

Extending the benefits of One Laptop per Child to health

Plans to equip every child in developing countries with a computer present possibilities beyond education. **Paul Fontelo and colleagues** tested the laptop's capabilities in medical settings

The XO computer is a rugged, low power, low cost laptop intended for educating children aged 6-12 in developing countries. One Laptop per Child, a non-profit programme originally created at Massachusetts Institute of Technology in America, distributes them to governments of developing countries that are committed to funding and supporting its programme to enable learning through collaboration, exploration, and experimentation. It believes that young children learn best by doing.

Nearly 400 000 computers (each costing \$210 (£133; €145) have been delivered to children and teachers in 20 countries, with another

Features of XO computer

- The XO is a child-sized laptop that is rugged, inexpensive, and energy efficient
- The XO works as a standalone computer or connected wirelessly in a network with other nearby XOs or to a school server. Only the school server needs to be connected to the internet to get internet access. An XO out of direct range of the school server can connect to the internet by leapfrogging through neighbouring XOs. (This could work well as an institutional intranet)
- It has an energy efficient LCD colour screen that is readable even under bright direct sunlight and a full but compact, dust and water resistant, international keyboard. The battery can be recharged either through a regular electrical outlet or using solar, push-pull, and yoyo-like battery chargers
- The XO uses a solid-state disk rather than a moving hard disk and it also has three USB ports and a SD card (the card that is used in digital cameras) slot for adding data storage and other devices (such as mouse, dial-up modem, or mobile phone)
- Wireless connectivity is provided through wi-fi. As soon as the XO starts up, it immediately seeks nearby computers, easily connects to them, and shares applications
- The OLPC wiki¹ provides step by step instructions for configuring the XO computer. It also lists preinstalled and downloadable software for the XO, although some of these applications are not yet fully functional

quarter of a million on order. If this ambitious programme even partially succeeds then many regions of the world with poor resources but high health needs will have access to these computers. Given the computer's functionality, we wondered whether some of the benefits could be extended to health care.

The National Library of Medicine has developed portals for handheld devices, mobile phones, and computers in low bandwidth environments, and our initial aim was to find out how well the XO computer accessed PubMed. But as we continued to explore, it became apparent that it has many other features that could be useful in health care. We did most of the testing at the National Library of Medicine. However, we simulated what currently exists in developing countries through repeated testing in wired and wireless networks in homes. We connected the XO to an internet service provider using dialup analogue modems through a regular landline telephone. We also used a mobile phone to access the internet.

Health applications

Web browser and email

We found the default web browser the most useful application. Once we connected the XO to the internet, we could access PubMed for Handhelds² and BabelMeSH, a multilanguage search portal for PubMed.³ The web browser displayed Arabic, Russian, and Latin text well but not some Chinese, Japanese, and Korean characters, which we remedied by installing the missing fonts. A search for journal articles on "clinical trials," "malaria," and "bed nets" using the PICO (patient, intervention, comparison, outcome) tool retrieved 43 citations. We successfully downloaded and read a 10 page pdf file with colour figures and tables. Using the French version of BabelMeSH we showed that the XO works with newer internet technologies, such as Ajax.

Using the default browser for accessing webmail applications such as Gmail, Microsoft Outlook, and Yahoo mail, we were able to read email and display inline images consist-



ently. With Gmail we were able to "chat" with colleagues in other countries, making it a useful tool for discussing consultations.

Podcasts and social networks

The XO allows international collaboration through blogs and other social networking websites. Many websites, including those of medical journals, inform viewers when their content changes through short clips of information. A news reader can access these items and link to the full article.

Podcasts and webcasts may behave differently: audio podcasts from *BMJ*⁴ streamed directly, but podcasts from the National Library of Medicine⁵ had to be downloaded first. Videocasts, including science and health files from YouTube, did not function well. Appreciating these differences is important if educational materials are going to be delivered this way.

Health education tools

Although the XO did not open PowerPoint files, lecture slides converted to pdfs could be shared with other computers. We tried to create a presentation using the Write and Etoys software bundled with the XO but were unsuccessful.

A downloaded Flash Player was needed to show virtual slides.⁶ Pathological changes



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were clearly evident in the magnified sections. All navigation buttons worked well. Although unlikely to work with a slow internet connection, virtual slides could be distributed using hard disks and then archived locally. This may be the solution to disseminating educational materials that do not require frequent revision.

Electronic health records

To simulate an internal network in a health facility, we installed OpenEMR⁷ and Indivo⁸ as prototypes of open source electronic medical records on a local server. We also tested CHITS,⁹ a community health information tracking system deployed in the Philippines. These worked well on XO.

Telemedicine

Photographs of skin lesions, wounds, and surgical specimens and short movie clips to show neurological signs can be taken with the built-in camera and sent by email. They can also be saved to a USB disk or archived for teaching. Internet phone calls are possible, and video chat is under development.

Clinical images, taken with a digital camera and transferred to the XO through the memory card slot, can be a useful basis for case discussions and for creating teaching materials. Images of unusual and challenging cases

Nigerian pupils work on XO computers in Abuja: these robust laptops could also be useful for the delivery of health care in developing countries

could be shared with colleagues in developed countries.

Public health uses

We successfully accessed Epispidr, a website on global outbreaks of infectious diseases derived from many sources.¹⁰ A mobile phone connected to the computer could be used to monitor treatment of tuberculosis and store data for analysis. In the absence of internet access, mobile phones could be used. Educational materials could be developed locally or with partner institutions, saved as pdf files and distributed for viewing.

Alternative devices and developments

Soon after the XO's introduction, several other manufacturers released computers directed at children. Other devices with solid state disks like the XO's, classified as subnotebooks, netbooks, or ultramobile personal computers were also announced. They are characterised by their light weight, small screens, portability, low energy consumption, and relatively low cost. Most models are more expensive than the XO, but they run faster and have more memory. Recently, One Laptop per Child

announced that future computers would be distributed with Windows operating system, although the original operating system, Sugar, will still be used.¹¹

Observations and wish list

We found the XO a robust and capable computer, unsurprising given its Linux operating system. However, it is sluggish compared with alternative subnotebooks and today's fast new computers. We encountered occasional freezing when too many applications were running, large files were open, or when we pressed too many buttons in quick succession. The XO also tends to slow down after an extended period of use because the memory gets full (it automatically saves all activities). It is programmed to automatically delete old files, but they can also be deleted manually if needed.

Apart from these minor correctable inconveniences, the XO is suitable for use in health care and education in developing countries. Improvements to its open source operating system and applications are continuing. One application on our wish list is remote videoconferencing for remote consultations and distance education. A whiteboard for marking and discussing images would be a plus, although with email, images can be annotated and sent for consultation. Although internet connections are often slow in developing countries, this would be a good application to have once faster networks are available.

A projection tool for the XO's output would also be useful, although the XO screen can be shared using an overhead projection device. This would enable educational content to be shared with a larger audience.

With a large group of volunteers committed to developing and improving current software, the XO can only get better. Local user groups and domain interest groups are growing, including in health.¹² An educator portal has developed¹³ and an ePals activity can connect with students and teachers worldwide.¹⁴ Perhaps, user groups in developed countries can create collaborative partnerships with those in developing countries and share experiences and solutions to challenges. Online learning forums and learning communities directed towards XO health and medicine communities could be developed as well.

We found that the XO computer could be useful for health education, public health, and in the delivery of health care. We are certain that users in developing countries will find even more innovative applications than we have thought of. Perhaps, these can be enhanced through collaborative projects between developing and developed countries.

As these computers are already available or are being distributed to developing countries, the possibility exists of using them as a shared community resource between education and health care: one laptop per child equals one laptop per clinic.

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developed innovative methods of remote communications. MA's research interests range from medical imaging to telemedicine and he led NLM's Visible Human project. PF conceived and designed the study, performed experiments, and drafted the manuscript. He is the guarantor. FL contributed to the study design, developed software for the study, performed experiments, analysed results, assisted in drafting the paper, and approved the final version. KZ contributed to the study design, developed configuration software for the study, performed experiments, assisted in drafting the paper, and approved the final version. MA contributed to the study design, participated in some experiments, and critically revised and approved the manuscript.

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Commentary: the joy of mesh

Wherever there are several XO laptops, a so called mesh can be formed. A mesh network is a highly resilient form of network in which data, voice, and instructions can transfer between network nodes through a series of hops in a wireless peer-to-peer fashion. In its simplest form, a mesh network is ad hoc: your computer can join or invite other computer owners to the network, provided that they are within range. It is enough for one computer in the mesh to have an internet connection for everybody to get access to the internet, and many other resources can also be shared, such as a printer connected to a USB port on one of the computers.¹ The data rate across this network will not be high but should still easily serve a few dozen computers with good results, as ongoing tests indicate.

Getting connected

The XO has two ways of connecting to the internet, in addition to the simple mesh access. If you are close to a wi-fi hotspot you may connect without a mesh, and if you are close to a school server mesh network you may use that server's internet hook-up. The school server can also take care of back-ups and, for example, build a database of homework assignments. Part of One Laptop per Child's vision is children forming simple mesh networks in their homes and connecting to the school server when at school (or indeed, at the clinic). This is not as easy as you might think to configure, since mobile ad hoc networking means that no network manager can know exactly which computer to expect at a given time. Even if no distribution of IP addresses is needed, a fixed computer



The future is green

network is a lot easier to maintain and secure, and even portions of the internet itself constitute mesh networks. For the XO user, the graphical depiction of the "neighbourhood view" makes it simple to network.

Such interfaces were first developed for military applications of wireless mesh networks. So called blue force tracking—knowing where your vehicles are—is enabled by graphical views of node tracking. For the clinic, patients could interact with each other just like at school, but more importantly with the medical staff. One or more clinic servers could be set up to provide for patient interaction, such as letting waiting patients fill in forms and submit them to the server. Reasonable security could also be provided, chiefly through passwords, to let patients access parts of their health records. A clinic server can be hoisted up a flag pole each morning and be partly powered by solar cells.

In the developing world, wireless access is sometimes faster and more reliable than fixed connections, and forming a simple mesh is free. The One Laptop per Child project was not the starting point for mesh networking in the developing world. In South Africa, for

instance, the Wireless Africa movement has been experimenting with mesh since 2005.² Many developers are currently working on efficient and reliable protocols for such networks (based on the IEEE 802.11s standard and targeting the developing world's rural areas in particular), a bottom-up development made possible by the open source Linux platform of the XO computer. Indeed, long before the start of the One Laptop per Child programme the early German Freifunk (free radio) mesh had a similar slogan (one laptop per (street) corner) almost five years ago.³

The future

One Laptop per Child's objectives includes extending the range of the XO neighbourhood view to a kilometre or more. In addition, movements like Freifunk are now contributing much downloadable content and web based applications for the XO. Solar power and other alternatives to the crank handle are also being developed. In the next few years more opportunities for the clinic will no doubt arise—for example, it may be possible to view film and graphics via a clinic server within a year. Video conferencing and other high bit rate applications, however, will remain a long term goal.

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