In search of solutions

Some ideas for chemical egg races and other practical problem solving activities in chemistry

by Peter Borrows

Introduction

History of this Book

The idea of "egg-racing" started in the mid-1970s, with a challenge set by BBC Television: how far can you move one (intact!) egg with the energy stored in one rubber band? Astonishingly far, was the answer, using thoughtful engineering design, strong lightweight materials, low friction bearings and other technological wonders. Many other problem solving activities followed: construct a bridge between two tables 1 m apart, capable of supporting as great a load as possible, using only two sheets of newspaper and 50 cm of adhesive tape; or what is the tallest tower, capable of supporting the weight of an Oxo cube, that can be constructed from dressmakers' pins and drinking straws?

In the early 1980s "egg-racing" took off. Not only did the BBC competition continue, but clones sprang up around the UK SATROs (Science And Technology Regional Organisations) ran many of them, and they even featured in GCSE training sessions. Such events appeared frequently in the programmes of BAYS (British Association of Young Scientists) branches and, as a result, the BAAS (British Association for the Advancement of Science) published two collections[1,2] of ideas for such problem solving activities. However, a perusal of the 200 or so ideas listed in these books showed none requiring the use of any chemical principles. Concerned that physicists seemed to be having all the fun, and worried that chemistry was missing out, I wrote an article in Chemistry in Britain[3]. As a result of this, Malcolm Frazer, then Professor of Chemical Education at the University of East Anglia, persuaded the Royal Society of Chemistry to sponsor a working party to try and produce some CHEMICAL egg races, to put the FUN back into chemistry[5,6].

When the Working Party started to meet it quickly became apparent why chemical egg races were scarce – it is very difficult to devise appropriate tasks. It is curious that it has proved so difficult to do this in chemistry, that supremely technological activity[4]. Nevertheless, thanks to the contributions of many chemists, a bank of ideas was gradually built up and some were tested – through local Chemistry Teachers' Centres, ASE (Association for Science Education) meetings, BAYS Days *etc.* Progress was slow, but in 1989 Dr Neville Reed, newly appointed Schools Liaison Officer for the Society, gained funding from the Society for a School Teacher Fellow. One of the main tasks of that Fellow was to bring the collection of ideas to publication. Karen Davies started in September 1989... and this book is the product.

It may be problem solving, but is it Chemistry?

The original intention was to publish a collection of ideas for chemical egg races, *ie* for enjoyable, competitive, practical problem solving activities which required some application of chemical principles. Many of the previously published ideas for egg races involved constructional projects of some sort: towers, bridges, *etc.* There is no very obvious' chemical equivalent. However, another common theme is the use of a rubber band - to drive a vehicle, to raise a load, and so on. This book introduces the idea of the 'chemical rubber band'. Anything you can do with a rubber band, you can do with one teaspoon of sodium hydrogencarbonate (bicarbonate) and three teaspoons of anhydrous 2-hydroxypropane-1 ,2,3-tricarboxylic acid (citric acid): a roughly stoichiometric mixture. You can drive a vehicle as fast as possible, or as far as possible - although on the whole a boat is preferable to wheeled or flying vehicles, because the mess is then confined to a tank of water. But is this chemistry? The amount of chemical understanding required is minimal, although some knowledge of handling gases is helpful. At least a chemical reaction is involved, and in any case most of the published egg races require *very* little explicit knowledge of physics.

However, there are only a limited number of things you can do with a (chemical) rubber band. Once you get beyond that stage you are into 'real' chemistry, which poses problems about how much you can reasonably assume that any particular target group actually knows – but it's always less than you would think. There are ways around this. For example, you can "sell" contestants information by deducting points from their final score. Or you can warn them in advance that they may need to *have* met the idea of, say, gradually adding measured amounts of an acid to an alkali to neutralise it (as in "Oranges and Lemons"), without really giving too much of the game away. Alternatively, you can allow "open book" competitions (as in "A Salt and Battery").

Competitions versus Investigations

Some activities produce a clear winner, *eg* the most accurate chemical clock, the largest current. Others do not. Thus as ideas were collected and tested, it became apparent that some desirable activities did not lend themselves to a competitive situation. They were enjoyable, they involved practical problem solving with a chemical flavour, and we felt therefore that they should be included. The collection gradually increased to include a range of non-competitive problem solving activities.

The idea of all this is to attract young people into chemistry by showing them that it can be fun. Some of the activities in this book are ones which teachers have been doing for years. In recent years, problem solving has become more prevalent as a day to day laboratory activity. So where does egg-racing end, and straightforward practical chemical problem solving begin? Perhaps it doesn't matter too much. The tower made of pins and straws started out as an egg race, but later became incorporated into a training activity for teachers, and is now doubtless forming a part of the practical assessment of thousands of pupils. It is also worth remembering that one of the aims of the GCSE National Criteria for Chemistry[7] is "...to stimulate students and create and sustain their interest in, and enjoyment of, chemistry..."

There is, however, no reason why pupils should have all the fun. Adults enjoy these too, as we have found out when trying them out on teachers. Some schools may want to consider using these activities on open days for parents or governors, to give them an idea of what modern science teaching is about. The Royal Society of Chemistry is very concerned at promoting the public understanding of science. What better way of doing this than through a practical problem solving event?

Have fun!

Dr Peter Borrows

Chairman, 1987-90

The Royal Society of Chemistry's Great

Chemical Egg Race Working Party

References

1 Ideas for Egg Races, British Association for the Advancement of Science, 1983.
2 More Ideas for Egg Races, British Association for the Advancement of Science, 1985.
3 P. Borrows, Chem. Br., 1985, **21,** 635.
4 P. Borrows, Educ. Chem., 1988, **25**, 164.
5 Educ. Chem., 1986, **23**, 100.
6 Educ. Chem., 1987, **24**, 35.
7 GCSE: The National Criteria, Chemistry. London: HMSO, 1985.
8 Science in the National Curriculum. Department of Education and Science and the Welsh Office. London: HMSO, 1989.

Acknowledgements

The membership of the Working Party fluctuated somewhat over its lifetime. Some members' contributions mainly took the form of ideas, and comments on other people's ideas. Some were co-opted onto the Working Party as a result of having tried a chemical egg race at an ASE or similar meeting. Such meetings were also a fruitful source of new ideas, and of volunteers willing to test them out in their own schools. Originators of ideas for chemical egg races are acknowledged on the relevant page, where we have been able to identify them, although sometimes they may have been modified (almost out of recognition) as a result of trialling. To all who contributed in any way – our most sincere thanks. Please accept our apologies if your contribution has not been fully acknowledged – we will try to get it right next time.

The following served, at some stage, on the Working Party:

Dr Peter Borrows

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Practical problem solving – 'Advice for Teachers'

by Karen Davies

"If we do not experiment with concepts they will remain remote theory, or as much use as hieroglyphs to the average man".

(Charles Handy,

"Understanding Organisations".

London: Penguin Books Ltd., 1985)

The main aim in writing this book was to provide teachers with a useful resource of chemically-based problem solving activities, egg race style experiments and further 'ideas' for use in the classroom – all of which highlight the 'fun' of chemistry. In choosing experiments for inclusion the Society has taken a broad based interpretation of what constitutes 'chemistry' and has tried to include a few experiments suitable for children of primary school age.

The experiments are grouped together in "topic categories", *eg* acids and bases, electrochemistry, separating substances *etc,* so that they can be easily accessed by users. They can be used not only to enhance a topic taught in 'lesson time', but also as an end of term activity, in science clubs, or on open days (or open evenings) where parents could take part in a 'problem solving' activity, thus encouraging, in a wider context, the public understanding of science. The Society also hopes that any groups organising large science events for schools will find this book useful.

Most of the material is suitable for further development, and only the more obvious curriculum links have been highlighted. The book is not meant to be prescriptive and there is scope for developing the experiments to suit individual needs and situations.

In my own teaching I found problem solving to be a very rewarding, but demanding, experience. It can be used to:

- enhance the understanding of the concept being studied. In this respect it acts very much as a reinforcing tool since it requires students to apply and, therefore, understand their acquired knowledge;
- gauge students' understanding of their work, and can thus be incorporated into student assessment;

- develop students' social and communication skills since it requires them to work in project teams;
- build CONFIDENCE and aid MOTIVATION.

Furthermore problem solving encourages students to use the scientific principles and concepts that they have been taught and equips them with skills that can be applied in everyday life, to a wide variety of situations.

However, problem solving does not provide a single, magical, answer to the problem of stimulating and maintaining students' interest in chemistry: one teaching method does not meet the needs of every child. There are many ways to learn, and although problem solving places many demands on students (as well as on teachers and technician support) it is not advocated that problem solving should be used in every lesson. Instead problem solving should be seen as one of several complementary techniques available for use by the science teacher.

As teachers we also need to look carefully at the ways in which we get students to report on their work. There are many options open to us: poetry, drawing, letters, plays, songs, interviewing; so why do we often present them with only one option? In this respect many of the activities included in this book lend themselves to ways of presenting results other than the straightforward 'what we did' approach.

All of the experiments have been trialled in schools around the UK and the comments within quotations are feedback from those schools.

The "Teachers' Notes" provide an indication of some of the approaches used by students and teachers when tackling the different problems. (However, it is wise to keep an open mind and to encourage lateral thinking.) When using problem solving in the classroom try to ensure that students don't change too many variables at once, but rather adopt a step-by-step approach. Safety should be paramount and it is essential that the importance of safe working practices is stressed. Students should also be encouraged to consider safety aspects in the planning of their experiments and all students should have their ideas checked by the teacher at the planning stage, before being allowed to put their plans into action.

Equipment that all participants need can be put out at each work place. Generally, however, choosing suitable equipment or chemicals is part of the problem to be solved. Therefore have a range of items, including distractors, on tables/benches at the side. These should be arranged in a logical way, *eg* separating chemicals from equipment. Experience also suggests that for experiments requiring junk items it is better to display these separate from non-junk items, such as laboratory equipment.

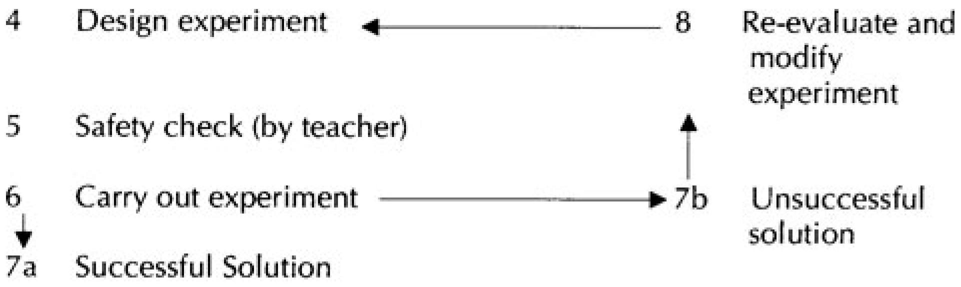
Problem solving activities are not meant to be carried out by individuals, so students should be organised into groups the size of which will vary depending on the situation. Two may not be a suitable size: it is not fair on the student who has to partner a deadweight! However, if the size of the group gets too big, too many people sit around, without having 'hands-on' experience. Through discussion, brainstorming and the sharing of ideas and tasks, students will be ready to take up the challenge provided by the experiment – as a result they will get a feel for what it is like to work in a scientific team.

The problem solving process

1 Identify the problem

2 Identify possible solutions

3 Choose best solution



Health & Safety

Safety can cause difficulties in open-ended problem solving activities. It is in the nature of a problem that you cannot always anticipate what a participant will do. Indeed, some of the best solutions during trials of these problems were the unexpected ones. Most teachers will have had the experience of asking a class to measure the temperature of water being heated, only to see one child stick the thermometer straight into the Bunsen flame.

Teachers need to be particularly vigilant during practical problem solving activities, especially when chemicals are involved. A higher degree of supervision is needed than in activities which have more closed outcomes. Students must be encouraged to take a responsible attitude towards safety, both their own and that of others. A statement to this effect could appear prominently in the instructions for the problem. In planning an activity students should always include safety as a factor to be considered. Plans should be checked by the teacher before implementing them (unless chemicals and equipment are so constrained as to make that unnecessary). Remember, however, you are not checking whether it will work, but whether it is safe.

If in any doubt insist on eye protection if there is a hazardous activity taking place in the laboratory. Even if a particular student's activity has no significant hazards associated with it, or they have not yet started any practical work at all, the student on the opposite side of the room may be doing something that is decidedly hazardous! Judges must set a good example themselves: if eye protection is required for the class, all adults present should be wearing it too. During a problem solving event, and especially if artefacts are being tested in some way at the end, there can be a high level of excitement. Do not allow things to get out of hand, or competitors to put themselves in positions of potential danger.

Under various regulations employers are required to carry out a prior risk assessment before hazardous chemicals are used or made or before hazardous activities are undertaken, Almost all employers at school/college level, including local authorities, multi-academy trusts and independent schools have adopted various nationally available publications as model (or general) risk assessments, usually those of CLEAPSS[1], or, in Scotland, SSERC[2] or ASE[3]. Before undertaking a practical activity schools must then consult such model risk assessments and consider whether they need modification to cater for the particular situation of this class, this school, this room, this teacher. Any significant deviation from the model needs to be recorded. If there is no model risk assessment which adequately covers the situation, schools would need to contact CLEAPSS or SSERC for a Special Risk Assessment.

In general, we have tried to stay within the limits of the model risk assessments. The more unusual the activity, the less hazardous are the chemicals suggested for use. Nevertheless, a teacher must always comply with her/his employer's procedures and in some cases may decide that a particular activity is inappropriate in their situation.

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[1] www.cleapss.org.uk

[2] www.sserc.scot

[3] www.ase.org.uk

How to judge chemical egg races and other problem solving activities

by Ron Lewin

When judging chemical egg races and other problem solving activities, the aim of the activity should be carefully considered. Originally such activities were developed to raise an awareness of the challenge and excitement of science and technology. However, with the implementation of the National Curriculum Science and Technology documents the activities can usefully enhance the attitudes, qualities and skills needed by scientists of all ages.

Judging projects involves both objective and subjective decisions. It is important to ensure that the project is carried out in a purposeful way; that both the problem and the relevant scientific and technological principles are understood; that a range of alternatives are considered; and that the experimental programme reflects the information collected. It is also necessary to consider how the experimental data was collected, displayed and finally what conclusions were drawn.

Of equal importance in judging projects are subjective factors such as ingenuity, curiosity, novelty, enthusiasm, commitment, perseverance, team work, practical ability and an aesthetic sense. Remember that egg race projects/problem solving activities have been developed to encourage young people to take part in scientific pursuits in a warm and encouraging way. We should expect scientific rigour, relevant to age and ability, but at the same time the activity should be enjoyable.

If the above points are borne in mind, egg races/problem solving activities can enrich and complement more formal school science. Not all the factors will need to be included for each activity and teachers will need to choose those relevant to the particular occasion. To avoid misunderstanding, it is worth explaining to participants the basis of the assessment and how marks will be awarded. The following is a list of criteria for which marks could be awarded:

- Understanding the problem
- Use of scientific method
- Collection of information
- Consideration of alternative procedures
- Experimental design
- Practical work
- Recording information
- Interpretation/critical assessment of results
- Success in solving the problem
- Suggestions for further work
- Co-operation, team work (if relevant)
- Originality, novelty and ingenuity
- Curiosity and inquisitiveness
- Aesthetic sense
- Perseverance
- .. .. ..

Teachers must decide which to use, how they should be weighted and whether any other factors need to be taken into account.

Junk list

Many of the chemical egg races require the use of 'junk'. The following is a list of the type of item envisaged:

plastic lemonade bottles

'squeezy' bottles (washing up liquid containers)

empty beer/soft drink cans (dry)

coffee tins/syrup tins

coffee jars/jam jars

yoghurt pots/margarine tubs

shoe boxes/cereal packets

cardboard tubes from toilet rolls/kitchen towels

blocks of expanded polystyrene packing

polystyrene meat trays/egg boxes

disposable foil trays (oven ready)

lollipop sticks

wood off-cuts/cotton reels

used tights (empty!)

NON-JUNK ITEMS often used alongside junk:

sticky tape

glue &/or glue gun

blu-tack/plasticine

string

rubber bands

paper clips/split fasteners

pegs

wire

pins

aluminium kitchen foil

cling film

balloons

plastic bags

drinking straws

plastic tubing

assorted bungs & corks

plastic syringes

plastic gloves

paper towels

stapler

ruler

simple tools: tin snips, saw, bradawl, file, stanley knife *etc.*

Credits

Health & safety checked

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