinclair Research inspired a whole generation to embrace computing, helping the UK become one of the leading nations in software development, digital entertainment and technological innovation. From the Acorn Atom to the ZX Spectrum, the BBC Micro to the Oric Atmos and Jupiter Ace, these machines and the companies that created them helped to pave the way for the PCs, tablets and consoles we enjoy using today.

Only now the picture isn't so rosy. Technology, software and games development remain huge industries in the UK, but our companies are recruiting from a shrinking pool of homegrown talent. Between 2003 and 2010, applications for computer science degrees dropped from 16,500 to 13,600, at a time when overall university applications were rising.

For the younger generation, there's a growing disconnection between the consumption of IT and the work that goes into making it. Last August, Google's Eric Schmidt accused the UK of "throwing away [its] great computer heritage" by failing to teach computer science in schools: "Your IT curriculum focuses on teaching how to use

software, but gives no insight into how it's made."

Yet history might just be repeating itself. In Cambridge, a charitable foundation of academics, businessmen, engineers and developers – which includes some familiar names – is trying to recapture the spirit that put UK computing on the map. Their secret weapon? A $25 (£15) computer running open source software that will work with any HDMI-enabled TV, which – like the charitable foundation behind it – goes by the name of Raspberry Pi.

The computing brain-drain

One of the six trustees behind the Raspberry Pi foundation is David Braben, head of UK games studio Frontier Developments and co-author of the seminal 1984 space-exploration game, Elite. The idea of Raspberry Pi was born after he observed a lack of new programming talent entering the industry. "Even before Raspberry Pi was conceived, many of us had noticed that the number of graduates coming through with computer science skills had dropped off dramatically," he explains. "You'd think they'd be continuously increasing, but there was a precipitous drop-off".

Talking to friends, colleagues and various university advisory boards, Braben discovered that he wasn't alone in his recruitment troubles. The number of graduates was dropping because the number of applicants was dropping.

Braben and other concerned parties looked for a cause. "In my opinion, the rot started much earlier," he says. "It started in the secondary schools with ICT – basically, teaching Microsoft Office and how to use a PC." Like Eric Schmidt, many other luminaries of the UK computing scene and, more recently, secretary of state for education, Michael Gove, Braben realised that the ICT curriculum taught the consumption of software at the expense of the skills needed to build and maintain it.

Another trustee, Alan Mycroft, professor of computing at the computer laboratory of Cambridge University, links this to "the steady push to use products invented by someone else that are too mysterious to learn how to work". Mycroft relates this to modern cars: "You look under the bonnet and you don't know what the bits do – and that's probably necessary." The difference is, as Mycroft says, that with cars "we still don't say that, therefore, we don't need anyone who knows anything about cars apart from how to drive them".

"A group of us felt that we must be able to do something about this," says Braben, "and so the formation of Raspberry Pi as a charity to try to solve the problem." Braben explains that several solutions were mooted, ranging from new devices to

Cambridge, the hub of British computing in the 1980s, is home to the Raspberry Pi

software. "A lot of people said, 'well, why not just make it a software platform?', but actually the problem is a bigger one. We needed the spirit of the 1980s."

write out to it, but it isn't like the old BBC."

And it's this gap that Raspberry Pi can address. Simply getting to grips with a language and a compiler might be daunting enough, but that's without the difficulty and expense of setting it up on a modern PC. "Thinking back to if I were 15 or 16 now, what would I do?" says Braben. "It would actually be very difficult to get into programming, because even if I had a PC at home I'd have to beg, borrow or steal a compiler and get it set up. Unless I have a well-motivated parent, this is actually a big challenge."

> "The number of graduates with computer science skills has dropped off dramatically"

Why the Pi?

So why a new device? First, compatibility. Braben talks of a meeting of the working group, Computing at School, at which a teacher demonstrated an amazing piece of software designed to teach principles of object-oriented programming to children as young as 11 years of age. Other teachers wanted to try it, but hit the usual obstacles – different operating systems, different compilers, a total mismatch.

More importantly, there's a feeling in the foundation that the current generation of computers is too opaque. They make it simple to use features and functions that have already been created, but not to make anything yourself. As Mycroft puts it: "How can I put an X on the screen in Microsoft Windows, or in Linux for that matter? Well, I can get the right graphics interface and I can

The development of Raspberry Pi was inspired by the struggle to find graduates with computer science skills

The joy of the 1980s home computers, and even of the 16-bit computers that followed them, was that there was only the tiniest gap between consumption and creation. On the ZX Spectrum or the BBC Micro, the environment through which you used the PC was also the environment you used to program it; you could go from powering on to "Hello World" within minutes. Braben talks of feeling "a sense of wonder at seeing a ten or 15-line program, and being able to understand what it does". Mycroft loves the immediacy. "It isn't an emulated or interpreted environment. You're doing it on your kit, which is here – not some mysterious bit of something on the web."

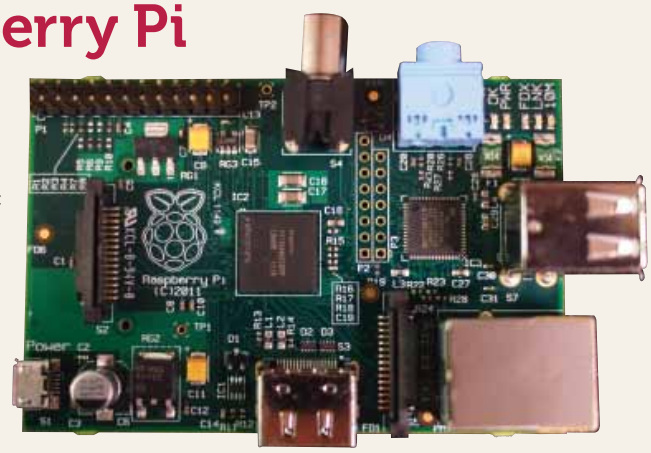
"There's something about this that gives you a soft look – a smooth introduction – into programming," adds Eben Upton, another of the Raspberry Pi founders. "I think all of us have ridden that learning curve, and one of the things we're trying to address is the fact that the front bit of that learning curve has been chopped off."

Pi in the classroom

Remodelling the learning curve is at the heart of how Raspberry Pi will be used in schools. The plan is for a two-step launch, with the current bare developer boards going out to enthusiasts, partners and developers over the next few months, and an educational/consumer product release mid-year. In Braben's words, the point is "to get something that fires up in a very understandable way, much more like the philosophy of the BBC Micro. We haven't decided exactly what it will be, and what people do over the next few weeks and months will probably influence that strongly."

The key thing, in Mycroft's words, is that Raspberry Pi will have "a smaller depth between what you do and what comes out", providing an environment where programming is straightforward, and where a child can write a program, wrap it into a website or a simple app, and share it with others. "It might be rude, it might be funny, but they made it," Braben says.

Hands on with the Raspberry Pi

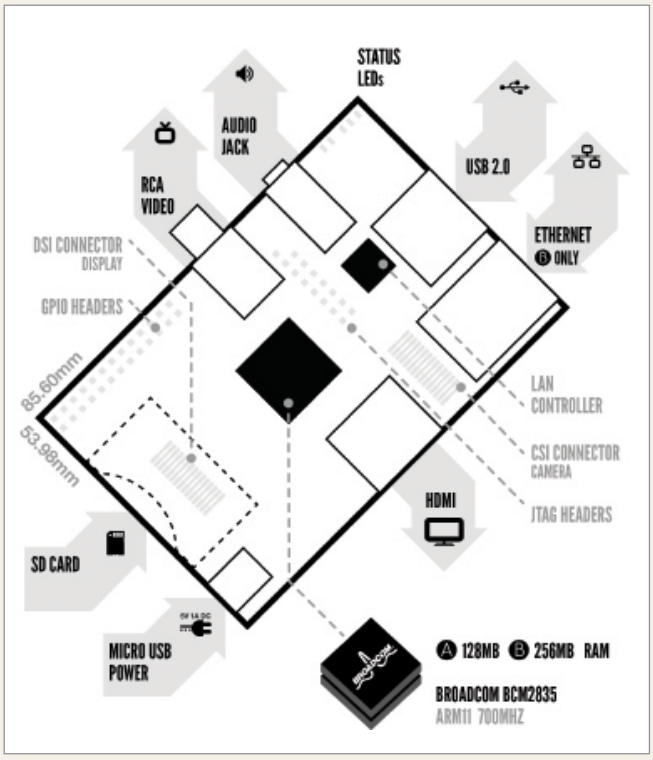


Roughly the size of a credit card, the Raspberry Pi development board is about as simple a computing device as you can imagine. It uses a 5V micro-USB power supply, has a single USB 2 port for input, HDMI and RCA composite video outputs, and audio output through either a 3.5mm jack or over HDMI. The development board comes in two flavours: Model A with only 128MB of RAM and no built-in Ethernet connection, and Model B with 256MB of RAM and an Ethernet port.

The power of the device is down to its Broadcom BCM2835 embedded processor. It's based on a single-core 700MHz ARM11 processor and a dual-core VideoCore IV multimedia processor, which is designed to decode and play 1080p H.264 video streams at 30fps, and which supports the OpenGL ES 1.1 and two 3D graphics APIs.

Eben Upton believes that the processor offers higher performance than Nvidia's Tegra 2 and Apple's A5 processor across a range of 3D and multimedia content. In effect, he suggests, by harnessing hardware designed for set-top boxes and mobile devices, Raspberry Pi can offer the feature set of a 2003 PC for pocket money.

In the flesh, there's evidence to back this up. It might look puny and primitive, but Raspberry Pi plays back 1080p video without a hint of a stutter using a simple command line video player. Support for H.264 and MPEG4 formats is built in, although the cost of licensing has ruled out AAC and AC3 audio and MPEG2 video – in hardware anyway. Upton expects most users to get playback through the XBMC media player, which has already been ported to the device.



And while we didn't see it running in our time with the board, Raspberry Pi has been publicly demonstrated running id Software's Quake III at full 1080p resolution with 4x anti-aliasing at speeds of between 30 and 35fps, albeit with occasional lapses into single figures due to issues that are being ironed out. Raspberry Pi has the makings of a great homebrew gaming platform.

More importantly, it also makes a perfectly usable Linux desktop for word processing and web browsing. Debian, Arch Linux and Fedora are all supported. "We've been really indebted to Red Hat and to the Fedora community in getting Fedora ready for this," Upton says. There's unquestionably work to do on UI performance – the LXDE desktop environment we were shown suffers from laggy scrolling and the odd slow update – but it's definitely usable, and the foundation and community are at work on transitioning the rendering engine from software to hardware, which should yield significant improvements.

The device boots and runs entirely from an SD memory card slot, and you can switch from one distribution or setup to another simply by swapping cards. For developers, teachers and inveterate tinkerers, this gives Raspberry Pi one other key advantage: it can't be bricked. With no firmware on the board – only good old-fashioned ROM – the only thing that can be corrupted is the data on the SD card. If this happens, simply reformat and repopulate, or replace the SD card, and you're back in business. Upton foresees situations where teachers simply remove all the SD cards at the end of a lesson, use a bulk SD programmer to bake a new batch, and give the next bunch of students a clean machine. Raspberry Pi will also work with USB 2 memory sticks and even hard drives – either of which, he claims, will offer significant performance boosts.

Upton talks of the work the foundation is doing in taking existing tools and preparing them for Raspberry Pi and the classroom. On one hand, there are simplified coding environments such as MIT's Scratch, which exemplify fundamental principles of programming in an easily understood, building-blocks way. On the other, there are tools such as KidsRuby, which provide a higher-level approach.

The point is to give children access to something that goes beyond simple scripting or the assignment of properties to objects, and that takes in proper conditional models of programming. "We've been doing some work with YoYo Games, which is based in Dundee, and has a tool called GameMaker," says Upton. "It occupies this scripting place, but you can go much further with it. Big, commercial Android games are being written using GameMaker."

What's more, there's a good chance that more familiar tools may return. "The other thing, bizarrely, is BBC Basic," says Braben. "We haven't confirmed it yet, but it looks like we can use it, which would be fantastic." For Braben, the power of BBC Basic is that "you can have a very short program that can embody something that's really quite sophisticated". He talks of simple programs that work as inline filters for text, taking a Twitter feed, spotting keywords such as a friend's name, and adding rude words in front. "Now, a kid can get endless joy from that." It's typical of the enthusiasm and anarchy that fuelled 1980s home computing, but it also teaches important principles.

The Raspberry Pi foundation aims to bring real computing back to classrooms

And that isn't all. Braben describes the wealth of data available on the internet, from images of the dwindling Amazon rainforest to asteroids in space, and how children could program Raspberry Pi to analyse and make something from it. "The data is online. There's a lot of data that you can download and process, and I see it as a very liberating thing."

The desire is to make computing more rewarding and fun. As Braben says: "If you're asking kids what their most boring subject is, most will say 'ICT' these days – and that's shocking. It should be the most exciting." Even in the 1980s, with BBC Micros controlling robotic turtles, there was a tendency for dry teaching to make the subject less exciting. With Raspberry Pi, Braben feels there's potential to make these activities more game-like, so that it isn't merely about a turtle drawing a pattern, but about turtles racing to complete objectives or navigate a maze, for example.

YoYo Games – maker of the Android title Rick O'Shea – is working with Raspberry Pi

> "We have teachers who want to do more, but currently they're not given the support to do so"

The challenge ahead

Of course, finding teachers to teach this stuff is a very real challenge, and not only for Raspberry Pi. The Government wants to promote programming as part of the curriculum, but is faced with a situation where, of more than 27,000 teachers qualifying in 2011, only three had a computer science degree. Upton says that situation must be rectified. "There's a tendency for anyone who can program not to end up working as an educator in the secondary school education system. The industry will vacuum out anyone who can program. It's difficult. It works well for the industry in the short term, but in the long term it's a tragedy."

Yet there is hope. Through the Computing at School group, Braben claims to have found more than 1,000 experienced IT teachers who would like to teach computer science. "Don't get me wrong. I'm not trying to criticise the teachers," he says. "It's what they're mandated to teach that's the problem, and an awful lot of ICT teachers – particularly the 1,000 I've just mentioned – are already going off-piste and teaching things that are way above and beyond what's in the ICT curriculum. And that's spot on. We'll see more and more of that."

Upton agrees. "This is why we think we have a chance. If we thought we were fighting against the inclinations of Government, teachers and children, then this wouldn't be a thing we felt would be worth doing. The reason why we think we have a chance is that we have children who are keen on computers but who are being put off by the current state of affairs. We have quite a large body of teachers who would like to go beyond what they're currently teaching. They want to do more, but they're not being given the support to do that. And we have a Government that is, to its very great credit, starting to wake up to the fact that we have a serious issue."

That's why the foundation is now working hard, not only to get Raspberry Pi's educational software stack in shape, but to get teachers the help they need to use it. Through the developer community, and partners such as Computing at School, it hopes to get teaching and learning materials in place before the educational/consumer launch, and get a full set of tools up and running.

There's also a desire to create a central repository where teachers can share programs, lesson plans and other materials and – as in the open source approach – contribute improvements. Braben talks of rewards in terms of glory and achievements, and of this extending down to the students. "If a kid makes a piece of software that's downloaded 10,000 times, then that should be something they could point towards in interviews… It's that philosophy that I think could change people's attitudes towards the whole of IT."

Beyond education

However, there's more to Raspberry Pi than a next-generation BBC Micro. The foundation also pins its hopes for success on its potential as a platform for other applications – or, as Braben puts it, "a vehicle for people to really play around with".

Braben cites the Gertboard, an add-on expansion board designed by Broadcom employee Gert van Loo, which can be used to operate LEDs, motors and sensors. Through this, Raspberry Pi could take robots that are currently tethered to a PC and make them properly autonomous. He also mentions "the idea of attaching a camera, because one of the beauties of things such as image processing is that you can make things that are quite simple, code-wise – little edge-detection filters – that are quite explainable, and what you can get out of them is phenomenal."

Upton, meanwhile, sees real potential in the embedded boards market. "It has a real chance of producing effects that we haven't even thought of in that area, whether it's in-car electronics or something else." Media players, for example, are a natural fit for a tiny, low-power device that can decode 1080p H.264 video and run it at 30fps, and the powerful open source XMBC media player is one of the first major Linux applications to have been successfully ported to Raspberry Pi.

Finally, it's easy to forget Raspberry Pi's potential purely as a simple, low-cost computer. "When we got overwhelmed back in May, when we first talked about this," explains Braben, "one of the things that surprised me was the number of people in the third world – charities and organisations – who said that this would be great, because PCs don't survive out there, whereas there are TV screens everywhere."

This, he notes, was the driving force behind the addition of a composite video output to the Raspberry Pi board. What's more, it's trivial to produce a variant with a VGA output, allowing Raspberry Pi to work with CRT and older flatscreen monitors that are creeping towards obsolescence.

The Raspberry Pi team added a composite video output to make it easier to use beyond the West

Can Raspberry Pi succeed?

Eben Upton understands why people have doubts about the Raspberry Pi's chances in a world of sophisticated smartphones, tablets and games consoles. Many companies and organisations, including the One Laptop per Child programme, have tried in the past to produce and sell small, cheap computers, and few have had unalloyed success. "So many people have tried to do this in the past and it turns out that it's really quite difficult.

> "Raspberry Pi offers an attractive level of performance at a price enthusiasts will love"

Even coming from this privileged position where we have trustees of the foundation who are well connected with the local business community, well connected with the local academic community, and privileged access to a chip manufacturer – even with all those advantages it's extremely difficult to do."

However, Upton feels that Raspberry Pi has plenty in its favour. For one thing, price. "There are two things you can do with Moore's law. Either you can pick a price, and every two years double the performance that you get for that price, or you can pick a feature set and – in theory – ride that curve down. This, I guess, is an attempt to do that second thing." Raspberry Pi offers an attractive level of performance at a price where enthusiasts will find it irresistible. This is something where rival products, such as Solid-Run's CuBox, the BeagleBoard or the Rhombus-Tech Allwinner A10, struggle to compete.

Second, the developer board is only the beginning. The consumer-level product, which is to be released mid-year, will add a case at relatively little extra cost, and the foundation will actively encourage licensed clone manufacture, so that companies that want to build a Raspberry Pi computer can do so. After that, and with everything tied down, there are plans to make the design open source, so that anyone can make one. "If this thing goes to plan, it really changes what cheap computers look like," says Mycroft.

Cheap hardware may not be enough in itself. "One of the ambitions we have is to be able to give these away to kids, so that we could give them to a whole cohort or a whole year," says Braben. "That would be my ambition; not to charge for them. It's ambitious – but not totally out of the question." Sponsorship, for example, could be one way forward.

In a way, Raspberry Pi brings computing back home. As Upton notes, "Cambridge University doesn't have a computer science department, it has a computer laboratory – and this reflects a historical bias in Cambridge towards making stuff. This thing we're trying to do here is positioned in that long line. It's nice to be building computers in Cambridge again." Amen.