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Ideas and Inspiration supporting Science & Technology for all Local Authorities



Cabomba Tricolour
Climate change - are plants the answer?

How wide does a laser cut?

Smart uses of QTC

Anne Adams 1950-2011



Many of you reading this will have known Anne Adams and it is with heavy hearts and great sadness that we have to let you know that Anne died on February 15th 2011. Anne joined SSERC in 2001 having worked previously at Stevenson College and in industry. Anne was without exception thoughtful, supportive and caring of others and, despite many sadnesses in her life, she brought much joy and laughter to all of those with whom she had contact.

Anne was a consummate professional. 'Let's make those practicals work' was the title Anne chose for technician workshops and this could have been her mantra. She worked tirelessly to develop reliable and practicable experimental work, much of which is currently in use

in classrooms across Scotland. Nothing was too much trouble for Anne whose technical expertise and friendly manner contributed significantly to SSERC's advisory service. Many teachers, technicians and senior pupils have benefited from her wise advice and huge sense of fun.

We at SSERC have enjoyed Anne's company for ten years and feel privileged to have worked alongside her and to be able to count Anne as a wonderful colleague and friend.

Whilst the Biology Group has responsibility for the contents of this article the practical work described would not have been possible the contribution of Anne.

Background

A significant proportion of the Biology Group in SSERC is old enough to remember using the textbook by McKean [1] when studying biology in their early years. One of the experiments recommended by McKean is the use of *Elodea* (Canadian pondweed) to investigate factors which affect the rate of photosynthesis. Some 40 years later, the same experimental system is still recommended in more contemporary texts. Whilst we do not subscribe to the view that one needs 'green fingers' to be successful when it comes to practical work in the classroom, we do recognise that experiments with *Elodea* often fall into the 'unreliable' category. Despite the difficulties often associated often with *Elodea*, many schools and colleges continue to use it with varying degrees of success. In a recent publication [2] we explored how *Cabomba* might be used as a reliable alternative to *Elodea* and we wish to extend these observations in the experiments described here. In the experiments that follow (described in more detail in a related publication [3]) we present an experimental set-up which provides a stimulating way of engaging students and we contend that this will lead to greater understanding that plants respire continuously and of the effect of light intensity on the rate of photosynthesis.

Materials and Methods

The aquatic plant *Cabomba* is available from most tropical fish suppliers as well as on-line [4, 5]; see the Science3-18 website for more information on maintaining your stock of *Cabomba* [6].

The light source used in these experiments was a 35 W fluorescent tube (product number 56427) purchased from Focus DIY although similar results can be obtained with a variety of light sources likely to be available in the school laboratory. We would recommend that you avoid lamps which might lead to significant changes in the temperature of the solutions. Transmission filters were obtained from Lee Filters [7].

A stock solution of hydrogencarbonate indicator is prepared as follows:

1. Cresol red (0.10 g) and thymol blue (0.20 g) are dissolved in ethanol (20 cm³).
2. Sodium hydrogencarbonate (0.85 g) is dissolved in freshly boiled, cooled distilled water (approximately 200 cm³) and combined with the ethanolic solution of cresol red/thymol blue and made up to 1.0 dm³ with distilled water.

For routine use 100 cm³ of the stock solution is diluted to 1.0 dm³ with freshly boiled, cooled distilled water.

Results and Discussion

The use of hydrogencarbonate indicator to monitor CO₂ levels in aqueous solutions is well established [8].

Figure 1 shows how the colour of the indicator solution changes over the pH range 6.8 to 9.2.

One might predict that if some *Cabomba* were introduced into a solution of hydrogencarbonate indicator and irradiated for a sufficient period of time then one would see a colour change in the indicator as CO₂ is removed from solution. To test this hypothesis we set up 2 measuring cylinders containing a single strand of *Cabomba* and hydrogencarbonate indicator. Prior to illumination, the pH of these solutions was approximately 7.4 (orange) as shown in Figure 2A. Both cylinders were placed in front of the lamp for 4 hours of illumination. The photograph shown in Figure 2B is of a cylinder which was covered with black paper (and, therefore, received no light) during the illumination period whereas the cylinder shown in Figure 2C received 100% of the incident light.

The cylinder in Figure 2C has turned a purple colour because photosynthesis has taken place with a consequent reduction in the concentration of CO₂.

The cylinder in Figure 2B also shows a colour change from its starting point but in this case there has been a lowering of pH indicating a rise in CO₂ concentration (the pH after 4 hours in the dark has fallen to approximately 6.8). This is an interesting observation which can stimulate much discussion. The explanation for this observation is that the *Cabomba* in cylinder B is not photosynthesising but that it is producing CO₂ through respiration and this gives rise to the colour change.

So, does respiration occurs in plants which are photosynthesising? Results obtained using the experimental set-up in Figure 3 show this to be the case. We have taken a single strand of *Cabomba* and in 2 places along its length have placed discs cut from the base of a Styrofoam™ cup. The diameter of the disc was such that it was the same size as the internal diameter of the measuring cylinder. A small hole (diameter 2 - 3 mm) was cut in the centre of the polystyrene disc and a further cut made from the centre of the disc to its outer edge. This allows the disc to be placed around the stems of the strands of *Cabomba* and thereby act as a collar. The *Cabomba* and discs were placed in a measuring cylinder containing hydrogencarbonate indicator (pH 7.4).

One third of the measuring cylinder was covered in black paper; one third was covered with a filter which allows 50% of the light to be transmitted and the remaining third was left uncovered. The purpose of the discs is to reduce diffusion of hydrogencarbonate indicator between the 3 regions. The measuring cylinder was then placed in front of the lamp and irradiated for 4 hours. The resultant colour changes are shown in Figure 3. One could of course ask students to predict what they might see before removing the filters to reveal the colour changes which have taken place. In our experience removal of the filters from the measuring cylinder in Figure 3 gives rise to one of those perhaps infrequent yet indulgent moments in teaching when your students say 'wow!' or some such similar remark as they note the variety of colours present in the cylinder.

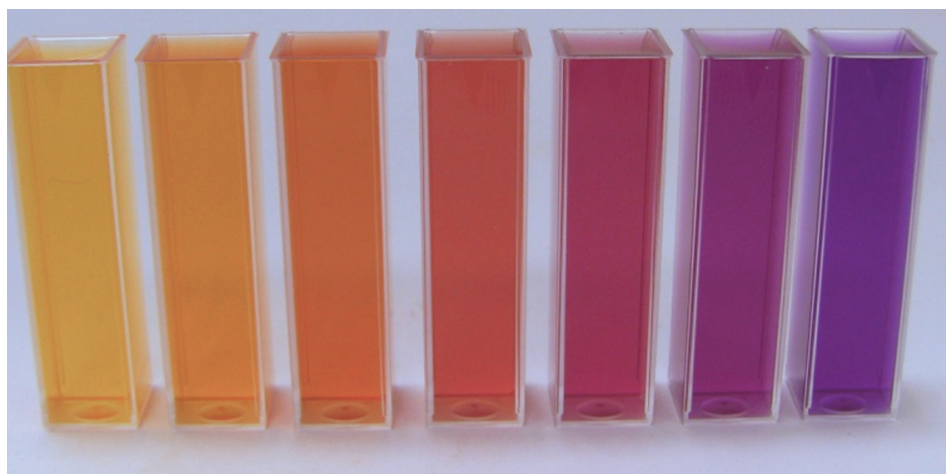


Figure 1 – Hydrogencarbonate indicator solutions in the range pH = 6.8 (pale yellow) to pH =9.2 (purple). pH increases in increments of 0.4 units.



Figure 2 – Effect of irradiation on *Cabomba* / hydrogencarbonate indicator mixtures.
 (A) Prior to irradiation (pH measured to be 7.4)
 (B) After 4 hours irradiation during which the cylinder was covered in black paper (pH measured to be 7.0);
 (C) After 4 hours irradiation (pH measured to be 8.3)



Figure 3 –

(A) Styrofoam™ fashioned to fit inside a 100 cm³ measuring cylinder

(B) Strand of Cabomba showing 2 collars in place

(C) Effect of irradiation (4 hours) on Cabomba / hydrogencarbonate mixtures. Prior to irradiation the pH was measured to be 7.4.

(i) Upper portion of cylinder covered with black paper during irradiation, (ii) middle portion of cylinder covered with 50% neutral density filter during irradiation, and (iii) lower portion of cylinder uncovered during irradiation after 4 hours irradiation.

It can be seen that both respiration and photosynthesis occur at the same time in the same plant – the bottom one-third, receiving 100% of the light, goes purple (pH has increased to 8.3) implying CO₂ uptake and hence photosynthesis dominates; the middle one-third, receiving 50% of the light, also shows a colour change which implies nett CO₂ uptake (pH has changed to 7.6) and hence photosynthesis dominates; the colour change in the top one-third, receiving no light, shows a reduction in pH (pH has

reduced to 6.8) which in turn can be explained by the fact that only respiration is occurring. From the observations shown in Figure 3 we might additionally conclude (i) photosynthesis does not take place in the dark, and (ii) the rate of photosynthesis is greater than the rate of respiration at the light levels used.

A subsequent experiment in which black paper is placed over the top one-third of the measuring cylinder shown in Figure 3, with the bottom one-third uncovered,

followed by a period of illumination leads to a reversal of colour change. In theory this reversal process can be repeated many times but in practice diffusion through the pores and gaps in the polystyrene disc eventually make the colour changes less clear.

We believe that the experiments shown here (i) can be used to suggest that both photosynthesis and respiration can occur simultaneously in a single plant, and (ii) can be described as beautiful!

References

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- [4] Blades Biological – see www.blades-bio.co.uk/ (accessed March 16th 2011).
- [5] Urmston Aquatics – see www.urmstonaquatics.com/ (accessed March 16th 2011).
- [6] Science education 3-18 home page – available at <http://www.science3-18.org/> (accessed March 16th 2011); please note that to access the full suite of resources on this website a log-in ID is required.
- [7] Lee Filters – see www.leefilters.com/ (accessed March 16th 2011).
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Background

Sixty percent of the photosynthesis on our planet is carried out by a huge variety of water-dwelling plant species. Of these, phytoplankton, which make up less than one percent of the planet's biomass, contribute about fifty percent of its photosynthesis.

Vast populations of ocean dwelling phytoplankton (comprising a diverse group of microscopic algae, photosynthesising bacteria, cyanobacteria, plant-like diatoms and calcium carbonate-coated coccolithophores) have recently been of interest to climate scientists. There are two main reasons for this:

1. Phytoplankton are responsible for most of the transfer of carbon dioxide from the atmosphere to the ocean. Carbon dioxide used up during photosynthesis is 'fixed' in the phytoplankton, just as carbon is stored in the wood and leaves of a tree. Most of the carbon is returned to near-surface waters when phytoplankton are eaten, or decomposed, but a significant quantity falls to the ocean depths where it can remain for decades. Phytoplankton, therefore, play a crucial role in reducing levels of the atmospheric carbon dioxide which contribute to the greenhouse effect [1].

2. Phytoplankton population growth requires trace amounts of iron as well as the availability of carbon dioxide, water, sunlight, and nutrients (such as nitrate, phosphate and calcium). Iron stimulates growth of cyanobacteria that fix atmospheric nitrogen, and the extra nitrogen stimulates phytoplankton proliferation. In addition, iron is essential for the production of ferredoxin proteins which mediate the transfer of light energy-stimulated electrons in photosynthetic pathways [2]. In large areas of the ocean where iron concentrations are low, phytoplankton growth is limited.

Enhanced phytoplankton growth occurs where frequent upwelling of cool, deep water carries nutrients, including iron, to the surface. Windblown dust from the land is the main input of iron to the ocean. It has also been observed that where natural iron enrichment of the



Figure 1 - Satellite image from the European Space Agency (ESA) showing the swirls of phytoplankton blooms south of a cloud bank off the coast of Ireland (see [3]).

ocean by iron-rich volcanic ash has occurred, huge phytoplankton population explosions ('blooms') visible by satellite have ensued. [3]

One particularly striking example of a bloom was spotted off the coast of Ireland in May 2010 and Figure 1 shows a satellite image of the bloom; the large swirls of turquoise water, south of the large cloud mass, are due to the presence of a species of phytoplankton known as *Emiliana huxleyi* (see electron micrograph in Figure 2). This phytoplankton bloom followed the 2010 volcanic eruptions at *Eyjafjallajökullin*, Iceland.

So, could the growth of phytoplankton blooms be stimulated by artificially 'seeding' the ocean with iron? And would the resulting increase in photosynthesis also result in increased transfer of carbon from the atmosphere to phytoplankton for subsequent deep-ocean storage?

Ocean iron fertilisation (OIF), as it is called, has already been carried out by research groups around the world using iron sulfate. While satellite images confirm the creation of phytoplankton blooms, consequent increased transfer of carbon dioxide from the atmosphere is yet to be proven. Of course the marine

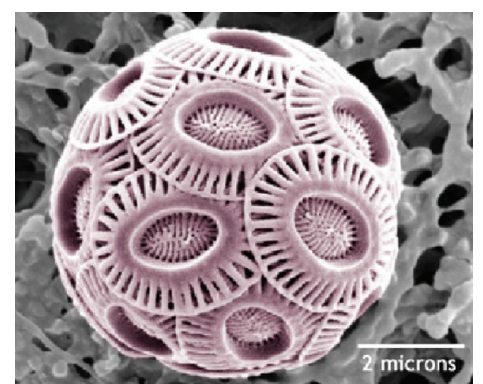


Figure 2 - Image of *Emiliana huxleyi*. (Image taken from <http://earthguide.ucsd.edu/earthguide/imagelibrary/emilianiahuxleyi.html>).

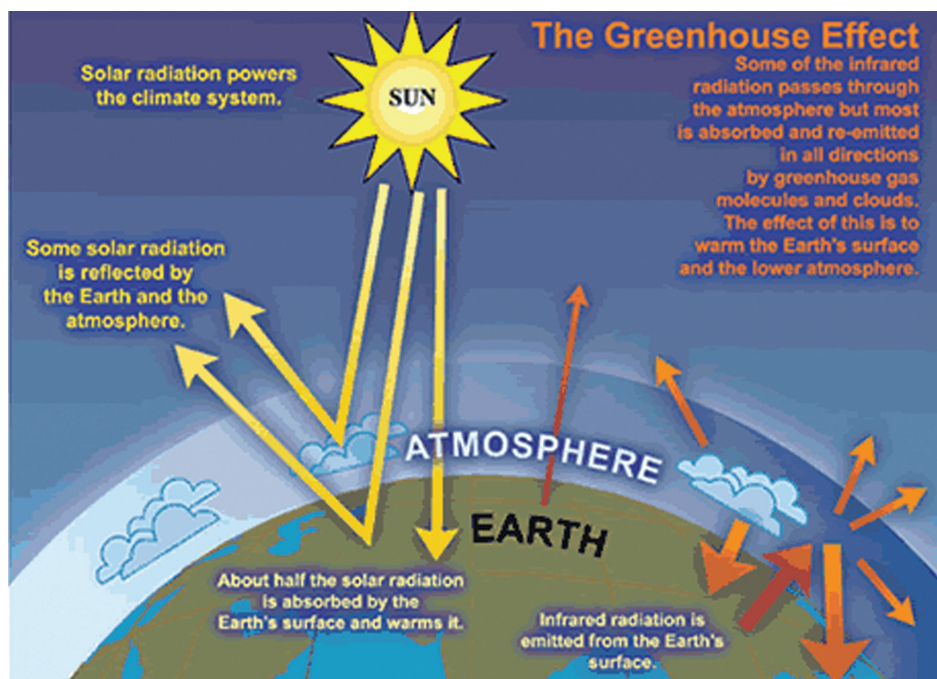


Figure 3 – Greenhouse effect

ecosystem is a complex interaction of biological, chemical and physical processes and the potential disruption and knock-on effects of OIF on it are not yet understood. Like many issues related to climate change, OIF is complex and controversial [4].

Developing global citizens through sciences, social studies and technologies

The complex global issue of climate change was the focus of three regional Learning and Teaching Scotland events held in November 2010. These events aimed to demonstrate how climate change provides a rich context for learning and for promoting global citizenship within the curriculum. SSERC's Biology Team was pleased to be asked to contribute a workshop at each of these events.

A major focus of our workshop, *Are plants the answer?*, was to present some simple activities which might support the learning and teaching of photosynthesis and its role in sustaining life and maintaining the atmospheric gas balance of our planet. By thinking about photosynthesis on a global scale, pupils can begin to explore ideas relating plants to possible climate change solutions. In light of positive feedback from workshop

participants, we thought our ideas and activities would be interesting and useful to science departments delivering aspects of the *Curriculum for Excellence Sciences Experiences and Outcomes* [5] related to climate change.

Through the workshop we sought to:

- consider the role of phytoplankton in the gas balance of the atmosphere
- establish curricular links to the wider topic of climate change
- carry out practical activities to support the learning and teaching of photosynthesis
- suggest activities which will allow young people to engage in the discussion of the science and controversy around climate change.

In the sections which follow we give a flavour of the activities used and highlight their availability on the Science 3-18 website [6].

Misconceptions and prior learning

Workshop delegates agreed that many pupils, while having some knowledge of photosynthesis, fail to grasp the idea that plants also carry out respiration. Another commonly held belief is that plants

photosynthesise in light and only carry out respiration in darkness. By arranging statements relating to photosynthesis and respiration on a simple 'T chart' (The animal-plant game) [6], pupils and teachers can establish what is already known, or misunderstood.

Discussing carbon dioxide as a 'greenhouse gas' can often point up misunderstandings about the greenhouse effect. Again, teachers noted that pupils have some knowledge of this but commonly fail to realise that the greenhouse effect is necessary to maintain our planet's temperature at life-supporting levels. Many simple, colourful illustrations of the greenhouse effect are available on line (Figure 3).

Practical Activities

Since we wanted to encourage thinking and learning about the role of phytoplankton in global photosynthesis we decided to use unicellular algae in SSERC's Practical Activities 1 & 2 [6].

1. A relatively straightforward activity demonstrates the effect of photosynthesis in *Scenedesmus quadricauda* on hydrogencarbonate indicator. We found that a small quantity (1 cm³) of algal suspension added to indicator (6 cm³) in a small container, such as a Bijou bottle, brings about a colour change (orange → purple) within 20-30 minutes when placed in bright light. The rate of photosynthesis in bright light far exceeds the rate of respiration. So, although both photosynthesis and respiration are taking place, there is a nett consumption of carbon dioxide by the algae. The resultant increase in pH causes the hydrogencarbonate indicator to change colour from orange to purple. The colour change will take place within a normal

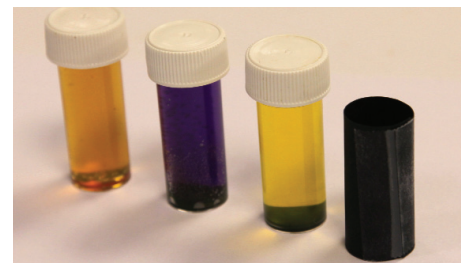


Figure 4 - Bijou bottles showing results of activities 1 and 2 (see [6]).

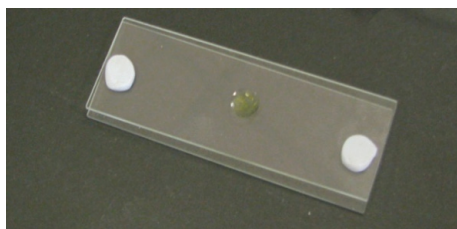


Figure 5 - Hanging drop using two microscope slides (see Practical Activities [6]).

teaching period, providing almost instant evidence that the algae have removed carbon dioxide from the surrounding solution.

2. In a similar set-up, from which light is excluded by covering the Bijou bottle with a tube of black paper, the colour change (orange → yellow) occurs. In this case, because no light is available to the algae, only respiration is taking place. Since the rate of respiration is slower than the rate of photosynthesis in bright light, the release of carbon dioxide and consequent indicator colour change is also slower. This set-up would have to be left until the next lesson to see the result. However this affords another opportunity for discussion of the two processes.

3. In another activity a 'hanging drop' of mixed algae [6] is prepared for microscopic examination. The protocol for this activity describes a method of making the hanging drop using two microscope slides. This avoids the use of fragile coverslips and has the added advantage that standard microscope slides are significantly cheaper than cavity slides.

Since most of the algae in the mixed algae sample are larger than *Scenedesmus quadricauda* they are easier to see. The use of mixed algae also underlines the fact that 'phytoplankton' is a term that describes a diverse group of organisms. We believe young learners will find the beautiful and diverse forms of the algae fascinating.

Other learning activities

One of the questions asked of pupils by the worksheet which accompanies the practical activity *Observing unicellular algae* [6] is, 'How can such tiny organisms be important to global photosynthesis?'

The fact that scientists study phytoplankton both 'macroscopically' and 'microscopically' is thus introduced. Water containing phytoplankton can be examined in the laboratory under a microscope. The formation and health of phytoplankton blooms can be studied by examining images from space.

The *Background information* sheet [6] describes how climate scientists use satellite images to monitor activity and health of phytoplankton blooms.

There is also scope for pupils to carry out their own research into the idea that phytoplankton are a potential solution to the climate change problems associated with imbalance in the greenhouse gases. The controversies surrounding OIF provide further scope for research, discussion and debate.

The suite of activities related to this article, which can be found on the *Science education 3-18* website, includes some suggested active learning and research tasks (based on the work of Petty [9]) together with a table outlining *Curriculum for Excellence* contexts.

References

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- [2] Rayner-Canham, G and Flynn, C (2010) Iron ocean seeding. *Education in Chemistry*, **47**, 140-143.
- [3] Marine Institute (2010), Giant Bloom of Harmless Plankton Visible from Space – available at <http://www.marine.ie/home/aboutus/newsroom/news/GiantBloomofHarmlessPlankton.htm>.
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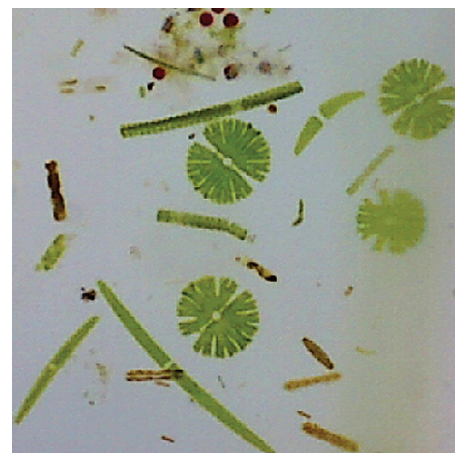


Figure 6 - Mixed algae available from Sciento (see [8]).

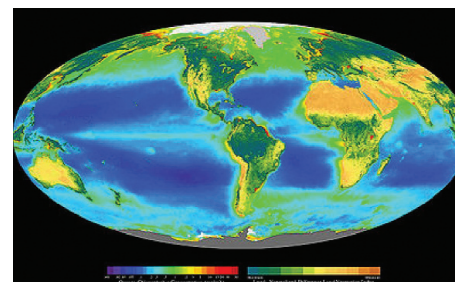
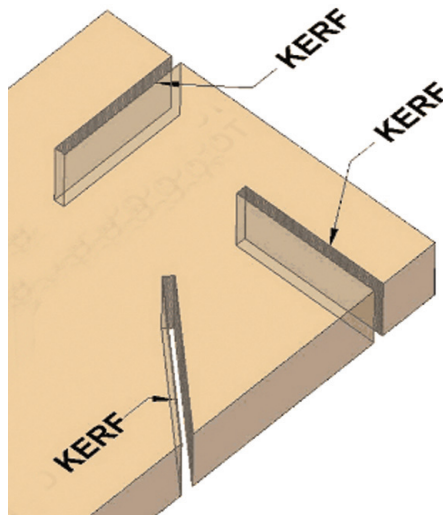


Figure 7 - Composite image showing the global distribution of photosynthesis, including both oceanic phytoplankton and land vegetation. [10].

How wide does a laser cut and does it really matter?

By definition, a saw kerf is the width of a saw cut (below), the kerf being wider than the saw blade due to the set of the saw teeth. We are aware of the size of a circular saw kerf, usually around 3 mm material removed for each saw cut, we make allowances for this dimension.



When we cut with saws, we cut on the waste side of 'the line' to ensure correct dimensions after sawing. But what about the size of a laser cut kerf, it is usually assumed to be so small that it doesn't matter, but can we really make this assumption? Laser cutting say a 50 mm square from CAD software, does it really produce a product 50 mm square? What about the laser kerf width, is it a constant? Does it matter if the square is cut externally or internally?

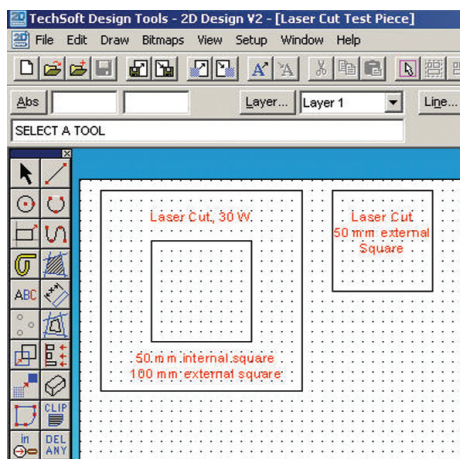


Figure 1 – Two laser-cut test pieces

Using a 30 W powered LaserCAM (Techsoft) cutting 3 mm acrylic, the dimensions of artefacts compared to the original CAD dimensions were investigated.

Laser kerf width is actually a function of the speed of the laser, for 3 mms thick acrylic, cutting is achieved with a 100% power setting and a 3% Speed setting. Light engraving for acrylic is with a 50% Power setting and a 100% speed setting.

A CAD file was produced via 2D Design v2 software. Figure 1 shows two test pieces, a 100 mm square with a 50 mm internal cut, in addition a 50 mm square was produced.

Acrylic (3 mm) was then cut using a laser. The laser beam was focused on the top surface of the acrylic. Using digital callipers, all sizes were measured as shown in Figure 2.

From Figures 2 & 3 and Table 1 it can be seen that as a general rule for 3 mm thick acrylic, external cuts produce smaller artefacts compared to the desired CAD dimensions, while internal cuts are larger than that designed via the CAD system.

In many situations such oversize and undersize after laser cutting is not a problem, however, when inserting for example different colours of acrylic, the laser cut materials produced are far from a 'push fit'. The 50 mm square produced from the laser cut test piece CAD file (Figure 1) can be visually moved inside the '50 mm internal square cut'. Consider Figure 8 there is a 0.42 – 0.39 mm difference in sizes in both the X and Y axis.

Considering the test piece CAD file in Figure 1, measurements were made comparing the 50 mm internal square cut out and the scrap square removed. From Figure 8 the internal square hole measured 50.25 x 50.18 mm while the scrap square removed was measured as 49.84 and 49.78 mm, hence a kerf width of $0.41/2 = 0.205$ mm in the X axis and a width of $0.40/2 = 0.2$ mm in the Y axis was obtained. Laser kerf size actually vary across different materials and also

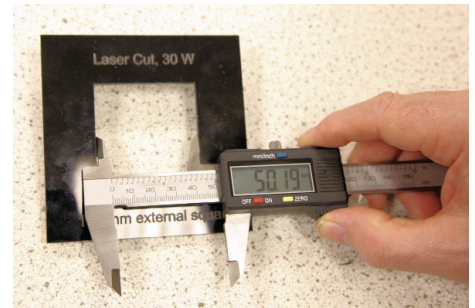


Figure 2 – Measuring the external 50 mm square.

for different thicknesses of materials.



Figure 3 - Measurement of the internal 50 mm square.

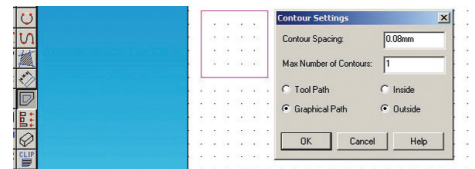


Figure 4 - Creating a contour around the 50 mm square

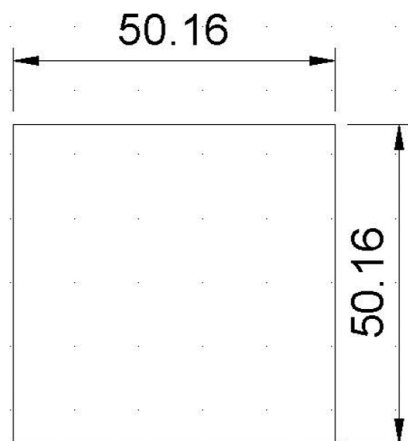


Figure 5 - CAD Dimensions of a 50 x 50 mm square after using a 0.08 mm contour setting

How wide does a laser cut...?



External Square 100 mm	External Square 100 mm	Internal Square 50 mm	Internal Square 50 mm	External Square 50 mm	External Square 50 mm
X axis	Y axis	X axis	Y axis	X axis	Y axis
99.64 mm	99.67 mm	50.19 mm	50.17 mm	49.83 mm	49.79 mm

Table 1- Actual measurements taken from test pieces.

CAD 100 mm External Square, X axis, actual size	Undersize X axis	CAD 100 mm External Square, Y axis, actual size	Undersize X axis
99.64 mm	0.36 mm	99.67 mm	0.36 mm

Table 2- Comparison of CAD sizes with actual laser cut sizes, 100 mm external cut.

CAD 50 mm Internal Square, X axis, actual size	Oversize X axis	CAD 50 mm Internal Square, Y axis, actual size	Oversize X axis
50.19 mm	0.19 mm	50.17 mm	0.17 mm

Table 3- Comparison of CAD size for an internal 50 mm square cut.

CAD 50 mm External Square, X axis, actual size	Undersize X axis	CAD 50 mm External Square, Y axis, actual size	Undersize X axis
49.83 mm	0.17 mm	49.79 mm	0.21 mm

Table 4- Comparison of CAD size with actual size of a 50 mm external square cut.

Internal 50 mm Square (A)	Internal 50 mm Square (B)	External 50 mm X axis (C)	External 50 mm Y axis (D)	Difference in X axis (A-C)	Difference in Y axis (B-D)
Actual X axis	Actual Y axis	Actual X axis	Actual Y axis	mm	mm
50.25 mm	50.18 mm	49.83 mm	49.79 mm	0.42	0.39

Table 5- Distance differences between the internal and external squares of the test piece.

CAD Size (mm)	Actual size of square (mm)	Width 0.08 mm contour setting	Width 0.15 mm contour setting	Width 0.20 mm contour setting
50 x 50 mm	49.83 x 49.79	50.06 x 49.95	50.2 x 50.06	50.25 x 50.21

Table 6- Actual measurements taken from test pieces.

Considering 3 mm acrylic, if push fit quality was to be obtained then the quality from using correct CAD sizes and the difference in actual sizes obtained is too large and adjustments need to be made. Thankfully the 2D Design software has a 'contour icon' (Figure 4) which enables additional size to be added to a sketch.

With a contour spacing of 0.08 mm as shown in Figure 5 the CAD system redraws the shape, drawn around the outside of the original (Note - 'Outside' set in Figure 5). The distance from the original shape equals the 'contour spacing' setting. Hence, for a 50 mm square, the new square would have the dimensions in the CAD software shown in Figure 10, as:

$$50 + (2 * \text{contour spacing setting})$$

Table 6 shows the actual sizes after laser cutting of a 50 x 50 mm external square

cut, initially using the CAD sizes and then using three 'contour spacings' 0.08 mm, 0.15 mm and 0.2 mm.

In order to obtain a good 'push fit' the internal 50 x 50 square which is actually 50.25 x 50.23 mms (Table 5), requires the fitting piece to be of greater dimension than 50 x 50. From Table 6, the 0.20 mm contour setting obtains 50.25 x 50.21, this in fact gives a good push fit. This contour setting (0.20 mm) is the laser kerf size previously considered.

Sequence for the 'Contour Icon Tool'

- Using the CAD software, draw a 50 x 50 mm square;
- Highlight/select the square;
- Select the Contour Icon, set the required contour setting size; select 'Outside'
- Zoom in and see an additional square drawn outside the original 50 x 50 mm square.

- Delete the original square (50 x 50 mm)
- This gives a square of 50 + (2*contour setting) each side.

Testing with various materials and thicknesses in this manner will obtain the required 'Contour Setting' in order to ensure a push fit.

Laser kerf width is a function of the speed of the laser, long straight edges tend to have a narrower kerf than slowly cut curved edges. Using circles rather than squares in this exercise, it would be expected to produce a slightly wider laser kerf.

Further details on prices and ordering details for the equipment and software mentioned will be made available on the SSERC website.

Quantum Tunnelling Composite (QTC) was first produced in 1996 and has proved to be a very versatile pressure sensor as its resistance changes from the order of 1012 Ω to 1 Ω when pressure is applied. It can be directly interfaced to electrical and electronic devices. Carbon composites have been known about for many years. Traditionally their resistance changes with pressure but only by a factor of about a hundred. The deformation required to cause a factor of ten change in resistance is significantly greater than for QTC. QTC is therefore more sensitive to changes in pressure. Unlike QTC, composites cannot be regarded as insulators when no pressure is applied, so they cannot be used as switches. These unique properties have enabled QTC to be used as a sensor in a wide variety of applications e.g. electronic blood pressure and respiration rate monitors. Interactive whiteboards are sensitive to pressure and make use of QTC. A variable speed drill makes use of the decrease in resistance of QTC with pressure applied to it. The tighter the handle is gripped the faster the drill turns. Prosthetic hands that are sensitive to touch have a sensing skin of QTC.

This novel material is used in sportswear to monitor foot pressure distribution while running and to register a scoring hit when an opponent's sword has touched the jacket of a fencer. In terms of Curriculum for Excellence these activities are of relevance to the Learning Outcome - *Novel materials & their properties* SCN 4-16a

Here we illustrate the use of QTC to control the motion of an MFA buggy using simple QTC switches, as well as a design for buzzing flip-flops that can sense pressure on the soles of the feet.

Using QTC switches to control the motion of an MFA buggy

- pellets of QTC, 2x
- flexible plastic sheet (3x6 cm)
- sheet of craft foam (3x6 cm)
- aluminium piece (3x6 cm)
- 1.5 V batteries, 4x
- battery holder for 4x AA batteries
- battery connector.

Buzzing shoes

Using a pair of flip flops, a buzzing shoe can be very easily assembled at low cost.

All you need is:

- pair of flip flops with the straps removed
- buzzer, 3 V dc x2
- aluminium squares, 4 x (3 x 3 cm)
- battery holder x2 for 2 x AA batteries and 4 x AA batteries
- 4 pellets of QTC
- Corriflute
- Velcro 20 cm width, 140 cm length
- sheet of craft foam
- pair of pointed scissors and a craft knife
- Elastic 0.5 cm width, length 48 cm

Place the flip flop on top of the one of the pieces of Corriflute and with a felt tip pen mark the position of the battery holder, the position of the two holes in the flip flop that the straps went through at the heel end of the flip flop and the single hole at the toe end on the Corriflute. Use the scissors to cut away the top layer of the Corriflute where the battery is to be (see Figure 5), this indent will keep the battery holder in position.

This piece of Corriflute forms the sole of the shoe. Cut 2 cm slits starting at the position of the holes in the flip flop at the heel end and going towards the toe end and either side of the single hole 2 cm from the edge of the Corriflute at the toe end as indicated in figure 5. Cut slits in the same position in the flip flop and in the top layer of Corriflute. These slits are for the Velcro to be threaded through.



Figure 1 - Cut a 3x 6 cm piece of foam and mark on 3 x 3 mm squares for the QTC pellets 1.5 cm from each end and from each side. Using a sharp pair of scissors cut out the squares in the foam sheet. Insert one QTC pellet into each of the square holes.

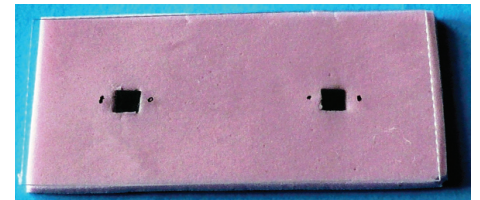


Figure 2 - Lay the plastic sheet on top of the foam sheet and mark the position of the holes for the connecting wires so that the wires are centrally located either side of each of the QTC pellets.

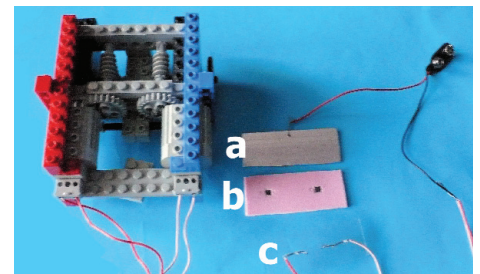


Figure 3 - Make a hole in the aluminium sheet 0.5 cm from one side and 3 cm from each end (a) and thread the bare wire from the battery connector through it. Fold the wire back and twist the wire round itself, or solder, to make a good electrical connection. Make holes in the plastic at the positions indicated so they are just large enough for the wire to pass through. Take one wire from each of the motors and strip 1.5 cm of wire from the end of each. Thread one of the wires from each of the motors through the holes in the plastic as shown in (c).

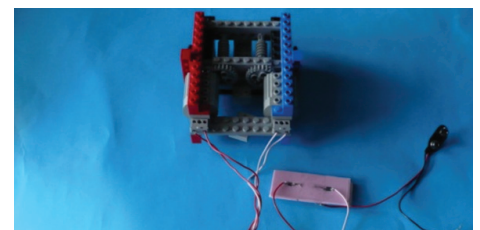


Figure 4 - Place the plastic sheet over the foam sheet, ensuring the QTC pellets are located under each wire, put the 3 x 6 cm strip of aluminium under the foam and wrap Sellotape round them to hold the layers in position. Connect the other wire from the battery connector to the other wire coming from each of the motors by twisting all three wires together or soldering them together. Connect the battery holder to a 6 V supply. On pressing the plastic above each of the QTC pellets, the motors can be turned on and off and their speed controlled so the buggy can be steered around a course.

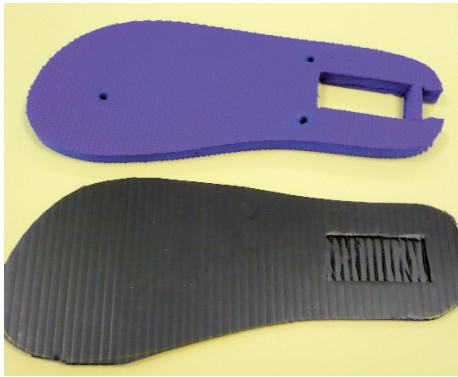


Figure 5 – Lay one of the flip flops on top of the Corriflute, draw round it and using a craft knife cut out the shape of the flip flop in Corriflute. Repeat this so you have two identical pieces of Corriflute.

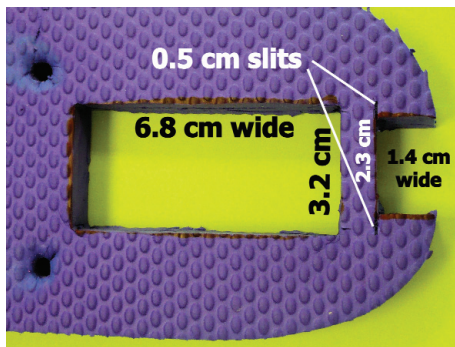


Figure 6 – At the heel end of the flip flop cut out a 2.3 x 1.4 cm shape for the buzzer to fit in. The buzzer has two mounting sockets, to accommodate these cut two slots 0.5 cm in length. The slots will hold the buzzer in place. One centimetre from the buzzer opening cut out a rectangle 6.8 x 3.2 cm for the battery holder.

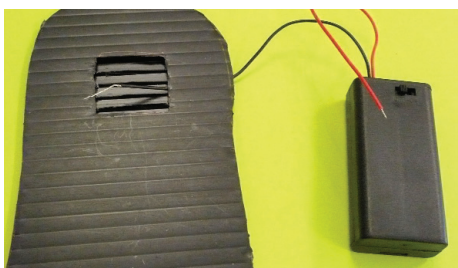


Figure 7 – Take the second piece of Corriflute and on the side next to the flip flop 1 cm from the heel end of the battery holder position, mark out a 3 x 3 cm square and cut away the top layer of the Corriflute so that one of the pieces of aluminium just fits into the cut out square. This ensures the QTC switch is below the on off switch for the battery.

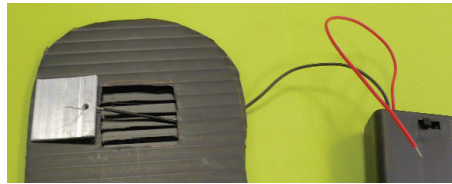


Figure 8 – Strip 2 cm of wire from the black wire on the battery connector and thread the wire through the Corriflute as shown. Thread the wire through the hole in the aluminium square and twist it around itself or solder to make a good electrical connection.



Figure 9 – Place the aluminium square in the square cut out for it in the top layer of Corriflute.



Figure 10 – Strip 1 cm from the end of the red wire attached to the battery and 1 cm from the end of the red wire attached to the buzzer, twist or solder these bare wires together to make a good electrical connection. Strip 2 cm from end of the black wire connected to the buzzer then thread it through the hole in the second 3 x 3 cm square of aluminium. Twist the wire round itself as described previously or solder to make a good electrical connection between the buzzer and the second sheet of aluminium.



Figure 11 – Cut a 3 x 3 cm square piece of foam. Cut a 3 x 3 mm square hole in the centre of the square foam for two pellets of QTC to fit in, one on top of the other. Place the foam square on top of the aluminium square located in the Corriflute.

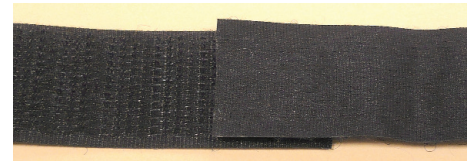


Figure 12 - Cut a 35 cm length of Velcro. Pull the Velcro apart and rejoin the ends so they stick together. Place the join under the bottom piece of Corriflute half way between two of the slits closest to the heel end.

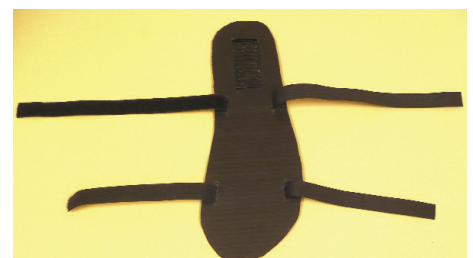


Figure 13 – Slot the Velcro through the slits cut in the bottom layer of Corriflute then slot the Velcro through the slots in the flip flop.



Figure 14 – Thread the Velcro through the slots cut in the flip flop.

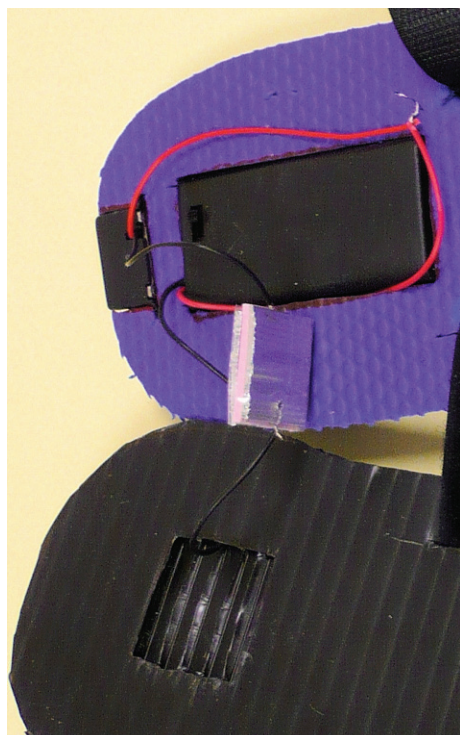


Figure 15 – Push the battery holder into the space cut out for it in the flip flop and push the buzzer into its slot at the heel end. Sandwich the pink foam, with the two QTC pellets embedded in it, between the two aluminium squares. Ensure that the wire connections are on opposite sides of the square so that no shorting out is possible. Hold them together using Sellotape. Check the buzzer functions by switching on the battery and squashing the aluminium plates together. If no sound is heard, widen the top half of the slits to allow enough space for the vibrations of the buzzer, keeping the bottom of the slits narrow so the buzzer is held in place.



Figure 16 – Push the aluminium square sandwich into the square insert cut in the top piece of Corriflute and Sellotape it in position. Thread the Velcro through the slits in the top piece of Corriflute and pull it through so the two pieces of Corriflute and the flip flop are held firmly together.



Figure 17 – Cut a 24 cm piece of elastic and sew each end of the elastic to the Velcro on either side of the shoe at the heel end, 5 cm up from the top layer of Corriflute.

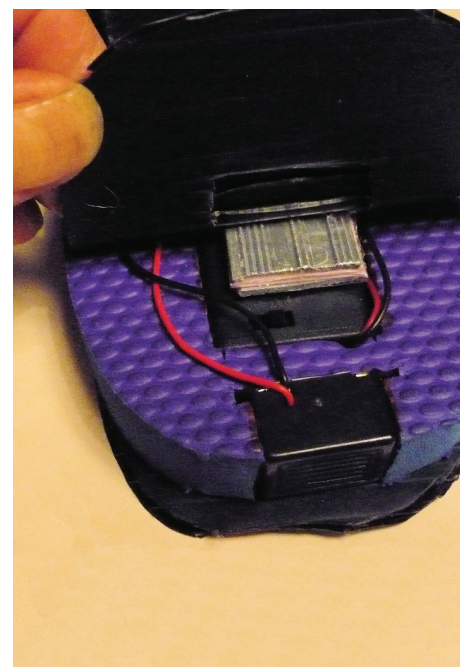


Figure 18 – Lift up the section of Corriflute at the heel end and switch on the battery.



Figure 19 – Attach the shoes to your shoes using the Velcro fastening. Walk along and every time pressure is applied to the heel a buzzing sound will be heard. Remember to switch the battery off after use.

Further reading

More detailed theory <http://www.peratech.com/qtscience.php>
 Applications of QTC <http://www.peratech.com/qtapplications.php>

Component	Source	Product code and price
QTC pellet	www.mutr.co.uk	QTC 001, £0.15 per pill
Battery holder	www.mutr.co.uk	EC1035, £0.26
3 V d.c. Buzzer	www.mutr.co.uk	EW2 002D, £0.62

[1] For advice on safe soldering, see: <http://www.sserc.org.uk/members/SafetyNet/bulls/199/3-4.htm>