THE MICROSCIENCE PROJECT AND ITS IMPACT ON PRE-SERVICE AND IN-SERVICE TEACHER EDUCATION

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This paper was originally prepared for the workshop, the Secondary Science Education for Development (http://www1.worldbank.org/education/scied/Training/training.htm), which was organized by the World Bank, Human Development, Education Group in April 2000. The workshop aimed to explore some of the issues involved in science education reform within a larger context of social and economic development. We welcome your comments.

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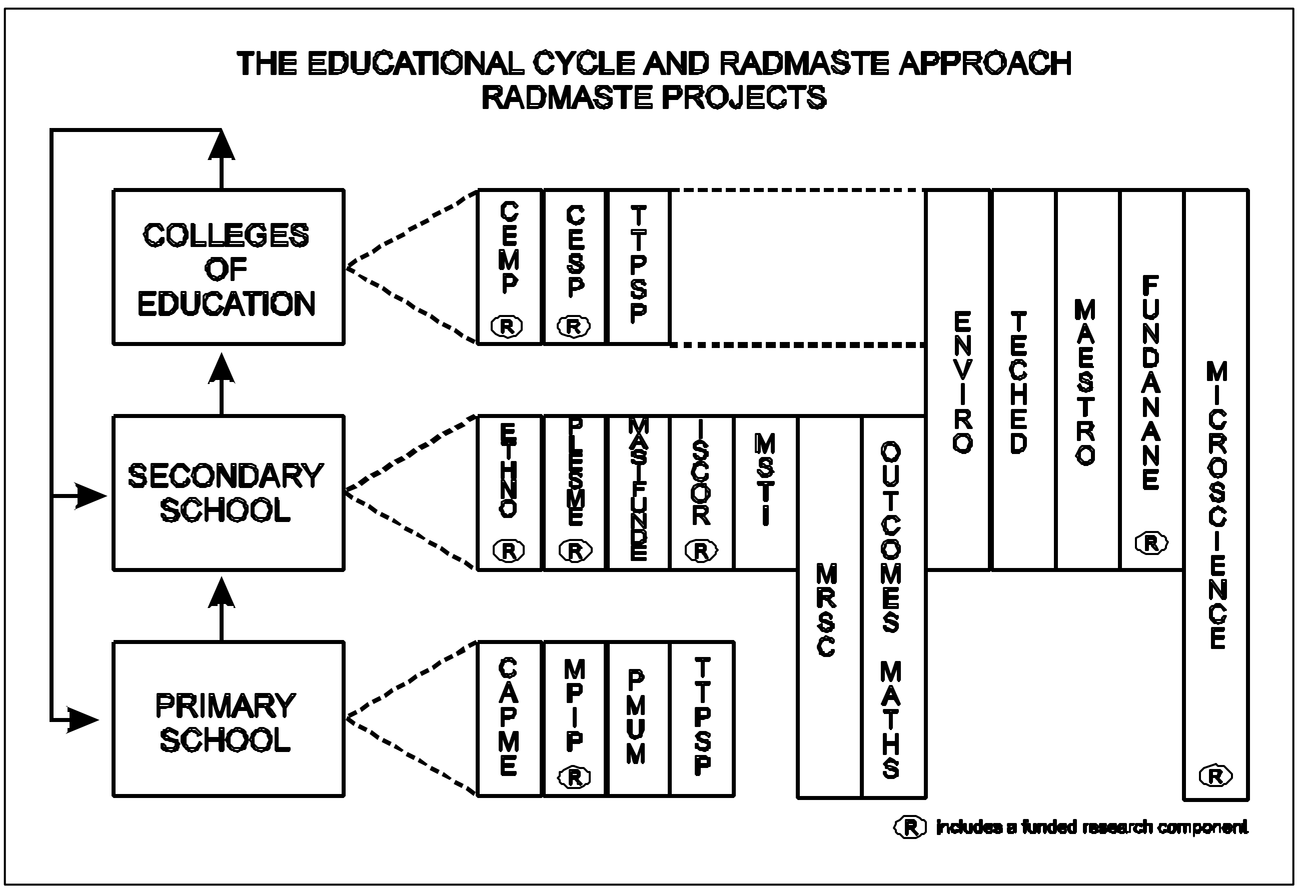
The RADMASTE Centre

This case study derives from activities carried out by the RADMASTE Centre (Centre for Research and Development in Mathematics, Science and Technology Education, University of the Witwatersrand) during the past 9 years. The mission of this Centre is to improve the quality, relevance and accessibility of mathematics, science and technology education. The strategy is to focus on long-term benefits with maximum leverage and to accompany our developmental work with research wherever possible (Bradley, 1999).

The RADMASTE Approach

From the start we perceived that we should give some attention to each level of education, bearing in mind the typical educational cycle (Fig 1).

Figure 1



The figure shows that this gives rise to a matrix of interests with regard to levels (primary, secondary, tertiary) and subject areas (mathematics, science and technology), through which we can endeavour to make a coherent improvement to the educational system. Many projects and organizations have a much narrower focus (e.g. primary mathematics, secondary physical science). The difficulty with these is that change in the one is not linked to changes in the others, creating inevitable stresses for students, teachers and schools. Indeed such stresses are bound to inhibit the desired changes and perpetuate gaps (Manyatsi, Rollnick, Lubben and Bradley, 1998). Our approach recognises the intimate relationship among the three learning areas of mathematics, science and technology, as well as that between the different educational levels. In this case study we shall discuss two of the projects shown in the matrix - CESP and MICROSCI. In doing so the concept of a coherent approach will be illustrated across educational levels in science.

The Colleges of Education Science Project(CESP)

Within this matrix we have always seen colleges of education as key components. This is because they are the main source of both primary and secondary school teachers in South Africa: few school teachers emanate from universities. Until a few years ago, there were more than 100 colleges offering three-year teacher diplomas (Arnott, Hall, Kubeka and Rice, 1997). Unfortunately, the average quality of human and physical resources at these colleges was rather poor; furthermore the colleges generally attracted students who could not get entry to a university. Crudely put, poor lecturers with poor resources and poor students used traditional, teacher-centred methodologies to provide the main corps of teachers for the school system. This situation, probably reflected in most developing countries, goes far to explaining the generally unsatisfactory state of school education in South Africa, particularly as regards mathematics and science.

Starting in 1991, for seven years we had a programme of interaction with the colleges. A major part of this involved workshop courses twice per year to which all maths and science lecturers were invited. These courses lasted from 3 to 5 days and normally were held at the RADMASTE Centre. Typically, more than 100 lecturers from all over the country would attend. The format of the courses varied, but included activities dealing with subject content and methodology, education policy, a visit to industry or commerce and a social event. New teaching materials were created for these events; these were designed to support learner-centred methodologies (Slotwinski, 1997; Pomario, 1998; Smith, 1998; Malcolm, 1999; Malcolm et al, 1999). There were lots of activities for students, with background information for the lecturers, and during the course lecturers would try many of the activities, analyse their strengths and weaknesses, discuss assessment, etc. The industry visit was always very popular. The objectives of this were to broaden the outlook of the college lecturers, inspire their engagement with the science-technology-society (STS) concept, and inform them on employment opportunities and needs. The lecturers seem to have found value in all this, because over the seven-year period they returned for more - this despite the fact that they had to pay for their travel and accommodation (usually partly paid by the college). This belief is supported by informal reports from researchers involved in a National Teacher Audit (Arnott, et al, 1997).

It was a substantial and sustained intervention and it is unfortunate that, due to circumstances beyond our control, it terminated in 1998. The circumstances were that the government decided to rationalise the colleges of education: 50% were disestablished over a period of four to five years and the remainder were linked with universities in their provinces. These drastic changes made continuation of our intervention impossible.

Practical Work and Learner-Centred Methods at Colleges of Education

One of the opportunities provided by the rather frequent contact with college lecturers was to uncover areas of major need. For the science lecturers, equipment for practical science soon emerged as a major problem (Bradley and Smith, 1994). This linked with information from other schools projects, indicating a widespread absence of equipment from school classrooms (Lynch, 1994). Now practical activity was perceived by us as a more-or-less non-negotiable feature of science teaching and learning: it epitomised learner-centred methodology for science. In our workshop courses we therefore frequently advocated and provided experience in, improvisation and use of locally-available materials, where traditional scientific equipment was not available. Such strategies have, of course, been advocated for many years and, for periods of time in particular places, considerable success has been reported (Musar, 1993). The traditional college curriculum made no allowance for these realities and required a range of traditional experiences with traditional equipment to be provided. For the majority of student teachers it was learning to conduct experiments that they would never use in the classroom. Of course, it might be claimed that performing such experiments served other purposes, such as learning the scientific method, gaining a better understanding of science concepts, etc. (Lunetta & Hofstein, 1991; Bradley, 1999). Research by Maake (1999) on what actually transpired, shows that the practical sessions did not achieve such purposes. They tended to be poorly managed, futile exercises, serving only to frustrate rather than motivate students. Ironically, classroom teachers invariably declared their conviction that practical science is a vital component of science teaching, but having no equipment or laboratory meant that they could not do any.

The Microscience Project (MICROSCI)

Enthusiasm for improvisation and use of locally-available materials was never great and it became evident to us that this did not represent a real solution. After some time we realised that microscale chemistry had promise and, five years ago we started the Microscience project. We knew that for a number of years, microwell plates and appropriate accessories, had been advocated as low-cost, safe and easy equipment to use for chemistry. Enthusiasts appeared at conferences, teachers expressed positive interest, but the world at large (outside the conference circuit) seemed unaware, or else unimpressed. To make the concept accessible to the majority we had to make it really convenient. We set about developing the concept in the form of an individual student kit which could be used anywhere: classroom, home, field, laboratory.

Figure 2

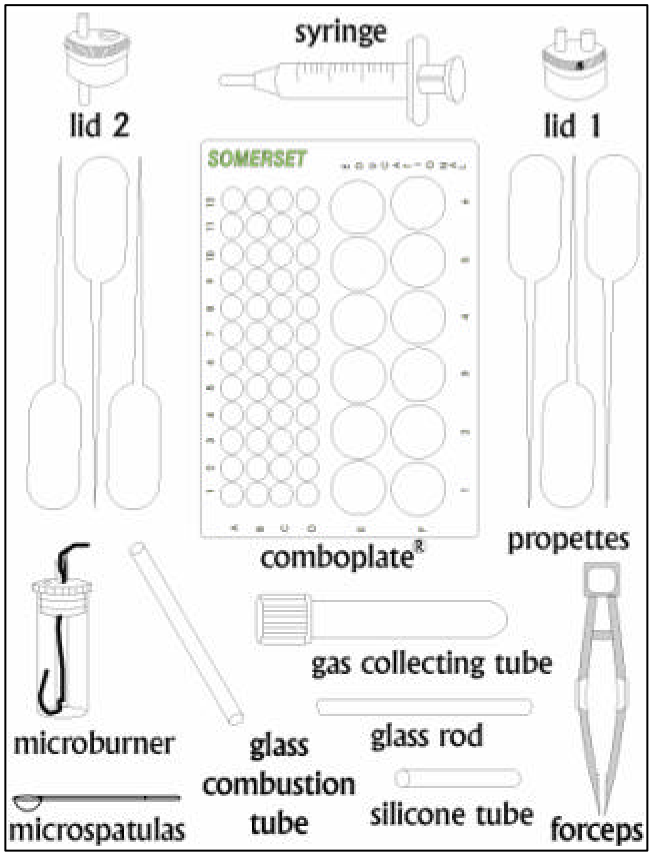


Figure 2 The RADMASTE Basic Microchem® Kit

It comprises a special microwell plate (comboplate®), some specially-designed items (such as special lids for the larger wells to facilitate preparation and use of gases) and some standard items (such as plastic syringe, propette). To accompany these kits we developed a teacher's resource kit (chemicals) and worksheets (with teacher's guide)(Bradley, Durbach, Bell, Mungarulire and Kimel, 1998). These developments have been undertaken in cooperation with Somerset Educational, a company located in a small rural town, Somerset East (S Africa). A rewarding feature of the development has been the extent to which the company has been able to draw into the manufacturing process, semi-skilled people from the local community.

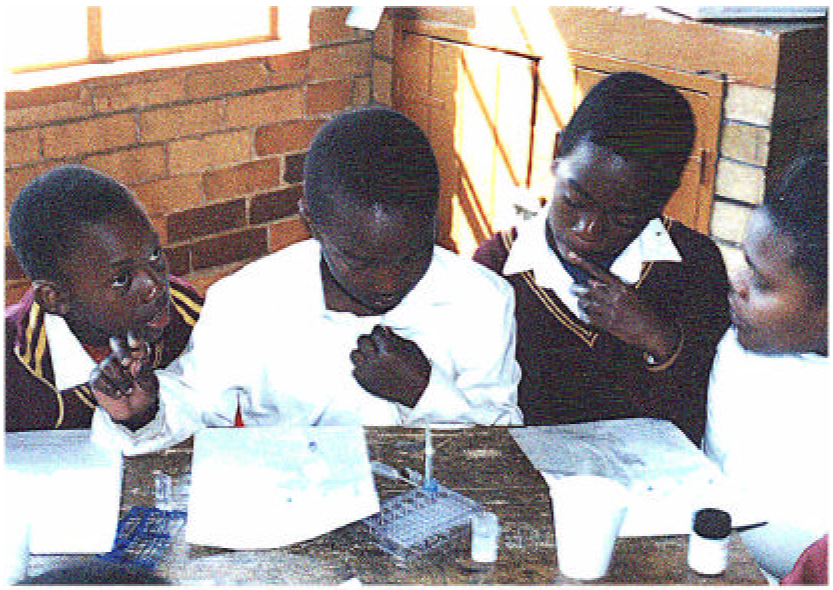
Figure 3 One of the many local inhabitants supporting the manufacturing process in Somerset East

We introduced early versions of these kits to college lecturers, who were mostly enthusiastic about them. Their low cost held strong appeal for them, as they had little or no budget for equipment and chemicals. One lecturer, who was at a relatively well-equipped college, said she was not interested in getting the equipment, but would try it with her students as a favour to us. A month later she phoned and said she was converted. Practical sessions were much easier than before and students seemed to be more interested. She got one student to speak on the phone and he explained that he had never been interested in the practical sessions because he knew that he would never get the equipment in his school classroom. With these microscale kits, he thought there was a real chance that he would get them, and he was excited. From this same college, student teachers went on teaching practice taking several kits with them. They were a big hit and everyone was very pleased! Previously, student teachers would undertake teaching practice in schools without science equipment, thus demonstrating the futility of the practical component of their curriculum.

Many colleges initially obtained microscience equipment as a result of donor funds we solicited. Some purchased the equipment for themselves. In one province it was officially endorsed and supported. In the longer term, penetration of the concept slackened for a number of reasons, including budget cuts and closures.

Fortunately, we had our matrix. We were active in a variety of secondary school projects, and the Microscience concept found its way into many different workshops, curricular materials (More Relevant Science Curriculum (MRSC) project), etc. The impact was invariably positive, everyone succeeded in using the new small-scale equipment immediately. In workshops, teachers smiled, and kept on smiling to the end, and in their classrooms they found the children smiled too.

Figure 4 Young Learners Enjoying a Microscience Lesson

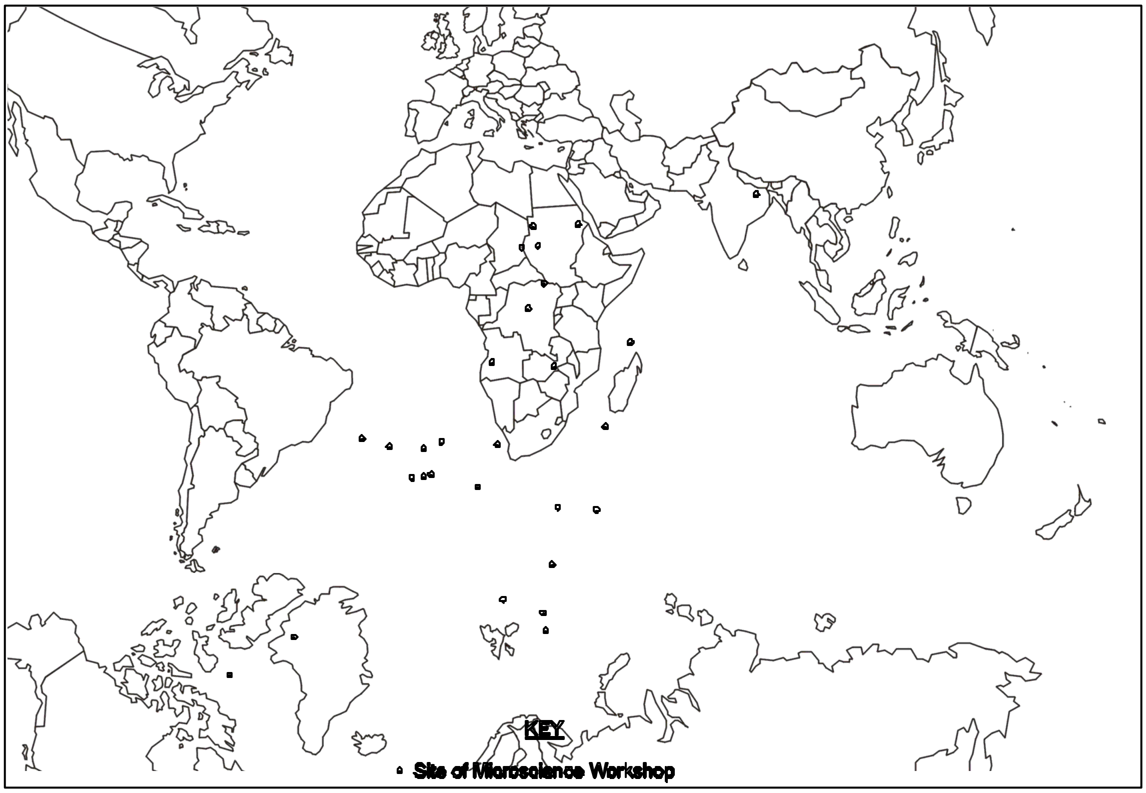


In brief, it was a hit in the schools too, and by the year 2000 microscience kits were in use in more than 1000 schools in South Africa. The majority have acquired kits through the generosity of educational trusts and corporate donors.

This positive reception has now been experienced in many other countries where the concept has been introduced. We have worked in close cooperation with UNESCO (Basic Sciences Division) and IUPAC in this process of diffusion.

Extensive implementation is taking place in 3 countries, whilst pilot projects are under way in 12 more. The chemistry worksheets have been translated into French, Russian (in part) and Arabic (in progress). Furthermore, following this success, we have developed other kits which enable low-cost and convenient activities in primary science (integrated science), basic electricity, biology, electrochemistry, titration and water quality testing.

Figure 5 UNESCO – IUPAC/CTC – RADMASTE GLOBAL PROGRAMME

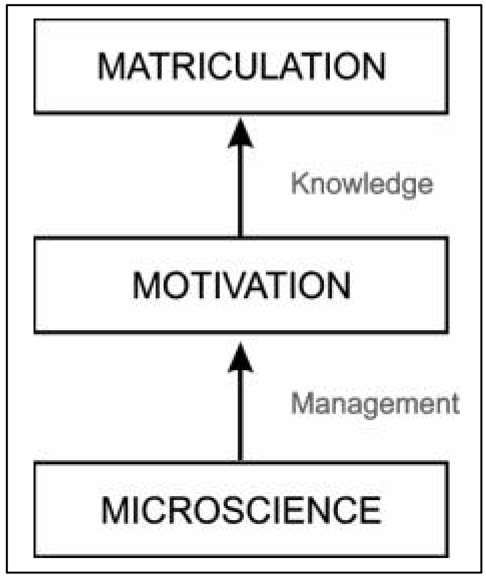


Science Concept Learning

At an early stage in the history of our Microscience project, research was undertaken to discover the attitudes of school teachers and students towards practical science on microscale and the extent to which learning of science concepts took place. The research studies showed (Vermaak, 1997; Kolobe, 1998) that attitudes of both teachers and students towards microscale practical work were strongly positive. The one study showed very satisfactory knowledge gains accompanying the practical work, but the other did not. The reason for the difference in results is clear: in the first study better teachers were involved than in the second one.

All that this confirms is that practical work, including microscale, will not result in concept learning by students unless the teacher is able to facilitate this happening. We have explained the situation to educators and education officials as follows.

Figure 6



We can almost guarantee that introducing microscale practical science will motivate students: it requires management skills of the teacher to ensure that this motivation is sustained. However to matriculate (pass the exams!) requires concept understanding and pedagogical content knowledge on the part of the teacher. Here is the problem that will not go away and cannot be solved merely by choosing either teacher-centred or learner-centred methodologies. Here is a priority for universities and colleges of education and for in-service training.

Curriculum 2005: Outcomes-based Education

Some three years ago, the implementation of a new school curriculum began in South Africa. Official documents are rich in polysyllabic jargon and any teachers who happen to get a copy are unlikely to get much comprehension. However, learner-centredness in terms of content and methodology are evidently a central part of the new official policy. Practical science is naturally endorsed also (National Department of Education, 1997):
"Experimental work is a defining characteristic of the natural sciences.....wherever possible, practical work should involve active student participation."

As the new curriculum has rolled out, official help for teachers in accommodating to it has been sketchy. Lack of human resources and a general shortage of money together have made the process very difficult. Many NGOs have been assisting and so has our Centre. Unfortunately, even when government funds are applied to this task, poor organization sometimes leads to less-than-optimal use of funds.

Meeting the Challenge of Implementing Learner-Centred and Practical Science with Microscience

It seems clear that the near-universal aspiration to provide practical science experiences for students is likely to be realised in many countries through the microscience approach. On the one hand traditional equipment is prohibitively expensive both in terms of its costs (running and initial) and in terms of safety and storage requirements which implicate full science laboratories (Caillods, Gottelman-Duret and Lewin, 1997). On the other hand improvisation and use of locally-produced equipment is very unattractive due to the severe demands made upon teachers, and the limited scope of most such equipment. For many teachers acquiring microscience equipment means enabling them for the first time to provide hands-on practical experiences for their students. For many teachers, furthermore, this is to a greater or lesser degree, the first time that learner-centred methodologies invade their classroom to any significant extent. Teachers often need to learn how to manage this new situation, because not only is practical science a novelty, but so also is learner-centred methodology. And beyond management lies pedagogical content knowledge, assessment, and more.

There are positive dimensions to this intimidating prospect. Teachers like to receive equipment - they have been indoctrinated to believe that equipment is needed for science, so their professional tools are being provided and they gain status. Furthermore they witness the excitement of the students using scientific equipment and engaging in "formal science" for the first time. All teachers pray for student motivation, because they know this is the key to opening the doors of learning. This can buoy up teachers as they feel the weight of the difficult tasks to be learnt (Charpak, 1996). We have begun now to use the introduction of microscience kits as the spearhead of interventions aimed at fostering learner-centred science and practical science. Our new strategy of science teacher education is summarised below.

Figure 7

Science Teacher Education

Students Outcomes	Teachers Needs
Motivation	Management skills
Practical Skills	Personal Experience
Concept Learning	Pedagogical Content Knowledge

To sustain student motivation with hands-on practical activities, the teachers require classroom management skills. For the students to develop practical science skills, teachers must be able to guide them on the basis of their own extensive personal experiences. For the students to gain conceptual understanding, teachers need pedagogical content knowledge. To implement this strategy in the pre-service preparation of teachers presents no particular problem. For in-service teacher education, extended programmes of workshops and classroom visits appear to be called for. However, self-development strategies can form part of an INSET programme. The portability of the kits makes it easy for teachers to use them anywhere they wish, including their homes. There is evidence (van den Hoek, 1997) that they can gain pedagogical content knowledge using appropriately-designed learning materials.

The microscience system is still developing. However it clearly promises to make an important contribution to the implementation of learner-centred and practical science.

Acknowledgement

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