The ROYAL COLLEGE of OPHTHALMOLOGISTS

focus

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Frugal Ophthalmology

Andrew Blaikie, Ophthalmology Consultant, St Andrews University

Ulrike Wachter, Digital Health Masters Student

William J Williams, Research Fellow

Unequal World

No one really knows why in 1847 Charles Babbage built a device that could view the inside of a living eye. But what we do know is that within just a few short years our understanding of eye disease had undergone a revolution. Technological change is unceasing – AI, big data, virtual reality and today we can study eyes in detail, with advances in image analysis being especially impressive, however the humble ophthalmoscope still has its place. This article explores engineering approaches to blindness reduction with a focus on the Arclight Project and efforts to merge frugality, design and ophthalmology together.

Consider a remote rural clinic in a resource poor country. The only 'instrument' might be a torch – can we really know if sight loss is due to cataract, refractive error, glaucoma or diabetic retinopathy?

Invention and all the talent and energy that goes with it, remains driven by and for the rich world. Medical innovation is only just beginning to target those at the bottom of the economic pyramid. Of 196 countries in the world, 25 are very rich (income $100,000+) and 25 are very populous and also very poor (<$1,000) with a slow path to growth and improvement. Although many promote roll out of AI and telemedicine, in truth there is little running at scale on a day-to-day basis in low resource settings. Simply widening equipment and education access would leverage and motivate the existing workforce. It is a complex area certainly – attention on what really matters over headlines will go a long way to tackling the scourge of world blindness.

Arclight Project

The Arclight Project is a mix of design, manufacturing, research, advocacy and part social enterprise based at the University of St Andrews. We enable those working in low resource settings such as NGOs or governments to equip, train and empower all grades of health workers to confidently diagnose and manage eye and ear disease. We are expressly not an NGO or training provider ourselves but are trying to think differently, to nudge and counter vested interests. The venture now includes a range of appropriate instruments, simulation tools and teaching content to help users make on the spot decisions themselves.

In low and middle-income countries (LMICs) traditional instruments such as ophthalmoscopes are expensive, complex, and heavy with few hospital-based health workers having access and almost none at the mid or community level. A broken bulb or flat battery often consigns devices to the 'graveyard' bottom drawer. The Arclight needs no ongoing consumables and is unique in being the only truly portable and solar-powered ophthalmoscope, otoscope and loupe in the world. Clever modern engineering and materials brings a highly effective tool to the masses at low-cost.

Frugality: Less is Often More

'Frugal' is defined as sparing, economical, simple or plain. "Less is more"; "Keep it Simple Stupid"; NASA's "Faster, Better, Cheaper"; Colin Chapman of Lotus cars said "Simplify, then add Lightness"– all these and more are a sort of folk wisdom. But why such reminders? Is it not obvious that with all things being equal, the simplest solution tends to be the best one, as William of Ockham said almost 700 years ago? Alas, most of us seem to have a definite tendency towards adding more things when developing answers to problems and we rarely seem to remove or simplify.

Less is however often more, and it's a surprisingly uncommon insight. We are certainly not the first, but our position on LMIC interventions is to avoid letting perfection be the enemy of the good – with any fair remedy better than the usual standard – nothing. An alternative twist was given by Watson-Watt (1930's Radar) who said, "Give them the third best to go on with; the second best comes too late, the best never comes." In other words, frugality and necessity when combined with firmly focusing on the basics can lead to useful and sometimes novel solutions.

Design

During the design cycle (Figure 2.1), we try at every stage to engineer problems out at source. Reducing the part-count and getting sub-assemblies or features to do several tasks all at once is a fantastic way of lightening, miniaturising and usually improving products. The most brilliant designs throughout history or in nature have always been like this. Think of the human hand with its delicate finger and power grips, or the magic of the single rotating part in a jet engine. At root, all design is a set of interconnected trade-offs – winning at one thing means losing on another – with balanced optimisation the sought-after but oft elusive goal. The best concepts somehow seem to glide through evaluations and are easily modifiable or can be put to new uses – but that's no accident!

If low-cost is made the highest priority from the beginning it forces two options: either relax the specifications of what any product can do to a core minimum or seek novel ideas, materials and manufacturing simplification. This self-enforced frugal mindset, can seem a bit bizarre and unnecessary, but slowly over time this dual approach can produce surprisingly useful results.

As a practical example: LEDs are rapidly secured by melting lugs that are part of the body itself (Figure 2.3). Called 'swagging' in industry, it is simplicity itself – no clips or bolts needed. The whole plastic area acts as a heatsink and its inherent black colour reduces reflections. The Arclight has no delicate mirrors or glass, screws, need of adhesives and uses as few components as possible – everything has to 'buy' its way in. Conceptual design occurs as if on a war footing, with a firm grip on the essentials. Plastic injection moulding is one of those stunning often underappreciated modern technologies: enclosures do a dozen jobs at once (clasps, optical, springs, ribs, clips, logos, rulers, texture...) all at low-cost while remaining dimensionally consistent even after thousands of parts have been made.

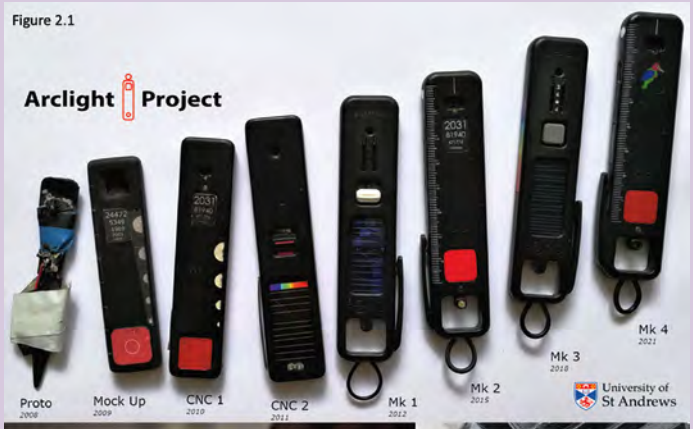
While quality modern ophthalmoscopes are flexible tools for the specialist, for the student or occasional user they come loaded with rarely used features. Removing filters, graticules and other options significantly reduces complexity and boosts ease-of-use for most health workers. We found that the drive to reduce size and mass made it thin, and that had unintended benefits – being easier to manoeuvre and get closer to the patient's eye for a wider and more stable field of view as well as attach to the camera of a mobile phone for recording video of clinical signs. This supports teaching, recording clinical signs to grade response to treatment and sharing of cases for remote second opinions. The raw simplicity of the open pinhole optics also reduces glare and reflections from dust and scratches. This makes it highly reliable in challenging rural environments. Any designer will tell you, the glamour and profit allure of feature creep has to be balanced against true and clever product expansion.

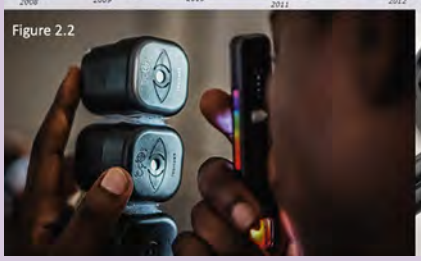
Research Base

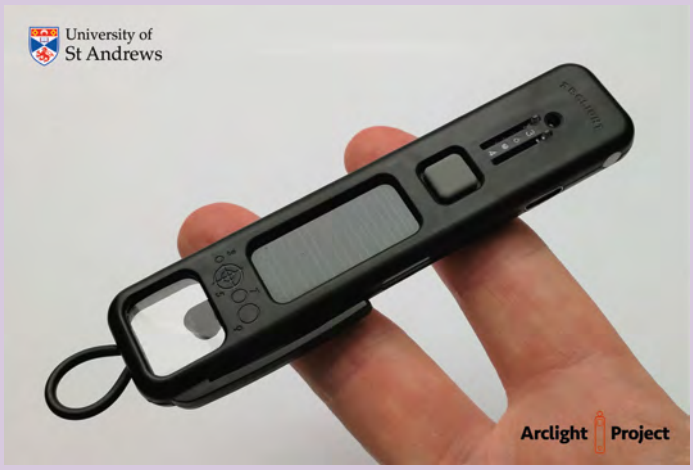
Despite its no-frills design the Arclight has been shown to perform as well, and in several ways, even better than expensive orthodox devices. Studies show there is little difference when examining the optic nerve and retina or in identifying fundal (red) reflex abnormalities to traditional tools. Low-cost realistic simulation eyes (Figure 2.2) help build practical skills and are ideal for remote hybrid teaching.

Recently we have developed a miniature binocular indirect ophthalmoscope (BIO) (Figure 3) and wide-field simulation eyes. Early studies published in Eye show it to be as effective on core examination tasks as an expensive spectacle-mounted BIO, with the simulation eyes showing promise for assessing trainees in identifying diabetic retinopathy and retinopathy of prematurity, as well as for training in the use of laser.

With the actual needs of those working on the ground in mind, we should aim to simplify, use plain language and iterate towards clever, genuinely scalable low-cost solutions.







Pouya Alaghband
Editor, Focus