MICROCHEMISTRY IN AFRICA
A REASSESSMENT

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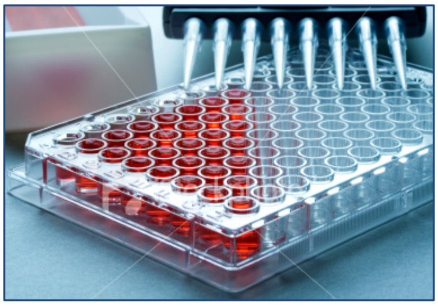
ABSTRACT

Microscale chemistry has been talked about and experimented with for many decades. Even the microscale chemistry deliberately designed for school-based practical activities has been around for more than 30 years. It is timely to reassess its scope and limitations, because many of the concerns that stirred interest originally are not diminishing but strengthening. *[AJCE, 2(1), January 2012: Special Issue]*

SOME BACKGROUND



A standard microwell plate
Image courtesy of http://www.istockphoto.com

Modern microscale chemistry took off when the potential of microwell plates was recognized. These plates, made of plastics, came into widespread use in medical and clinical laboratories, to service the surge in testing procedures and numbers of patients, widespread in the last 50 years. Used with a minimum of additional pieces of equipment, enthusiasts developed a repertoire of simple, microscale chemistry experiments. Often these were the same experiments used by chemistry teachers throughout the World, since the early days of school science teaching. But because they were easier and cheaper to do they appealed to some liberated chemistry teachers. These teachers also favored the greater safety that comes with the use of smaller quantities of chemicals and were aware of the growing environmental concerns amongst the general public about chemical waste.

For a number of years, conferences of science teachers and chemical educators would invariably include one or more of these microscale enthusiasts, who would conduct workshops and inspire participants with the simplicity of their approach. Literally thousands of such participants must have gone home and explained their experiences and excitement to colleagues. Unfortunately for many teachers enthused by the conference experience, the realities of school commitments and environment soon wiped the smile off their faces. For a score of reasons the long term impact of this conference seed-sowing was less than one might naively have expected.

But of course although many seeds failed to germinate, there were also a few that did and some even went on to sow their own seeds. UNESCO is a case in point. For many years they had advocated the development of low-cost equipment, mostly assuming traditional scales of experimentation and local manufacture (1). The aim was to reach out to poorer communities where there were little or no funds for traditional science equipment –usually imported from countries in the developed World. Success with this approach was patchy; dedicated enthusiasts would sustain projects for several years, but as they retired all too often the project withered. When microscale chemistry came onto the World stage, they recognized that it came with drastically-reduced costs, one of the basic criteria of their long-standing project. For a number of years they fostered (and continue to foster) a Global Microscience Project, which above all aimed to introduce the concept into needy countries (2). For this purpose, the Project used introductory workshops that were usually organized in cooperation with the Ministry of Education, which nominated selected school teachers, teacher trainers, curriculum developers, etc. The overwhelming opinion expressed at the end of a typical 2-day workshop was positive. Most participants saw that the microscale chemistry kits could at last bring practical, hands-on experiences of chemistry within reach of all classrooms.

Once again unfortunately, in many cases this enthusiasm wilted in the weeks and months following. In some cases there was basically no money available, a vacuum that could have been bridged by donors. But in addition there was the enormous inertia of the educational system, due to a mixture of lack of competence and experience, together with a normal human resistance to change.

In selected countries what should logically have followed upon the introductory workshops, actually happened. Pilot projects were started with government support and with expectation of a policy decision on equipping of schools to follow. But here too expectations were often unrealistic. The assumption was made that if microscale chemistry kits and chemicals were delivered to impoverished schools then they would be integrated into classroom chemistry teaching without undue difficulty. Unfortunately the teachers were usually ill-prepared to do this, completely lacking any experience of managing practical work. Where training had been provided this was not always informed by first-hand experience either. Hence not only were lesson experiences disappointing, but items of the equipment were lost and gradually the resources diminished and became non-viable. Replenishment of chemicals as well as supply of spare parts had usually not been planned for anyway. Unfortunately all these woes were often blamed upon the microscale approach itself, although they were clearly due to lack of experience in doing and supporting practical chemistry activities in the classroom.

A CURRENT ASSESSMENT

It is difficult to avoid a feeling of gloom after reading the Background, because there have been so many disappointments. However the concept is not dead. With amazing resilience in the face of our mistakes, it slowly but surely expands. There can be no more certain demonstration of its essential value! Conferences continue to include presentations and workshops devoted to microscale chemistry, invariably with items of novelty (e.g. 6th International Symposium on Microscale Chemistry 2011 (Kuwait)). Many teacher journals have regular contributions on the subject. There is a regular flow of buyers of the equipment. UNESCO continues strongly to promote it, for example, obtaining funds for major projects in selected countries (for example, recently in Tanzania). Some

Ministries of Education have made their own arrangements and are either well-advanced in implementation already (Cameroon) or are now starting out after a number of pilot projects have been completed and evaluated (Mozambique). A lot has been learned through the previous mistakes, and it is more often recognized now that greatly increased attention must be given to teacher preparation and support. Microscale equipment, once a chemistry interest only, is now accompanied by equivalent equipment for parts of physics and biology. This is important for a school system where science is of course not exclusively concerned with chemistry. And as global finance goes into greater and greater difficulties and the World's population increases, so the original concerns (cost, safety, environment) that promoted early interest in microscale chemistry remain and indeed strengthen.

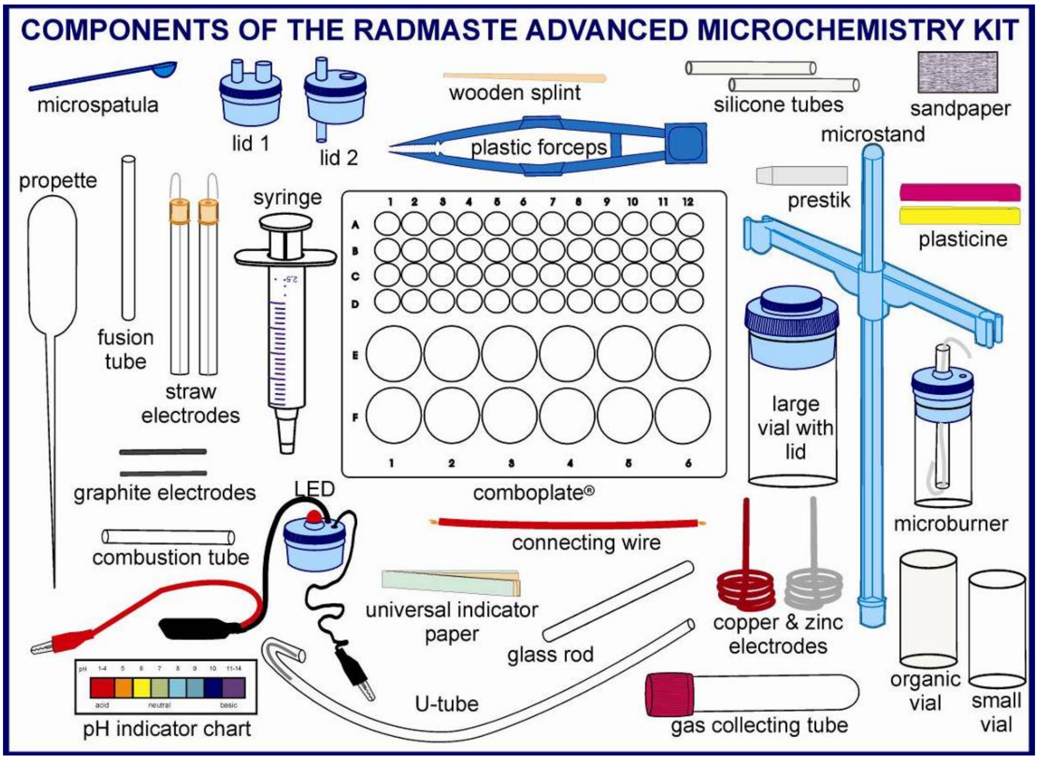
To assess where we stand today let us review a number of aspects.

1. Microscale Equipment

In principle teachers can buy individual items of microscale equipment as and when they require them. But in fact most teachers (especially in developing countries) are not in a position to do that, and need kits containing a selection of items. The diagram below shows an example of the student/learner kits we use.

In this kit, there are mostly plastic components, and they provide for transferring solid, liquid and gaseous chemicals, items for electrochemistry, a microburner (using spirits as fuel), some small glass tubes for substances needing strong heating, and the Comboplate – a microwell plate with two different sizes of microwells.

In these microwells almost all the chemistry happens, and there are two specially designed lids that fit into the larger wells which greatly enhance the possibilities.



The Advanced Microchemistry Kit

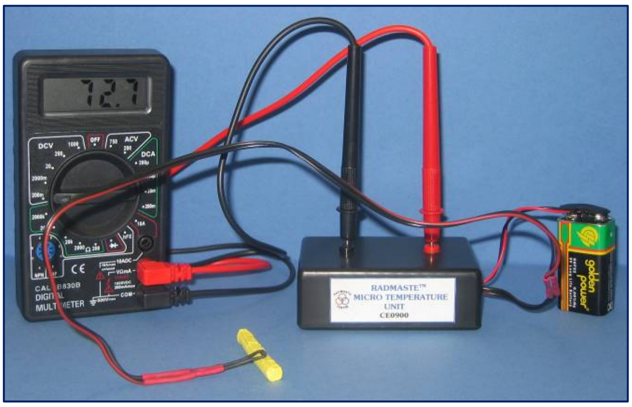
The kit takes up little space (good for limited storage in the classroom), is very portable (can be moved between classrooms, or taken outside), and the components are basically unbreakable. In most circumstances the equipment is easily cleaned; water does not stick to the plastic, so a quick rinse and a shake is often all that is needed. When strong heating of the glass tubes is involved however, cleaning can be more difficult, as is the case with traditional (glass) equipment. The one thing to avoid is leaving used equipment unwashed. Then solutions can evaporate, leaving a solid residue which may adhere to the plastic. Rough abrasive treatment may than cause scratching of the plastic. Also indicator solutions, which contain colored, organic dyes, should be washed out promptly: the organic dye molecules are absorbed into the plastic. But altogether the equipment has a long lifetime and the kit is most definitely not a disposable plastic kit!

With maturation of the approach, so there has been development of aspects of practical chemistry which were not in the original conception. This has brought in more advanced electrochemistry and organic chemistry, as well as some quantitative analysis – both volumetric and instrumental.

The RADMASTE™ Microconductivity Unit (far left) allows conductivity measurements of various electrolytes;

Boiling Point of a liquid can be determined with the Organic Microchemistry Kit (left).

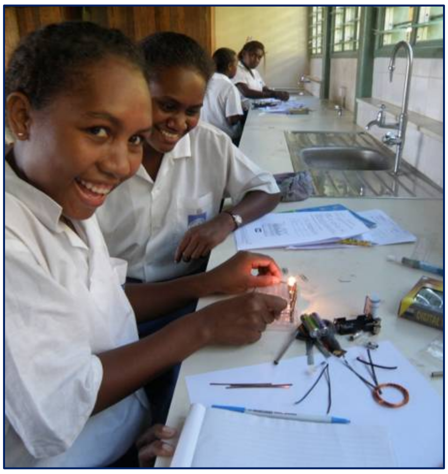
Learners use the Microburette to carry out a microtitration.



Temperature measurements of solids, liquids/solutions and gases can be made with the RADMASTE™ Micro Temperature Unit.

Microscale chemistry education should no longer be seen as limited to observing a few simple test-tube reactions in a microwell plate!

Nevertheless, not all practical science can really be done on microscale. As noted, there is already much microscale biological science practical activity available and in physics all the electricity and magnetism you could reasonably want is readily done on microscale (3). But a physics topic like mechanics is reasonably regarded as very comfortably treated traditionally.



The bulb lighting up puts smiles on the faces of learners working with the Basic Microelectricity Kit.

2. Microscale in the Classroom

Microscale chemistry can be practiced just about anywhere. In a school there is no need to do microscale experiments in a laboratory. In fact it is better if they can be done in a regular classroom, where the practical activity can be integrated with other "theoretical" activities. This is possible because the quantities of chemicals used are so small. Of course the teacher must be a good manager of the activities, but that is also a requirement for working in a laboratory. The kits and chemicals have a small volume so transporting them between store room and classroom, or between classrooms, is not difficult. Water is needed and may have to be brought into the classroom in a suitable container. Waste is generated too and requires that an empty container be brought into the classroom also. For washing up at the end of the lesson water is again required and often this might best be achieved by sending selected children to an outside tap or to washrooms if available.

Kits need to be maintained and this can only be achieved with the participation of the children. Individual children or groups of children must be made responsible for cleaning and packing kits after use. This sort of task is an important life-skill to learn so there should be no hesitation about requiring this of the children.

It has been claimed by many educators that experiments can be completed faster on microscale than with traditional equipment. Of course when used by novices it will not necessarily be so. But very soon, after a little bit of experience, it should be the normal expectation. Therefore it is quite possible for a teacher to plan a lesson around a practical activity. There should be time for introducing the aims at the start and for discussion of results at the end so as to make a meaningful learning experience. To achieve this of course the teacher needs to gain experience and needs to get support and encouragement in the beginning; having microchemistry kits will not be a magic bullet, but it can be the starting gun for a whole new way of teaching and learning which many teachers have only read about in books and children are innocent of.

3. Microscale in the Curriculum

Ministries of Education are responsible for national curricula and if they are persuaded they should implement microscience in selected schools or districts or even across-the-board, several things other than buying equipment need to be provided for.

Firstly, maintenance of kits. There will be few breakages with the plastic equipment (unlike glassware) but there will be losses. Good school management will minimize this; but with poor school management this can be a big problem. There needs to be a spare-parts service for schools.

Secondly, chemicals are consumables; it is unavoidable. Because of the micro scale the quantities used in the experiments are from 1-10% of what traditional experiments require. So the chemicals costs are comparatively low. However it should be recognized that supplies of replenishments must be routinely available to schools. Failure to set up local mechanisms for this will quickly destroy the original investment.

Other important aspects to be addressed are the syllabus descriptions, the textbooks, the examinations. In the sciences, each of these contains implicit or explicit reference to practical work and how it should be done. Consequently each of these needs to be reviewed and amended so that teachers are not deterred by official or quasi-official documentation that suggests if you use microscale your learners will be disadvantaged!

Finally, the existing collection of worksheets for microchemistry experiments (see UNESCO website: *http://www.unesco.org/new/en/natural-sciences/science-technology/basic-and-engineering-sciences/science-and-technology-education/the-global-microscience-experiments/unesco-teaching-and-learning-materials/*) should be studied in relation to the national curriculum. It would be expected that many existing worksheets address topics and concepts that appear in the national curriculum. They are quite suitable too for initial teacher training activities, but it is probable that they are not suitable for the classroom as they stand. It is therefore very important that any relevant existing worksheets be adapted to the national norms and the national curriculum. This task needs to be undertaken before widespread implementation otherwise teachers may feel alienated by being asked to use “foreign” materials.

THE IYC GLOBAL WATER EXPERIMENT

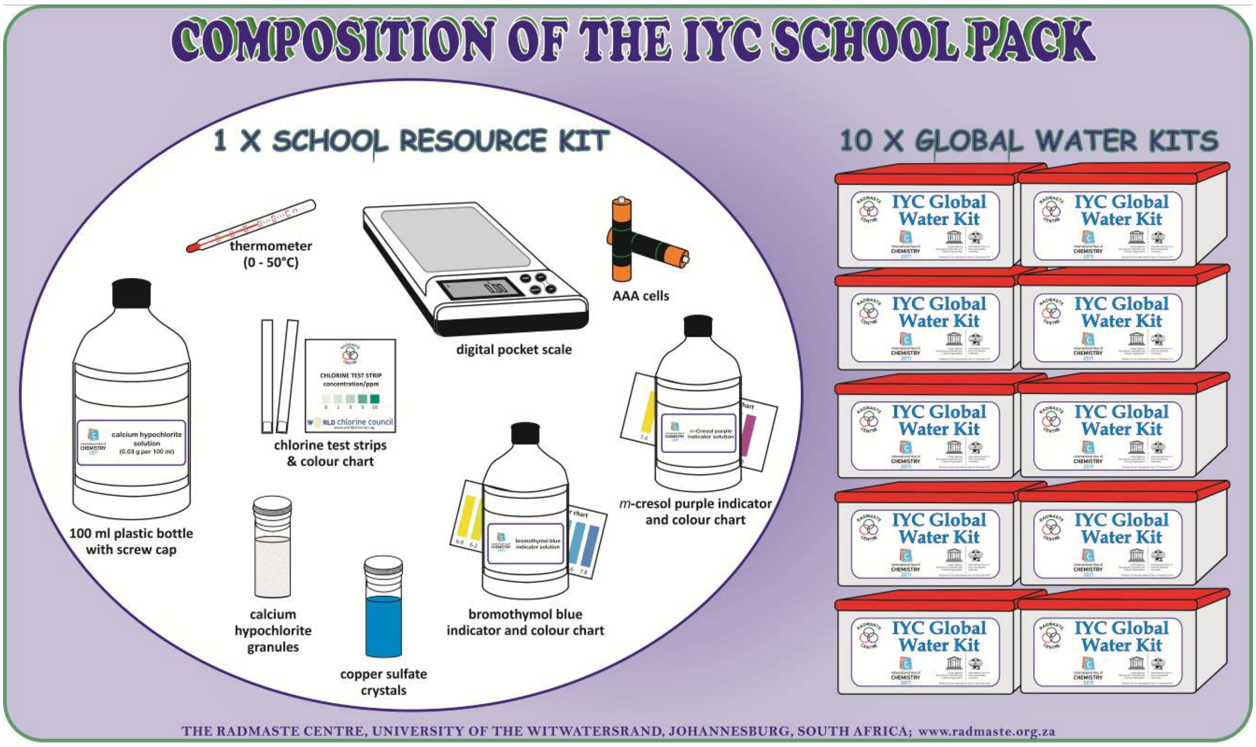
2011 is the International Year of Chemistry and UNESCO and IUPAC share responsibility for its success and impact. Around the World there have been many different events and activities that recognized the IYC and enhanced awareness of chemistry. One ambitious component was to develop and conduct a global chemistry experiment, in which children and the public, universities and colleges could all participate. Water - its quality and its treatment, soon emerged as the theme for this global chemistry experiment and an IUPAC Task team designed and developed four quite simple experiments for this purpose (4).

However it was realized that the majority of people and countries around the World would not likely be able to participate in the Global Water Experiment (GWE). Attention switched then to microscale chemistry activities that were equivalent to the traditional scale ones originally designed. This was done (E Steenberg) and at the same time a special microscale kit was developed to assist developing countries (and donors to these countries) to get involved. Almost all the equipment components were drawn from the contents of our existing kits, and even chemicals were included in this case (in solid form for easier and safer transportation).

Microscale kits for the Global Water Experiment.

Thus we created a Global Water kit for use by children and a School Teachers Resource kit (SRK) for teachers to support children's activities. A School Pack was then constituted comprising 10 GWKs and one SRK, which had everything required to do the four activities on microscale. English worksheets for learners and a Teacher Guide were prepared to support the kits. These have subsequently been translated into French, Spanish, Portuguese and Arabic with the help of UNESCO. Individual countries have also made their own translations of the materials, such as the Netherlands where Dutch microscale materials are available.

Under a UNESCO-sponsored project, five School Packs were sent to each of 32 developing countries around the World. 50 School Packs were also acquired by the UNESCO office in Montevideo for Latin American distribution. Altogether some 436 School Packs have so far been distributed to ? different countries, of which 15 countries are in Africa.



This recent story illustrates very well the power of the microscale chemistry concept to make for a more inclusive and richer science education. Many, if not most of the countries that acquired these kits to participate in the GWE would not have done so without microscale chemistry kits. To cater for all the children around the World is still impossibly costly to do immediately, but with a bit of time and effort it could be achieved.

IT'S TIME FOR AFRICA

A number of positive reports have appeared in the past year suggesting that there are very good prospects for Africa. The subtitle "It's time for Africa" is in fact taken from an "attractiveness survey" published by Ernst & Young in 2011 (5). It is gratifying for Africa to be seen in such positive terms, but as is well understood there are serious educational imperatives underlying the realization of these hopes and expectations. One of these imperatives is the strengthening of science education at all levels. The implications to us are clear: there is now yet greater urgency to meaningfully improve access to hands-on science for all. It is through this that interest in science and public understanding of science will grow. And it is through this that the necessary scientific and technological development and maintenance will become achievable. Without this, the resources of Africa will be plundered and the "owners" left empty-handed.

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