

# Small-Scale Chemistry

by J.D. Bradley

It is widely believed that practical work is an essential part of chemistry education. However, in most countries there is no provision for such personal experiences, and even at universities, provision is limited. This problem has been recognized for many years by both UNESCO and IUPAC, and a number of initiatives were taken to address it. The microchemistry program started in 1997 aims to address the problem through promoting a small-scale, low-cost approach, and done by means of introductory workshops for chemistry educators in different countries. The concept has been received enthusiastically in nearly 40 countries now, and pilot projects have been initiated in several of these. This year, UNESCO and IUPAC have renewed their collaboration on this project. In his lecture at the 8<sup>th</sup> International Chemistry Conference in Africa (8<sup>th</sup> ICCA), 30 July–4 August 2001, in Dakar, Sénégal, Prof. Bradley presented the project and its outcomes. His lecture entitled “UNESCO/IUPAC–CTC Global Program in Microchemistry” is published in July 2001 issue of *Pure and Applied Chemistry* (Vol. 73, No. 7, pp 1215–1219) and reproduced below.

A revolution in chemistry education has begun. Practical work is an integral part of science education. Ask any science educator, and you can be almost certain he or she will agree. The implication that practical activity is, therefore, a frequent component of science teaching is usually left an unspoken assumption. The following quotes surely reflect a universal opinion and expectation:

“Experimental work is a defining characteristic of the natural sciences . . . wherever possible, practical work should involve active student participation.”<sup>1</sup>

“. . . chemistry is fundamentally an experimental subject . . . education in chemistry must have an ineluctable experimental component.”<sup>2</sup>

Yet, the reality in science education is quite otherwise. Ask any honest educator, and the appalling reality will invariably be disclosed. In the majority of school science classrooms, there is no practical activity. In rich societies, you may find virtual substitutes; in poor societies, you will find blackboard descriptions. The latter will freely acknowledge that the real experience cannot

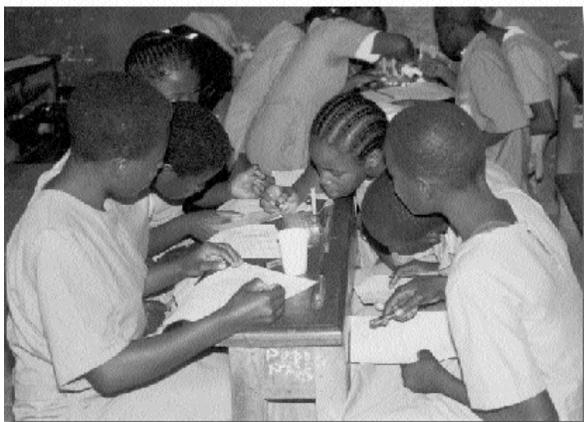
be afforded; the former will cite concerns about safety and environment. When really pressed, many teachers in both contexts will admit they are not really prepared (trained) for it. At the university level, difficulties are also evident. Almost everywhere, the burden is felt of providing practical experiences for increasing numbers of students in a context of increasing costs of chemicals and equipment. In poorer countries, the battle has been lost: practical work has been ossified and eroded to the extent that students graduate with little practical experience and little understanding of science.

This situation is not something that has developed recently.<sup>3</sup> Both UNESCO and IUPAC have known about it for decades. At UNESCO, low-cost equipment for science education has been on the agenda for action as long as people can remember: it has principally been focused on primary and secondary education.<sup>4</sup> At IUPAC, the Committee on Teaching of Chemistry (CTC) took up the challenge at a tertiary level, focusing on low-cost instrumentation for chemistry.<sup>5,6</sup> The history of these endeavors is a matter of record, and it would be good to evaluate their long-term impact on science education.<sup>7</sup>

During the past five years, a new onslaught on this historic problem has been mounted in a cooperative program of UNESCO (Basic Sciences Division) and IUPAC–CTC. The central thrusts of the program have been to disseminate awareness of the benefits of small-scale, low-cost chemistry equipment; to facilitate meaningful consideration of how the capabilities of the equipment match the requirements of the curriculum; and to help initiate pilot projects that permit classroom-based assessment of the applicability of the approach.

## Small-Scale, Low-Cost Equipment

The equipment used in this program was developed in South Africa and is based on the use of plastic microw



Students doing microchemistry at Lycee Gen.Leclerc, Yaounde.

ell plates with two sizes of microwells. With this comes some familiar plastic items for handling solids (microspatulas), liquids [propettes (Beral pipettes), syringe], and gases (gas collecting tube); some specially designed items (e.g., two types of well-lids) for more complex reaction set-ups; some silicone tubing; a short piece of glass tubing; a glass rod; and a microburner. These items are packed into a plastic "lunch-box" to constitute a basic student kit. With this kit, a wide range of basic chemistry experiments can be carried out, very simply and quickly. With the addition of a few more items, numerous experiments in electrochemistry, organic chemistry, and/or volumetric analysis can be performed.<sup>8,9</sup>

This equipment is now embodied in a host of experiment descriptions and supported by packs of pre-prepared chemicals. The concept has been introduced and disseminated in different countries by means of two-day workshops. The workshops begin with an introductory exposition of the ideas, but the main component is hands-on experience interspersed with discussions. A videotape demonstration is also usually included. Normally, cautious interest is provoked by the introduction, hands-on activity then begins a little nervously, but within a half-hour, confidence and excitement become palpable. Invariably, the majority of participants—usually school teachers, science inspectors, and a few university lecturers—hail the experience as promising a solution to the problem of practical work provision.

The concluding discussion is often sobering, because it is here that the question "What now?" is addressed. While the majority may be persuaded that the solution can now be imagined, the fact remains that there are obstacles. The established curriculum needs to be scrutinized, the textbooks must be considered, the examinations must be taken into account, and, finally, the cost, which is low, but not zero. At this final session, all these problems surface, and there needs to be a conscious effort by individual participants to make a decision to tackle these problems.

### Matching Up To The Curriculum

In the workshop, a selection of experiments is offered to illustrate the scope and limitations of the approach. These experiments are almost universally included in curricula. To tackle the question of the extent to which a national curriculum can be supported by the new-style equipment, most teachers and inspectors welcome an extensive listing and description of experiments that can be done with it. Books containing descriptions of about 100 experiments, including teacher notes, have been prepared in English. To facilitate wider access, translation into other languages has been encouraged. Often a local chemistry graduate who is enthusiastic about the concept, proposes to undertake this. This has led to translation into French,<sup>10</sup> Russian, Arabic, Estonian,



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Persian, and Portuguese at the present time, with other languages in the offing. A decision to undertake such translation is often the next crucial step toward wider interest (including government interest) in the concept.

Therefore, some free copies of the book of experiments are distributed at the end of the workshop, and, if required, a CD-ROM version is distributed also. After some time has been spent on studying the full range of experiments, it is usually concluded that the equipment can satisfy a substantial fraction of a school's curricular needs. Some may argue that not everything is possible and therefore nothing should be done, but such views are a small minority. Some, too, may yearn for a traditional laboratory, where one must go to perform "real science," but they too are a small minority when compared with those who see the removal of the need for such a facility as immensely liberating.

### Initiating A Pilot Project

It usually emerges during workshop discussions that some instructors are ready and eager to try the approach in their own classrooms. Occasionally, there is one educator, usually at a private institution, who can get enough money to do so using the institution's own resources. More often, the cost of a pilot project needs to be met by a donor agency. UNESCO has had considerable success in locating sources of such funding—the final crucial step in the proper assessment of the applicability of the approach in the local context.

It is our impression that in most instances the assessment has been comparatively limited. Given the realities in most of the countries we have visited, this is to be expected. In most cases, too, it must be remembered that it's not a question of weighing the relative merits of traditional-and small-scale equipment: it's a question of seeing what happens when students are allowed to do their own, hands-on, practical work for the first time. Can the teacher manage the situation? Did anyone get hurt? What is the attitude of the students? These are the basic kinds of questions most local educators and government officials want answers to. Until a pilot project has been done, it is all conjecture and/or unverified claims made by the promoters of the concept.

It is our experience that on completion of a pilot project, the demand is always for wider implementation. This, however, is a national matter in which the UNESCO/IUPAC program has no direct role to play.

### Outcomes to Date

The cooperation between UNESCO (Basic Sciences Division) and IUPAC-CTC in this program has been very fruitful. Introductory workshops have been held in nearly 40 countries, which have led to pilot projects in nearly half of these. Many of these countries are poor, and their initiation of pilot projects represents a commendable effort to improve science education in very adverse circumstances. In three countries (South Africa, Cameroon, and Kenya), extensive implementation has taken place.

Donor agencies as well as ministries of education continue to support the spread of the concept in developing countries and countries in transition. As long ago as 1996, Beasley and Chant (in Australia), referring to beginning university courses, observed "the trend from macro is now established."<sup>11</sup> The outcomes of the UNESCO/IUPAC-CTC program since that time, reported here, give a global emphasis to this observation. Furthermore, chemistry education worldwide may be revolutionized as the need for a traditional laboratory is removed and a majority of students are able to experience chemistry firsthand.

### Conclusions

The experiences of the past few years lead to a number of conclusions.

- Active, focused collaboration between UNESCO and a scientific union (IUPAC) can be very effective in disseminating important ideas and information in science education outside the relatively small number of wealthier, developed countries. The political neutrality of these bodies is important for open communication. The model we have established might be extended to other scientific unions.
- The interventions "on the ground" are relatively costly, but essential for new ideas to be seriously considered. Electronic or printed documentation is cheaper, but is unlikely to achieve impact, although there is probably an important supportive role for this.
- The successes of the program have created new channels of communication. These should be nurtured for the benefit of all concerned. From the IUPAC point of view, the Committee on Teaching of Chemistry endeavors to keep informed of the developments and needs of chemistry education at all levels worldwide. Apart from practical work, in all but the richest countries there is a general dearth of good-quality (in the scientific, educational sense) teaching resources for the common, core chemistry content found in all curricula. Similarly, there is a

lack of teaching resources for topics of growing general importance, such as chemical safety. CTC has identified further opportunities and needs in these areas and is cooperating with UNESCO and with IUPAC's Committee on Chemical Industry to disseminate the DIDAC teaching resources (including posters for classrooms without electricity).<sup>12</sup> CTC is also working with IUPAC's Commission on Toxicology to disseminate a new resource for teachers that deals with chemical safety.<sup>13</sup> We hope to continue this program over the next few years, in the belief that a significant impact on chemistry education will be made.

### Acknowledgments

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