SSERC
SCOTTISH SCHOOLS EQUIPMENT RESEARCH CENTRE

# Science & Technology Equipment News

Number 2 Summer 1994

For teachers in Primary schools and of S1/S2 Science & Technology courses

The print run for Issue number 1 had to be doubled because of unexpected demand from Education Authorities for extra copies. This was gratifying if surprising since some of them hadn't even seen the "News" at the time. All told some 3,500 copies have already been distributed. Whether or not any primary teachers have actually got a copy or have then read it - we cannot yet tell. Of necessity Issue number 1 was a bit waffly because it tried to introduce primary teachers to a service with which most of them are unfamiliar. It was somewhat like a modern political manifesto - largely content free. Now comes the difficult bit! As one of SSERC's Board members reminded us recently, any fool can write a first issue. The ones to worry about are those from number two onward. I refuse to tie in the one about the man who fell off the Empire State building. No doubt you get more than enough of such old jokes from the kids.

Issue number 2 is largely taken up with basic ideas on optical instruments for use in a number of areas within Environmental Studies. This, we trust, keeps our promise that we will give simple, practical and reliable advice on equipment matters.

## Choosing optical instruments

Magnifiers, nature viewers and microscopes - all of these may find several uses in Topics loosely encompassed under "Environmental Studies". What then are the central ideas to be borne in mind when buying any such items and in deciding what is best to use when and where? The basic principles are not at all difficult to understand. Succinct and accurate explanation - without lots of maths and trigowhatsits - that's not quite so easy!

### Thinking small

That some things are just too small to see with the unaided eye is familiar from everday experience. For me it gets more familiar with each year that passes! The unaided human eye can easily separate lines or similar objects as close as 4 per millimetre at 250 mm or so from the eye. In ideal circumstances, it is possible to resolve (distinguish), objects spaced much closer than that. At their limits the human eye and brain are able to detect a visual angle equal to only one minute of arc - one sixtieth of a degree.

It is easier to grasp this idea in terms of real objects in, say, a typical classroom 10 metres long. At one end of that room a pair of parallel lines, each about 3 mm wide and 3 mm apart would just be discernible as such to a naked eye at the other. With any closer spacing however a pair or more these lines would not be seen distinctly as such. To pick out a separation of only 3 mm from 10 m away is still good going. Wondrous things the eyes - how do they do it?

### The eyes have it

Everything depends on the structure of the eye. Essentially it is that of a lens system (cornea and lens) which forms an image of what's before it, on a mosaic of light sensitive nerve cells - the retina. (Fig.1). These cells are tiny, closely packed and, in everyday circumstances, provide all the information necessary about any object in the field of view and provoking interest.

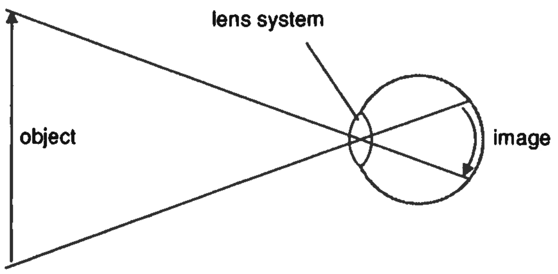


**Fig.1**

But there are limits to the detail which the retina can accept. When separate bits of the image are so close together that they both fall on the same nerve cell then the system is in trouble. So, an object can only be seen as minutely as the fine structure of the eye will allow.

To distinguish finer detail the image must be spread out on a bigger area of the retina until its components again become distinct. In other words, only a part of the original *field of view* must now cover more of the retina.

### Taking a closer look

In the ordinary way this is done by bringing the object closer to the eye so that it takes up more of the field of view (Fig.2).

As many adults are acutely aware, there is a limit to this expedient! This is because, unlike those of children, adult eyes are unable to accommodate (automatically focus[1]) at distances much closer than 250 mm, ten inches, or so. This is known as the least distance of distinct vision. We need a little help from our lens.

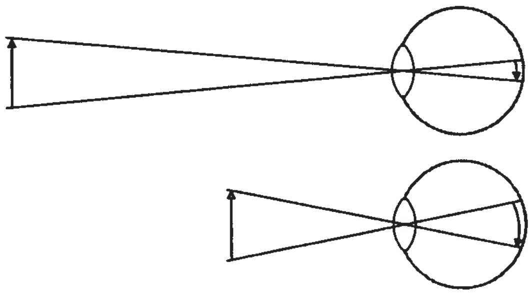

**Fig.2** Effect of bringing the object closer to the eye

### Getting even closer

A magnifying glass simulates an even closer look because it can artificially spread out the image on the retina (Fig.3). This brings us to another important idea which is that the eye and brain judge sizes of objects by their apparent distance from the observer. This is done by measuring visual angles (Fig.3). A lens system may increase the apparent angle. The brain then judges the object to be closer than it is. And if it's closer why then - it must be bigger!

This is a key function of the lenses in many optical instruments whether magnifier, microscope, binocular or telescope. Getting a magnified image of almost any size is not difficult. Strangely, this may be the least of our problems.

### Seeing more

Let's extend our classroom example and suppose that we look through an optical instrument at two lines which are so close together that the naked eye cannot separate them.

Suppose also that all that our instrument does is make the image bigger. It doesn't collect enough of the light leaving the object or transmit it faithfully to the image position and fully remake the pattern of the object (Fig.4) We may then still see one black blob - only now it's a bigger black blob! This is known as *empty magnification*. The device has failed to *resolve* detail which we know was there in the object.

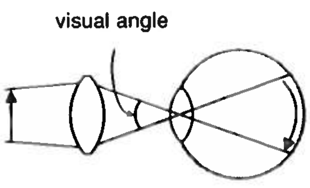


**Fig. 3** Effect of a magnifying lens allowing an object to be brought closer to the eye and remain in focus

[1] The cornea is the most powerful focusing part of the eye. It is the lens however which provides further adjustment for near or far-off objects. In many adults this ability to accommodate lessens with age as the lens starts to lose some of its elasticity.

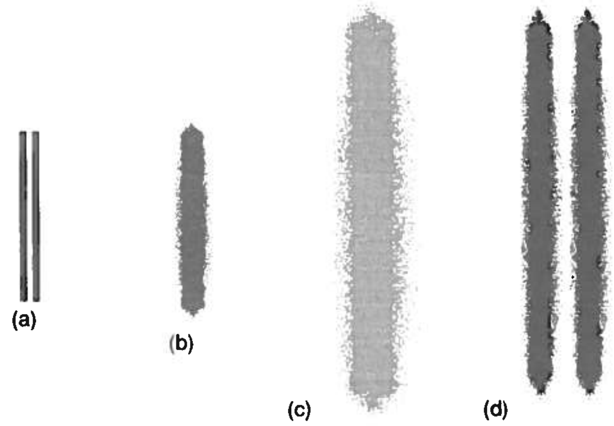


**Fig.4** (a) two lines that are so close that they cannot be distinguished by the naked eye (b).
The same two lines magnified with a poor quality lens (c) and again with a better lens which resolves them (d).

That's enough for now. Let us recap!

### Summary

*To see small parts of an object we may need to make the whole thing or bits of it look bigger. The simple way to do this is to reduce the distance from object to eye.*

*A lens, or combination of lenses, is only needed when that distance cannot readily be reduced or the enlargement needed is so great that the object has to be brought so close to the eye that it can no longer be seen clearly (focused).*

*The basic magnifying power of a simple magnifier is never greater than about x2 (e.g. in a fixed focus Nature Viewer). This arrangement may not aid young pupils a great deal since they already can focus on objects much closer to the eye than can an adult.*

*Greater magnification depends on the lens allowing the object to remain in focus when it is brought much closer to the eye than usual.*

*Magnification which doesn't retain the desired detail is a total waste of your time and effort (i.e. the system must resolve as well as enlarge).*

*As a general rule, the greater the magnification the smaller the field of view and, the smaller the distance over which the object stays in focus (i.e. the depth of focus gets less).*

*From some of our diagrams of simple magnifiers you will have seen that the image formed on the retina is upside down. This is quite usual and no problem for the brain which simply turns it right way up again.*

*More complex optics - such as those in a proper micro-scope (see also next section) - may throw an upright image onto the retina. You guessed it - the silly old brain, however good it might be at instant trigonometery, inverts it anyway so that we then really do see it upside down (and possibly also turned left to right). This may mince the heids of lots of children and those of not a few adults.*

### Applying these principles

Hopefully you are still with us still feeling little pain. We should now start to use these ideas broadly to answer the questions on patterns of purchase and usage which we posed at the outset.

Lack of space precludes too much detail on specific instruments. Table 1 (back page) provides a general summary of what types of equipment are best for a range of typical applications. Part II of this article will contain a more detailed table with recommended models and suppliers etc. It will also deal with other kinds of optical instruments such as telescopes and binoculars.

### Magnifiers or microscopes?

*Magnifiers :* Unless you have loads of money (hollow laughter) spend the first slices of cash on good quality magnifiers. Note the limitations of devices where the distance between object and lens cannot be altered (eg. *Nature Viewers, Midi-* and *Minispectors*, lenses on stands or fixed to a torch-like illuminator etc).

*Microscope look-alike :* Next - if you must have the caché of something that looks like a microscope - consider good quality fixed magnification devices such as Offord's *x20 Scientist*. This is versatile, can be used for solid objects as well as slides of sections, and resolves detail well at its limited magnification. An excellent explanatory booklet with lots of ideas for activities comes with this microscope. It has the further advantage that the images are upright. This means that when the object being looked at is moved the image appears to follow in the same direction. For young pupils this is pretty useful.

*Stereomicroscopes :* Got an energetic and generous PTA and a couple of hundred pounds or more to spend? Assuming there is full provision of magnifiers and other simple devices consider the purchase of a stereomicroscope. These are really two low-power microscopes in one (school models are usually x10, or x20, or both x10 and x20). Because they provide a separate image at each eyepiece they produce a three dimensional effect giving depth to the final single image. Another major advantage is that they do not produce inverted images. This means that, as in simple instruments - such as the Offord *x20 Scientist*, movement of the image follows that of the object. Types on a long-arm stand are more versatile since with them parts of large solid objects can be examined but, they are expensive.

*Conventional microscopes :* You already have all of the above? Now might be the time to consider the purchase of a conventional, compound microscope at prices upward of about a hundred pounds or so. Their use in Primary should be largely reserved for P7.

Although small solid specimens may be examined with lighting from above *(top-light)* this may mean images are seen in silhouette only. Specimens for this type of instrument are usually thin, transparent sections lit from below *(transmitted light)*. This brings problems even at secondary level and may lead to severe difficulties for younger pupils. The snag is that two-dimensional images have somehow to be tied back to a three dimensional whole. This is not at all easy especially if we also expect the children to relate structure to function.

A further difficulty is the business of inverted images. The compound microscope usually inverts both up-for-down and side-to-side. So, if the pupil moves the slide to the right the image moves off to the left. If he or she moves the slide away from him or her the image will shift toward them.

All of which means that any use of a proper, compound microscope in primary courses must be carefully considered and selective.

A final point concerns the issue raised earlier on the primacy of the resolution of necessary detail rather than of mere magnification. Whatever else you do, do not be taken in by catalogue descriptions or adverts for "Powerful microscope - quality optics magnifies up to 600 times . . . £32". At that price the untrue bit is undoubtedly the word "quality". Such an instrument will suffer from a host of optical faults and will grossly lack resolution. It will be little or no better than a toy. Don't buy it.

### Recommendations

Table 1 overleaf provides some general advice on what type of equipment to buy for certain uses. More specific advice on models, prices and suppliers will be given in our overall summary in the next issue.

*Magnifiers* - Before you buy any magnifier first obtain Offord's "Understanding Magnifiers" kit and then - never mind the kids - try out the worksheets and the practical exercises for yourself. Magic! This will provide a practical understanding of the key points made in this article. You should then be in a much better position to judge for yourself the quality, and value for money, of any other magnifiers you may be thinking of buying.

*Microscopes* - This may be beginning to read like an advertising feature for Offord. But, remember, our advice is independent. If you don't already have one then, before you buy any additional equipment in this line, first buy an Offord x20 Scientist then - as for magnifiers - do the exercises in the Offord booklet "A World to Discover with a microscope".

This may well provide you with a lot of good ideas on possible project and other work for the pupils. More importantly however it will also give you a practical understanding of what is meant by resolution and good general optical quality. These really are pre-requisites to making further sound buying decisions on other optical equipment.

| Specimen Type | Magnification Needed | Suitable Instruments | Expect to spend (Examples) |
|---|---|---|---|
| "Minibeasts' (e.g insects and other invertebrates) external appearance plant parts | x2 to x20 | x2 to x5 Nature viewers *Minispector*[1]<br>x2 Osmiroid *Magnispector*<br>x6 to x10 folding hand lens (must be used close to eye and object)<br>x10 or x20 stereomicroscope | £3 - £5<br>£15<br>£3-£12 according to diam. & quality<br>£90 to £300 |
| Detail in structure of everyday materials such (salt, sugar etc.) as fabrics, paper, crystals | x6 to x10<br>x20 | Magnifying glass/hand lens<br>Simple microscope (e.g. Offord *x20 Scientist, Motic MS-2*) | See above<br>£30 - £60 depends on source |
| Prepared slides and thin sections gross anatomy | x 20 | Simple microscope | See above |
| As above finer detail of internal structure | x100 to x200 | Junior microscopes (P7? and S1/S2) or use 35 mm transparencies | £90 - £150 or more so avoid if need be for Primary. |
| Micro-organisms such as yeast or bacteria etc. | x400 and more | Advanced microscope or use 35 mm transparencies | £150 or more so avoid at this level |

[1] Note some of the newer flat magnifiers based on Fresnel type lenses may be very convenient for some applications and are well worth considering.

**Table 1**

### Telescopes and binoculars

Many of the principles outlined here can also be applied and extended to telescopes and binoculars. Applications for these devices can be found in areas such as "Earth and Space" and in general work out of doors. We have no more room in this issue in which to sensibly advise on these types of equipment.

Watch out for Science News No.3 wherein we shall try to explain all that gobbledeygook about "ten by forties" and "seven by thirties".

*Meantime, may all your strands stay together! Have an enjoyable summer holiday. No doubt, as usual, you'll need it.*

### Materials & Components

See Issue No. 1 of SSERC's "Science & Technology Equipment News" for a list of simple components and materials which you may find useful for projects and other practical work.

### Useful Addresses

SSERC, 24 Bernard Terrace, Edinburgh EH8 9NX Tel. 031 668 4421 Fax. 031 667 9344

Berol Ltd., Oldmeadow Road, King's Lynn, Norfolk PE30 4JR Tel. 0553 761221 *(Osmiroid Magni-, Midi- & Minispectors).*

Griffin & George, Bishop Meadow Road, Loughborough, Leics., LE11 0RG Tel. 0509 233344

Philip Harris, 2 North Avenue, Clydebank Business Park, Clydebank, Glasgow G51 2DR Tel. 041 952 9538

Heron Educational Limited, Carrwood House, Carrwood Road, Chesterfield S41 9QB Tel. 0246 453354

C.E. Offord (Microscopes), Ticehurst Road, Hurst Green, Etchingham, East Sussex, TN19 7QT Tel. 0580 200739 *(Magnifiers Kit etc.).*

Roopers Company, 20 Ridgewood Industrial Park, Uckfield, East Sussex, TN22 5SX *(Offord Scientist etc.).*