THE MICROSCIENCE PROJECT
21 YEARS OF RESEARCH, DEVELOPMENT AND COMMUNITY ENGAGEMENT
PREFACE
An Overview of 21 Years of Research, Development and Community Engagement

RADMASTE MICROSCIENCE PUBLICATIONS
Microscience Publications - Academic
Microscience Publications - Electronic and Printed Resources for Educators and Learners

UNPUBLISHED RADMASTE MICROSCIENCE RESEARCH
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Introduction of RADMASTE Microchemistry in Disadvantaged Schools in Gauteng: A Case Study
A Trial Introduction of RADMASTE Microchemistry Kits in Chemistry I Practicals at the University of the Witwatersrand
A Case Study of the Micro Scale Primary Science System (MSPSS) as a Primary School Science Teacher Support Resource
The Effect of the Use of Individual Experimentation by Standard 9 Chemistry Pupils in the Vaal Triangle to Aid Understanding of Selected Chemistry Concepts
Factors Affecting the Use or Non-Use of Microscience Equipment Supplied to Mpumalanga Secondary Schools
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RADMASTE MICROSCIENCE CONFERENCE PRESENTATIONS

RADMASTE MICROSCIENCE EDUCATION AND TRAINING ACTIVITIES
in cooperation with UNESCO and Ministries of Education
An overview of 21 years of research, development and community engagement

The RADMASTE Centre was founded in November 1990 in the Faculty of Science with the aim of improving the quality, relevance and accessibility of maths, science and technology education. Insofar as science education was concerned the pathetic status of practical activities in South African school science was recognised. It was also apparent that this problem is global and thus it became a focus for RADMASTE research and development. The microscience kits were conceived by RADMASTE as a response to this pervasive problem, and between 1993 and 1995 the concept was tried out, an entrepreneur established a company (Somerset Educational) to manufacture the kits, and a PhD study on classroom implementation was completed. News of the RADMASTE Microscience kits spread rapidly and, following a meeting with UNESCO Basic Sciences Division in Paris in 1996, UNESCO established a Global Microscience Programme.

In the wake of these developments awareness of the RADMASTE Microscience kits spread like a forest fire, confirming the global need and interest. RADMASTE played a role in stimulating this interest, making conference presentations, conducting workshops, providing teacher training, and giving free global access to our worksheets and teacher guides in cooperation with UNESCO. In addition, RADMASTE has continued to develop the Microscience kits, so that there is now coverage of much that is required in chemistry, physics and biology at both primary and secondary school levels. There is now also a very large repertoire of worksheets and teacher guides, with authorised translations available in more than one language (and many more languages in unauthorised versions). In 2004 a UNESCO-associated Centre for Microscience Experiments was established at RADMASTE, in recognition of the partnership with UNESCO and to facilitate continuing cooperation.

In the first few years of the RADMASTE Microscience Project, a number of research projects were conducted in South Africa, either sponsored by FRD, HSRC or DBE or as higher degree studies. These confirmed the positive potential of microscience but also identified implementation problems. These problems originated in teacher limitations rather than kit limitations. Most teachers were found to have very limited practical science skills themselves and even less experience of managing classroom activities for learners. This situation was confirmed to be typical in most developing countries.
Much of the endeavours of the RADMASTE Microscience Project since then have focused on dealing with this problem. Numerous in-service teacher training projects for science teachers have been conducted and microscience kits and methods have been an integral component. In the last 5 years, Wits-accredited Short Courses have been the vehicle for teacher development, and by the end of 2014 a successful model had begun to emerge.

Whilst most of the latter has taken place within South Africa, national pilot and implementation projects in other countries (Cameroon, Rwanda, Tanzania, Mozambique) have also involved RADMASTE staff. More of this is anticipated in the future.

After more than 20 years, the RADMASTE Microscience Project has gained national and international recognition. This is attributable to a large number of individuals working at RADMASTE (including some who started the project originally), as well as a number of organisations:

Bina Akoobhai, René Basson, Beverly Bell, John Bradley, Shane Durbach, Pierre Kibasomba, Rina King, Louis Lubango, Maria Lycoudi, Ian McKay, Joseph Mungarulire, Mpunki Nakedi, Jill Ovens, Christa Roberg, Colleen Smith, Barbara Thorne.

UNESCO (Basic Sciences Division), IUPAC, IOCD, Somerset Educational.

Professor Bradley (Director: RADMASTE) and Mokone Nakedi (Marketing: RADMASTE) receive the 1998 NSTF award on behalf of RADMASTE in recognition of Microscience as an outstanding contribution to science, engineering and technology. The Minister of Education, Sibusiso Bengu, attended the award ceremony.

JD Bradley & I Vermaak, Microscale Chemistry from an African Perspective. Proc 14th International Conference on Chemical Education, Brisbane, Royal Australian Chemical Institute, pp 100-107, 1996.


JD Bradley, BCT Bell, S Durbach and J Mungarulire, From the Cape to Cairo: Microchemistry is Changing the Face of School Chemistry. Chem Proc (SA) 4(2), 11-14, 1997.


JD Bradley. The Microscience Project and its Impact on Pre-Service and In-Service Teacher Education. *In Hugerat, Schwarz and Livneh, Microscale Experimentation for All Ages*, Haifa: The Academic Arab College of Education, 2006.


MICROSCIENCE PUBLICATIONS –
ELECTRONIC AND PRINTED RESOURCES FOR EDUCATORS AND LEARNERS

1. RADMASTE-UNESCO MICROSCIENCE PUBLICATIONS

1.1 Electronic/Internet Resources

The following resources have been authored and prepared in Portable Document File format by RADMASTE, and made available for free access on the Internet by UNESCO (http://www.unesco.org/new/en/natural-sciences/specialthemes/science-education/basic-sciences/microscience/ unesco-teaching-and-learning-materials/). These publications have supported, and continue to support, the ongoing Global Microscience Programme of UNESCO.


1.2 Microscience Books for UNESCO Member States

The following A5 hard cover books were authored by RADMASTE with the support of the UNESCO-Paris Office (Basic Sciences and Engineering Division). The books were printed by Magister Press Publishing House in Moscow and distributed to several UNESCO-member states.

1.2.1 English Versions


1.2.2 French Versions of 1.2.1
   i. Module Avancé d’Enseignement et d’Apprentissage: Experiences de Microchimie
      (translation prepared by J Mungarulire, RADMASTE Centre), 2002.
   ii. Module Avancé d’Enseignement et d’Apprentissage: Experiences de Microelectricité
      (translation prepared by J Mungarulire, RADMASTE Centre), 2002.

1.2.3 Portuguese Versions of 1.2.1
   i. Módulos Avançados De Aprendizagem: Experiências De Microquímica (translation
      prepared by the RADMASTE Centre with assistance from Prof. E Maia, Lisbon), 2002.

1.2.4 Spanish Versions of 1.2.1
   i. Paquete Avanzado De Aprendizaje Y Entrenamiento: Experimentos De Microquímica
      (translation prepared by Prof. Jorge G. Ibanez: Centro Mexicano de Química en
      Microescala, Universidad Iberoamericana, Mexico); 2002.

1.3 RADMASTE-UNESCO Portuguese Manuals for Lusophone Countries
   The following publications were translated into Portuguese by the RADMASTE Centre with
   support from the UNESCO-Windhoek Office.
   1.3.1 Módulos Avançados De Ensino/aprendizagem: Experiências De Micro-electricidade -
      Versão Portuguesa, 2007. (direct translation of 1.1.5)
   1.3.2 Módulos Avançados de Ensino e Aprendizagem - Experiências de Microciência Para o
      Ensino Primário - Versão Portuguesa (Primeira Edição), 2005. (direct translation of 1.1.6)
   1.3.3 Biologia Experiências de Microciência: Materiais de Ensino e Aprendizagem para Biologia;
      Primeira Edição - Versão Portuguesa, 2007. (direct translation of 1.1.7)

1.4. Activity booklets and Teacher Guides in Support of the Global Water Experiment (GWE)
   of the International Year of Chemistry 2011 (IYC2011)
   The following RADMASTE booklets were approved by the IYC task force set up by UNESCO
   and IUPAC in 2010 in preparation for the GWE. The methods contained in these
   publications are small scale versions of the conventional procedures used for the GWE.
   1.4.1 Complete Sets of Water Activities (including teacher guides)
   i. B Bell B & E Steenberg. Microscale Global Water Kit Instructions: pH of the Planet (Testing
      the pH of Different Water Sources), 2011
   iii. E Steenberg. Microscale Global Water Kit Instructions: No Dirt, No Germs! (How Water
        Treatment helps us), 2011
       Water (Designing and building a Solar Still), 2011
1.4.2 Abridged Booklets of Microscale Global Water Kit Instructions (for Distribution with the RADMASTE microscale water kits for the Global Water Experiment of IYC 2011 - also available in French, Spanish, Portuguese and Arabic)


2. RADMASTE MICROSCIENCE PUBLICATIONS

Note: With the exception of the GWE materials listed previously, the publications listed in 1. above were already in existence prior to the onset of the UNESCO Global Microscience Programme. They are therefore, first and foremost, RADMASTE publications. The publications listed here are in addition to those authored in 1. above.

2.1 Chemistry Publications


2.1.2 B Bell, JD Bradley: RADMASTE™ Microtitration Manuals for Tertiary Level Students and Lecturers, 1996.


2.1.5 B Bell: RADMASTE™ Smaller Scale - a Safer Scale - a resource to guide educators on safety, care and maintenance aspects of using the Microchemistry Kits, 2009.

2.1.6 B Akoobhai, JD Bradley, E Steenberg: The RADMASTE™ Molecular Stencil – Activities for Learners, 2009.

2.1.7 JD Bradley: The RADMASTE™ Molecular Modelling System – Activities for learners using the RADMASTE™ Molecular Modelling Kits, 2009.

2.1.8 B Bell, JD Bradley, Pierre Kibasomba: Guidelines for the Use of the RADMASTE™ Micro Light Absorption Unit, 2010.

2.2 Physics Publications


2.3 Biology Publications

2.4 Publications to support the South African Physical Sciences CAPS Curriculum


2.5 Publications in Support of the International Year of Crystallography, IYCr2014


2.5.2 R Basson, B Bell, JD Bradley, M Lycoudi, C Roberg: RADMASTE™ Crystallography Activity Booklet, 2014.

2.6 RADMASTE Books Incorporating Microscience

Textbooks, Coursework Books and other Books where Microscience and Microscale Activities have been integrated into the text.

2.6.1 Textbooks


2.6.2 Microscience Support Books/Manuals


2.6.3 Course books Incorporating Microscience

RADMASTE has developed course books for Wits University Accredited Programmes (e.g. the ACE) and Short Courses. The books are concerned with delivering the content that educators need to know to pass the accredited courses, and microscale activities have been integrated wherever necessary to allow for the practical work component of the course to be completed using the RADMASTE Microscience Kits.

Examples include:

i. EDUC 2160: Electricity (FET) Course book and contact session booklets, 2010.


There are many other examples.

2.6.4 Miscellaneous Microscience Workshop Booklets

RADMASTE has prepared numerous workshop booklets for the purposes of informal teacher-training. The booklets are custom-designed for each workshop session, usually after conducting a needs analysis with the educators involved. The booklets provide the Centre with a rich resource of activities in addition to the publications previously listed. Booklets that form part of content training for teachers contain both microscience activities and the content linked with the practical work. Booklets intended for Introductory Microscience workshops usually contain only the microscience activities required for the particular workshop. These latter workshop booklets are available in English, French and Portuguese.

3 RADMASTE MICROSCIENCE DVDs

(A DVD for chemistry educators showing the use of the RADMASTE Microchemistry Kits to carry out practical activities for various chemistry topics. This DVD is also available in French, Portuguese and Arabic.)

(A DVD filmed prior to the GWE showing South African learners using the microscale Global Water Kits to carry out pH and water purification activities. This was the very first trial of the RADMASTE GWE activities involving school children. Parts of this DVD were used by UNESCO in promoting the GWE of IYC2011.)
UNPUBLISHED
MICROSCIENCE
RESEARCH
EVALUATION OF COST-EFFECTIVE MICROSCALE EQUIPMENT FOR A HANDS-ON APPROACH TO CHEMISTRY PRACTICAL WORK IN SECONDARY SCHOOLS.

JD Bradley and I Vermaak (1997)

Background

The driving forces behind this study were the realities found in science education at the time (1995), namely that:

- schools in developing countries – including South Africa – did not produce sufficient numbers of learners in science-related fields, even though it is considered that these are of utmost importance for the economic and technological growth and development of any country.
- in sub-Saharan countries in Africa, the pass rate in science was low and there was a growing unpopularity of the subject.
- the science education scenario in most developing countries is one of teacher and text book domination, which together with rote learning and lack of practical work, results in poor understanding of scientific methods;
- traditional cultural views could influence science learning to such an extent that commitment to science and applying scientific approaches to solving problems, were absent in some cultures.
- science practical work was neglected, shown by the existence of poorly equipped laboratories, unprepared teachers, and use of a single textbook as a source of information.

It became evident that practical work by learners and demonstrations by teachers did not necessarily take place, even when a well-equipped lab with properly constructed science practicals existed.

The Research

The study involved conducting a formal evaluation in South Africa of microscale techniques and their effectiveness. South Africa is a country of diverse cultures and at the time, the previous apartheid system had created inequalities in the different classes of schools: former “white” (TED) schools were known to have good facilities, well-trained teachers and smaller classes whilst “black” (DET) schools were found to be disadvantaged in many respects, with little evidence of any practical work being done.

The main purpose of the research was to evaluate small-scale equipment for a series of secondary school chemistry experiments, which were all designed by the RADMASTE Centre.
The following research questions were addressed:

a. “Is there an alternative strategy to effective pupil practical work where laboratories, equipment and funds are limited?”

b. “Will the engagement of pupils in hands-on activities result in
   • a more positive attitude towards science?
   • an increased understanding of certain concepts?”

A sample of more than 600 grade 11 learners from 30 South African schools was investigated. This included schools from the former TED and DET education departments. The schools were varied in location: some were urban, some peri-urban (“township”) and others rural. The learners had to complete five microscale experiments using the small scale equipment. These were:

- equilibrium reactions (effects of concentration and temperature)
- making an electrochemical cell
- rates of reaction
- the reduction of copper oxide to copper
- preparation of hydrogen sulphide and reaction of hydrogen sulphide with i) potassium dichromate and ii) metal salts.

All learners in a specific class were required to carry out the activities on an individual basis. Some of the experiments were linked to a higher grade and the learners had no prior knowledge of the concepts involved. Teachers were requested not to complete any theory on the activities used in the study. Identical pre- and post-tests were administered before and after the practical intervention. These were for:

i. attitude and
ii. subject understanding.

Gender differences, language and cultural differences were investigated as were different contexts and contrasts (comparing learners that had previously been exposed to practical work with those who had not).

Research Outcomes

- Learners showed a very positive attitude towards practical work, across the different cultures as well as genders. This was even more evident after the post-testing, indicating that learners favoured the microscale approach.
- There was an improvement of learners’ subject knowledge and understanding of concepts with all experiments trialed. Boys and girls in both disadvantaged and privileged schools showed this trend, with learners from former DET schools sometimes outperforming those in TED schools.
- The microscale practical interventions resulted in comparable benefits for girls and boys. Girls sometimes outperformed boys.
✓ The microscale approach characterized by low-cost, safe and durable apparatus, offers a solution to address the poor state of science education in African countries.

✓ “Good science teaching does not depend on sophisticated equipment.”
IMPLEMENTATION OF MICROCHEMISTRY IN SECONDARY SCHOOLS IN MPUMALANGA

JD Bradley and S Durbach (1997)

Background
This project was a pilot implementation of Microchemistry conducted during 1997 in 6 rural secondary schools in the township of Kanyamazane, in Mpumalanga. It was sponsored by the Human Sciences Research Council (HSRC) and focused on grades 8, 9, 11 and 12 in the selected schools.

The main objectives of the research were to:

☑ determine the qualifications of the teachers involved in each school, as well as the numbers of learners taught by each teacher through a baseline investigation carried out at the start of the project;
☑ determine the resources available at each school through the same baseline study;
☑ supply the schools with microchemistry equipment and chemicals;
☑ evaluate the attitudes of the teachers and learners towards practical work in general, and towards microscale chemistry activities in particular;
☑ evaluate the conceptual understanding of learners at the various grades targeted, before and after the implementation;
☑ identify problems related to an implementation of microchemistry in rural schools and by so doing, determine the factors which must be satisfied for an implementation of this kind to be successful;
☑ Provide research-based evidence to support the decision to use microscience for practical work in schools.

The Research
Four teacher-training workshops were run over a six-month period. During this time, the baseline study of each school also took place. Microchemistry equipment was distributed and pre- and post-questionnaires were administered. These related to attitudes of teachers and learners towards practical work, and subject knowledge of certain chemistry concepts.

Research Outcomes
☑ Rural schools in Mpumalanga faced several obstacles which hindered the ability of the learners to learn. These included the lack of typical classroom resources such as desks, textbooks, blackboards, electricity, chemicals, equipment and running water.
☑ Science teachers in Mpumalanga were poorly qualified, especially at the lower grades (8 and 9). Their subject knowledge was also lacking.
☑ The learners and teachers were especially pleased to receive microchemistry equipment for practical work. They referred to it as “real equipment” and were in agreement that chemistry could not be learned without doing practical work.
Learners’ conceptual understanding of chemistry concepts was enhanced by the use of microchemistry.

No significant differences were found between boys and girls regarding gains in conceptual understanding, despite the gender biases that were noted in their attitudes towards science practical work.
INTRODUCTION OF RADMASTE MICROCHEMISTRY IN DISADVANTAGED SCHOOLS IN GAUTENG: A CASE STUDY


Background
This case study was conducted in Duduza and Soshanguve in Gauteng province to establish how the RADMASTE Centre introduced the RADMASTE Microchemistry kits to science teachers at six schools involved in the Thintana Thousand Schools Project. The methods used by teachers to introduce the kits to Grade 12 pupils were also observed.

The Research
The content knowledge, skills and attitudes of the pupils were qualitatively investigated using interviewing, observations and questionnaires.

The teachers were monitored starting from the introduction workshops until the introduction of the microchemistry to their pupils. The pupils too were monitored in terms of their performance with the microchemistry kits.

Research Outcomes
Attendance of teachers at the introductory workshops was poor and they showed lack of content knowledge. The teachers largely failed then in introducing the kits to their pupils and pupils also showed poor content knowledge.

Almost all teachers and pupils had difficulties initially in using the equipment in the kits, but these were ameliorated quickly with practice. Despite all these problems both teachers and pupils felt positive about the kits and their potential.

The distressing situation reflected in these experiences starkly indicates how much time and effort will be needed to successfully introduce hands-on practical work (microscale or otherwise) in typical disadvantaged schools in South Africa. It also explains why so often when science resources have been “dumped” at such schools by well-meaning donors/projects, they are found later to be scarcely used at all.
A TRIAL INTRODUCTION OF RADMASTE MICROCHEMISTRY KITS IN CHEMISTRY I PRACTICALS AT THE UNIVERSITY OF THE WITWATERSRAND

JD Bradley, PA Huddle and M Sebuyira (2000)

Background
During the latter part of the 1990s, it had been increasingly accepted that small scale practical science was the preferred way to conduct science investigations. However, even though the move away from macro was established, there was no universal adoption of micro. Teachers and learners were mostly ignorant of the trend. It was therefore felt that research focusing on an individual institution could both inform the institution concerned about microscale work, as well as provide an example to similar institutions.

The study involved the first year chemistry laboratory courses at the University of the Witwatersrand, which is a major tertiary education institution in South Africa with a diverse intake of students. Despite the fact that the University had already been using small scale glassware for mostly second and third year undergraduate work in organic and inorganic chemistry, the Department of Chemistry still debated the small scale approach for the bulk of first year chemistry students. The research aimed to inform this debate by answering the following questions:

• “What is the attitude towards microscale practicals of students, demonstrators, lab managers and lab technical staff?”
• “Will the engagement of students in microscale or macroscale practicals result in any difference in knowledge?”
• “What are the advantages and disadvantages of microscale kits?”

The Research
Four macroscale Chem I laboratory experiments were adapted so that they could be performed with the RADMASTE Microchemistry Kits. Each experiment was carried out in a different laboratory session. A total of 65 students were used as the sample for investigation. Each student was required to complete 2 of the practicals on the macroscale, and 2 activities on the microscale. Students did not all do the same macroscale experiments, nor the same microscale experiments i.e. there was crossover between those who did experiments on macroscale and those who completed the same experiments on microscale. Students and demonstrators who had completed the first activity on microscale were required to complete attitudinal questionnaires. After the second and third experiments, all students were given knowledge questionnaires to complete. At the end of the fourth activity, attitudinal questionnaires were administered to all students and demonstrators. Two demonstrators and two students, as well as an academic lab manager and lab technical assistant were also interviewed.
Research Outcomes

Analysis of the various questionnaires and interview responses indicated that:

- Demonstrators, students, lab staff all had a positive attitude towards microscale experiments in the Chemistry 1 lab course.
- Students commented that using microscale equipment demanded more of their attention than macroscale apparatus. This does not amount to a difficulty but rather helps students to have better recall of their observations and the implications of the results.
- All involved in the study appreciated the greater safety associated with the small scale work and also that less time was needed to complete an activity on microscale.
- Although it was reasonable to assume that there would be no difference in knowledge gains from the small scale or conventional practical work, the evidence showed greater knowledge gains from the microscale work.
- There were less problems resulting from contamination when using the comboplate in the microchemistry kit as compared with traditional tests tubes. This is thought to be related to the large number of small wells in the plate that students can easily use without the need to wash between sets of investigations in the same experiment; the grid scheme used to identify the wells in use which allows for greater accuracy when adding things to the wells; and the ease of cleaning the plastic comboplate at the end of an experiment as compared with the glass of traditional test tubes.
- Other small scale apparatus used together with the microchemistry kits (in this case a low-cost portable conductivity unit) produced consistent results and was easier to use than the equivalent large scale apparatus.
- The need for proper training and management of the kits by students and other laboratory staff is extremely important, as emphasized by the loss of small plastic items from the kits during the trial. Although these items are much cheaper than glassware, users of the kits need to know that they need to maintain this kind of equipment in the same way that conventional apparatus must be looked after. With appropriate laboratory training, the belief that plastics are inherently disposable can also be eliminated.
- The cost of providing small scale experiences was shown to be much less than for macroscale experiences, with respect to both equipment and chemicals. At the time, the total chemicals cost per student for microscale was R 3.17 for four experiments whilst that for macroscale was R 10.24 per student.
- The overall conclusion is that there is enough evidence to suggest that Universities can use microscale plastic equipment to conduct laboratory practicals. Furthermore, the research showed that macroscale equipment had several limitations in the Chem I pracs because some activities related to preparation of gases, reactions of gases and electrolytic reactions had been excluded from the lab course, partly because there was no macroscale equipment available to the students. In contrast, the microchemistry kits do allow for these activities.
A CASE STUDY OF THE MICRO SCALE PRIMARY SCIENCE SYSTEM (MSPSS) AS A PRIMARY SCHOOL SCIENCE TEACHER SUPPORT RESOURCE

JD Bradley and EM Nakedi (2002)

Background
This study was linked to one of the largest primary microscience interventions in the country: the National Department of Education (NDE) Primary Schools Microscience Implementation Project. The research was carried out to investigate the potential of the Microscale Primary Science System (MSPSS) as a support resource for teachers in four primary schools involved in the implementation. The MSPSS is a low cost system which was developed by the RADMASTE Centre for learning and teaching of science at primary level (grades 4-7) through practical work.

The national intervention programme aimed to equip 400 primary schools (100 in each of the four participating provinces) with microscience equipment. The Project had a two-phased training component. The first phase of training involved 28 Education and Development Officers (EDOs), seven from each of the four participating provinces. The second training phase involved a series of four workshops, each involving 100 teachers at a central venue in each of the four provinces. The project took place towards the end of 2000.

The Research
The study comprised working in depth with four primary school teachers in the Rustenburg region of the North West province. The research was carried out on three of the five stages of the implementation plan. The first stage involved the piloting of the microscience system and some of the instruments used in the study. The second stage of the implementation plan involved the training of Education Development Officers at the RADMASTE Centre in Johannesburg. During the third stage, the four teachers took part in pre-tests and pre-interviews. The provincial teacher training workshops of the 100 teachers in each of the participating provinces made up the fourth stage of the implementation. The final stage involved observing the teachers in the classroom, as well as post-testing and post-interviewing of the four teachers.

The study was based on the results of clinical interviews, written questionnaires and qualitative analysis of the classroom sessions as primary methods of data collection. The researcher was intimately involved in all the stages of the implementation and research.
Research Outcomes

The initial (national and provincial training) stages of the project were judged by the participants as being successful. However, upon closer inspection of the regional implementation, as well as at school level with special focus on the four teachers, the project cannot be regarded as an unqualified success.

It was found that:

- the microscience system as a resource, offered the teachers a tangible tool around which they could develop competencies central to their educator roles.
- there were human resource factors that clearly interfered with the implementation process: The EDOs were over-committed with respect to departmental duties such that they could not support the implementation as would have been desired. The four teachers in the programme also faced challenges, representative of most schools involved in Cascade models.
- further training and support of teachers is necessary to ensure effective use of the system in the teaching and learning of science in the classroom.

An independent evaluation of the Primary Microscience implementation was undertaken by the Joint Education Trust (JET) in conjunction with the Department of Science, Mathematics and Technology Education (SMATE) at the University of Port Elizabeth (UPE). The evaluation indicated that:

- The microscience apparatus allowed for successful group work to be carried out with learners and provided opportunities for a wide range of experimental work to be done.
- The equipment, if cleaned and stored as instructed, is durable and sustainable.
- The cost of replenishments of chemicals is decreased, and safety hazards reduced by the use of small quantities of chemicals.
- The written materials contribute to the promotion of an active interest in science, especially since the worksheets are set in “interesting contextual situations” that link science to the real world and relate the practical work to everyday life.
- The use of the microscience equipment and the written material should result in improved results of learners.
- Educators rated the quality of the microscience apparatus as high. They believed that the intervention had changed their methods of teaching science, primarily because learners could do the practical work themselves and did not only have to rely on purely theoretical explanations. They reported that learners were much more engaged in lessons. Learners could be creative when carrying out experiments, indicating that teaching had changed from a “teacher-centred transmission of knowledge” to a learner-centred m
THE EFFECT OF THE USE OF INDIVIDUAL EXPERIMENTATION BY STANDARD 9 CHEMISTRY PUPILS IN THE VAAL TRIANGLE TO AID UNDERSTANDING OF SELECTED CHEMISTRY CONCEPTS

MJ Motaung and JD Bradley (2003)

Background
The purpose of the research was to find out if the use of individual experimentation can aid understanding of selected chemistry concepts of standard 9 (Grade 11) chemistry pupils in the Sedibeng area. Historically, performance has been poor and this may be attributed to the abstract nature of the syllabus, poor teacher methodologies, and absence of practical work – partly due to lack of equipment.

Individual experimentation has been identified as a form of practical work that could aid conceptual understanding in chemistry, and the availability of cost-effective small scale equipment makes this subject to test.

The Research
At the selected school an experimental group and a control group of pupils were taught the same topics (properties of hydrogen sulfide and sulfur dioxide) by the same teacher. The experimental group used the kits to carry out the practical activities and complete the questions on the worksheets themselves. The involvement of the teacher was kept to a minimum. The control group was taught by traditional methods (chalk-and-talk and a standard textbook) with all the answers being provided by the teacher. The teacher was experienced and held a HED from RAU. She was trained by the researcher in how to use the kits and worksheets, she also had a teacher’s guide prepared by RADMASTE, and she was very positive about the approach. An ordinary classroom was used for both groups. In the experimental group pupils could move around and interact, often helping each other and calling the teacher as a last resort. Motivation was observed to be high.

Research Outcomes
The experimental group showed significant improvement in conceptual understanding compared to the control group. This outcome was the same for both boys and girls. It thus shows that teachers can adopt a learner-centred approach to teaching with the help of resources like the microscience kits, worksheets and teacher guides. This teacher had an acceptable level of content knowledge, and was willing to learn more and to try the new approach. With the researcher as her guide she and her pupils achieved a superior outcome with this approach.
FACTORS AFFECTING THE USE OR NON-USE OF MICROSCIENCE EQUIPMENT SUPPLIED TO MPUMALANGA SECONDARY SCHOOLS

SJ Mkhwanazi and JD Bradley (2003)

Background
Between 1999 and 2000 the Mpumalanga Department of Education purchased microscience equipment for 261 secondary schools and provided training workshops for teachers.

The Research
The Department, being anxious to evaluate the success of the initiative, sought to find out the extent to which the equipment was being used and the reasons for the situation revealed by the study.

Research Outcomes
Amongst a representative sample of 20 schools, 55% were using the kits and saw benefits from doing practical work with them. In the other schools, teachers also claimed that practical work was desirable, but did not use the kits. Overwhelmingly the reasons for this emerged as lack of competence as regards subject knowledge as well as the carrying out of practical work. This was consistent with the conclusion from a previous study in the region that teachers of Grade 11 and 12 Physical Science holding only a Secondary Teachers Diploma are not sufficiently prepared for the task. This lack of competence extended to both subject knowledge and practical activities.

The teachers generally were competent in managing the classes, and the size of the classes was not commonly an issue for them. Teachers (especially those not using the equipment) appealed for more training: in the districts, in the clusters, and through individual school visits. Once-off orientation training was not sufficient for many of the teachers.

The general conclusion is that whatever science equipment is made available it is necessary to provide not only initial training but also to monitor the implementation and to continue support through cluster and site-based training.
PRACTICES OF SOME SECONDARY SCHOOL TEACHERS WHO USE MICROSCIENCE EQUIPMENT AND FACTORS INFLUENCING THE USE

V Mkhwanazi and JD Bradley (2003)

Background
This study aimed to establish a profile of teachers who used the microscience equipment supplied by the Mpumalanga Department of Education and hence to identify factors that led to the use.

The Research
Questionnaires were answered by 30 user teachers from 10 districts and classroom observations were made in 3 schools.

Research Outcomes
The study showed that the teachers were all professionally qualified though not academically qualified, and that the users of the equipment were no different from the non-users in this regard, nor as regards school resources. The state of the laboratories in their schools was not favourable for practical work either. Nevertheless these teachers managed to rise above the unfavourable conditions at their schools and engaged in practical work. They were all quite experienced teachers and seemed to be motivated by a personal purpose and vision to make a difference in the education of their learners.

It was also observed that the equipment was mostly used for group sessions, although sometimes it was used in pairs or individually. Some teachers even used it for demonstrations, a doubtful application in view of the small scale. In general the teachers found the equipment easy to use and the worksheets provided were a great help. There was overwhelming support for the equipment from these teachers.

Some of the affective aims of practical work were also achieved; learners were in all cases observed to enjoy the use of the kits and worksheets. This would have stimulated the teachers to do more.
Background
This study was conducted in the Beira district of Mozambique and involved both the teachers and the learners of four schools. Two of these schools received the kits and were the experimental schools; the two others did not receive the kits and were the control schools. The project was conducted over an 8-week period.

Research & Outcomes
Initially all teachers and learners thought practical work to be important for improvement of learning. They saw the main reason for the practical work as being to link theory with practice. After using the kits, teachers in the experimental schools considered that the practical work developed manipulative skills but mostly increased learner motivation and interest. Getting a feel of the phenomena was stimulating for learners.

Diagnostic pre- and post-testing showed gains in conceptual understanding in both control and experimental schools, but it was greater in the experimental schools. Insofar as recall questions are concerned the control schools improved more than the experimental ones. The influence of the teacher was evident in the significant difference between the achievements of the two experimental schools.

Questionnaires, classroom observations and teacher interviews confirmed the impact of the practical work on learner motivation in many different ways. The learners arrived on time for class, were more diligent about their homework, and became more inquisitive when engaged in chemistry content related to what they had observed practically. The fact that the kits were easy to handle and could be used on the desk created a remarkable impression on them. A laboratory was clearly not required.

As a result it was recommended that the Ministry of Education introduce the microchemistry kits more widely regardless of whether or not schools had a laboratory.
Providing Practical Science Experiences at Home for Students Studying Science Through Distance Education

JD Bradley and BJ Akoobhai (2008)

Background
Within South Africa, the Physical Sciences National Curriculum Statement (2007) requires that learners are able to carry out practical investigations. For learners studying science through distance education, there is a lack of practical science experiences and therefore practical work is divorced from the content. For practical work to be meaningful, it has to be integrated with the theory (Woolnough and Allsop, 1985). This can be achieved by learners/students using the microscience kits at home to do practical work while they are learning the theory.

The study took place during 2007. The following research questions formed the basis of the study:

- Can microchemistry kits enable science educators (those studying the Advanced Certificate of Education (ACE) through distance education) to experience practical chemistry at home?
- How did the experiences of educators influence their attitude towards practical work?
- What did the educators learn from ‘at home’ practical activities?

The Research
The sample consisted of 37 secondary school educators enrolled for a Physical Sciences ACE (Advanced Certificate in Education) programme at the University of the Witwatersrand. The ACE programme takes place over a period of two years, with educators completing 10 units or modules. The programme uses a mixed-mode approach i.e. educators attend residential during the school holidays and study on their own during the school term. They are required to post tasks, assignments, etc. to RADMASTE for assessment. The practical experience provided to educators formed part of the unit called ‘Chemical Reactions’ for which the researcher was the tutor.

The research methodology involved introducing the microscience kits to the students at the first contact session, and the completion of pre –attitude questionnaires on practical work. Each student was provided with a RADMASTE Microchemistry Kit and selected chemicals for completing experiments at home. These activities were integrated with the learning of concepts, which formed part of the unit on Chemical Reactions.
Once students had completed the experiments and filled in the worksheets, the latter were posted to the tutor for assessment. At the subsequent contact session, students completed questionnaires on post-attitude towards practical work, as well as towards their experiences in using the kits at home.

**Research Outcomes**

Analysis of the pre- and post-tests revealed the following:

✔ Educators believe that the aims of practical work, i.e.: stimulating interest, learning experimental skills and techniques, teaching the processes of science and supporting theoretical learning, can be achieved using the microchemistry kit at home.

✔ The unchanged or improved attitude from pre to post indicates that the experiences of the students in using the kit were positive. There was no indication of negative impacts of using the kit in the post attitude results.

✔ By doing practical activities at home, the educators felt that their knowledge, skills and attitude had benefited.

✔ The educators realized that carrying out the experiments whilst learning the theory was important in developing their understanding of chemistry concepts.

✔ The educators felt empowered and much more self-confident because they were given the responsibility of doing the practical work on their own. They are therefore more likely to do practical work in their teaching.

✔ “Doing practical chemistry at home is a challenging prospect. Using the RADMASTE microscience kit makes it feasible.”
MICROSCIENCE
CONFERENCE PRESENTATIONS
(including lectures, oral papers, poster papers and workshops)
MICROSCIENCE CONFERENCE PRESENTATIONS

16th National Convention on Mathematics and Natural Science Education, Johannesburg 1995
Oral paper: Small-scale Chemistry: Researching the Impact in the Schools
JD Bradley*, I Vermaak and S Durbach
Oral Paper: Linking Real Experiences and Abstract Concepts
JD Bradley

6th International Chemistry Conference in Africa, Accra 1995
Oral paper: Microchemistry – a Small, Strong Wind of Change in Africa
JD Bradley

14th International Conference on Chemical Education, Brisbane, 1996
Oral paper: Microscale Chemistry from an African Perspective
JD Bradley and I Vermaak
Poster paper: Expanding the Boundaries: Hands-on Practical Chemistry for All
JD Bradley, S Durbach and CT Smith

14th Annual Environmental Education Conference and Workshop, Stellenbosch, 1996
Panel Discussion: Water Quality Monitoring (WQM)
B Bell, S Camp, I de Lange, R O'Donoghue, G Pearson
Workshop: Managing Change – A Workshop of Hands-on Environmental Activities Aimed at Primary and High School Pupils and Teachers
IJ McKay, M Lycoudi, B Bell, X Kyriacou

Oral paper: Cost-effective Science Education in Reconstruction and Development
JD Bradley* and KV Sane

Oral paper: La Microchimie en Afrique – Perspectives de Cooperation
JD Bradley, S Durbach, B Bell, M Liwanga-Ehumbu and J Mungarulire
Poster paper: Etude de l’Impact de Microchimie en Afrique du Sud
JD Bradley, S Durbach, L Kolobe, J Mungarulire and I Vermaak

2me Seminaire Interafricain d’Harmonisation des Programmes de Sciences Physiques et de Technologie, Dakar, 1997
Oral paper: La Microchimie en Afrique – Perspectives de Cooperation
JD Bradley and J Mungarulire
3me Séminaire Interafricain d’Harmonisation des Programmes de Sciences Physiques et de Technologie, Cotonou, 1998
Oral paper: De Microchimie à Microscience
JD Bradley and JMungarulire

15th International Conference on Chemical Education, Cairo, 1998
Plenary lecture: Hands-on Practical Chemistry for All
JD Bradley

Ministère de l’Education Nationale, Cameroon: Séminaire d’Impregnation a la Microchimie, Yaoundé, 1998
Plenary lecture: Hands-on Practical Chemistry for All
JD Bradley

4me Séminaire Interafricain d’Harmonisation des Programmes de Sciences Physiques et de Technologie, Ougadougou, 1999
Oral paper: Les Nouveaux Developpements du Programme Microscience
JD Bradley and JMungarulire

1eras Internacionales de Ensenanza Universitaria de la Quimica, Santa Fe (Argentina), 1999
Plenary lecture: Practical Chemistry for All
JD Bradley

ICSU Conference on Capacity Building in Science, Budapest, 1999
Plenary lecture: The RADMASTE Microscience Project
JD Bradley

International Inaugural Conference of the Tanzanian Chemical Society, Dar es Salaam, 1999
Plenary lecture: Out of Africa: Chemistry Practical Work for All
JD Bradley

2nd International Workshop on Teaching of Chemistry, Minsk, 2000
Plenary lecture: How Microscale Chemistry Can Contribute to Excellence in Chemical Education
JD Bradley

1st International Conference of UNESCO Centres, Vilnius, 2000
Oral paper: The Aims and Activities of the RADMASTE Centre at the University of the Witwatersrand
JD Bradley

Televised lecture: The Microscience Project and its Impact on Pre-service and In-service Teacher Education
JD Bradley
**Microquim 2000, Mexico City, 2000**
Plenary lecture: Hands-on Access to Practical Science for All  
*JD Bradley*

**Workshop: Introduction to the RADMASTE Microchemistry System**  
*JD Bradley*

**16th International Conference on Chemical Education, Budapest, 2000**
Oral paper: Chemical Education Responding to Developing World Needs  
*JD Bradley*

**Workshop: Chemistry for a Healthier Planet – the Microscience Approach**  
*JD Bradley*

**14th Conference of Commonwealth Ministers of Education, Halifax, 2000**
Oral paper: Hands-on Access to Practical Science for All  
*JD Bradley*

**Inauguration of UNESCO Centre for Microscience, Yaoundé, 2001**
Plenary lecture: Les Experiences de Microscience: Pourquoi? Comment? Pour Qui?  
*JD Bradley*

Plenary lecture: Developpement des Experiences de Microscience en Afrique du Sud  
*JD Bradley*

**World Chemistry Conference – Chemical Education Symposium, Brisbane, 2001**
Oral paper: A Small Strong Wind of Change: the IUPAC/UNESCO Global Programme in Microchemistry  
*JD Bradley*

**8th International Chemistry Conference in Africa, Dakar, 2001**
Plenary lecture: The UNESCO/IUPAC-CTC Global Programme in Microchemistry  
*JD Bradley*

**International Symposium on Microscale Chemistry, Hong Kong, 2001**
Plenary lecture: The UNESCO/IUPAC-CTC Global Programme in Microchemistry  
*JD Bradley*

**Workshop: Exploring the RADMASTE Microchemistry System**  
*JD Bradley*

**2nd Arab Conference on a Systemic Approach to Teaching and Learning Chemistry, Cairo, 2002**
Plenary lecture: The Role of Microscale Chemistry in Implementing the SATLC  
*JD Bradley*

**17th International Conference on Chemical Education, Beijing, 2002**
Keynote lecture: The Real and the Virtual – Microscience Online  
*JD Bradley*
Chinese Chemical Society Workshop on Microchemistry, Xi-an, 2002
Oral paper: Hands-on Access to Science for All
JD Bradley

Philippines Workshop on Microchemistry, Manila, 2002
Oral paper: Hands-on Access to Science for All
JD Bradley

Singapore International Symposium on Chemical Education, Singapore, 2002
Oral paper: Microscale and Green Chemistry
JD Bradley

MINEDAF VII, Dar es Salaam, 2002
Oral paper: Microscience Experiences in South Africa
JD Bradley

39th IUPAC Congress, Ottawa, 2003
Oral paper: DIDAC and Microchemistry: a Marriage of Abstract and Concrete
JD Bradley

12th Annual Conference of the Southern African Association for Research in Mathematics, Science and Technology Education, Namibia, 2005
Oral paper: The Role of the Microscience System in Supporting Primary School Teachers to Assume Educator Roles Depicted by the Norms and Standards for Educators in South Africa
EM Nakedi

20th Philippines Chemistry Congress, Bagino, 2005
Plenary lecture: The Trend from Macro is now Established
JD Bradley

International Council for Distance Education, Delhi, 2005
Oral paper: Providing Practical Science Experiences at Home for Students Studying Science at a Distance
B Akoobhai

19th International Conference on Chemical Education, Seoul, 12-17 August 2006
Oral paper: Macro, Micro, Symbolic: Tools for All to Construct the Chemist’s Triangle
JD Bradley
Workshop: Macro, Micro, Symbolic: Experiencing the Triangle
JD Bradley and E Steenberg

Cambridge International Examination Science Colloquium: In and Out of the Classroom, Mauritius, 5-7 September 2007
Oral paper and workshop: Microscience – a Trend that Should be Supported
B Akoobhai* and JD Bradley
Hands-on Gender Inclusive Education for Employment, Lilongwe, 8-11 October 2007
Workshop: Introducing Microchemistry
JD Bradley

Workshop: Introducing Microscale Biology
J Ovens

Oral paper: Overview of the RADMASTE Microscience System and Latest Developments
M Lycoudi

Workshop: Linking the Experiential to the Theoretical in Teaching Electronics to Novices
M Lycoudi

20th International Conference on Chemical Education, Mauritius, 3-8 August 2008
Poster paper: Providing Practical Science Experiences at Home for Students Studying Science Through Distance Education
B Akoobhai*, B Bell and JD Bradley*

Workshop: Understanding the Air and Water Environment through Microscience
B Akoobhai, JD Bradley and E Steenberg

Virtual Conference paper: The RADMASTE Microscience System: Expanding the Small-scale Concept Across the Sciences
B Akoobhai, B Bell, JD Bradley, L Lubango and P Kibasomba

20th International Conference on Chemical Education – Satellite Conference, Nairobi, 11-12 August 2008
Plenary lecture: Low-cost Experiments in Chemistry
JD Bradley

Workshop: Understanding the Air and Water Environment through Microscience
JD Bradley

World Bank Technical Workshop on Secondary Education in Africa, Tunis, 1-3 February 2009
Oral paper: Practical Science Education for All? Yes we can!
JD Bradley

Workshop: Introduction to Microscale Chemistry
JD Bradley

International Congress of Science Education, Cartagena, 15-18 July 2009
Oral paper: Microscale Science: Hands-on Access to Science for All
M Lycoudi

Poster paper: Microscale Electricity – the RADMASTE Electricity and Magnetism Kits
M Lycoudi [Judged the best poster at the International Congress]

Workshop: Linking Theory and Practice in Teaching Electronics to Novices
M Lycoudi
42\textsuperscript{nd} IUPAC Congress, Glasgow, 3-6 August 2009
Poster paper: Lessons Learned from Microscience Development Activities in Africa
\textit{B Bell, JD Bradley and E Steenberg*}

21\textsuperscript{st} International Conference on Chemical Education, Taipei, 8-13 August, 2010
Oral paper: Low-cost Quantitative Microscale Chemistry
\textit{B Bell, JD Bradley, A Chikochi, P Kibasomba, L Lubango, CH Roberg and E Steenberg*}

SA Chemical Institute and Federation of African Societies of Chemistry Convention, Johannesburg, 16-21 January 2011
Poster paper: Can Low-cost Microscale Chemistry be Used Quantitatively?
\textit{B Bell, JD Bradley, A Chikochi, P Kibasomba, CH Roberg and E Steenberg}
\textit{JD Bradley and E Steenberg}

6\textsuperscript{th} International Symposium on Microscale Chemistry, Kuwait, 13-15 March 2011
Plenary lecture: Microscale Chemistry: from Conference to Classroom
\textit{JD Bradley}
Workshop: Introduction to the IYC Global Water Experiment
\textit{JD Bradley}

Practical Activities for learners using the RADMASTE Microscale Global Water Experiment School Kits
\textit{E Steenberg and R Sigamoney}

43\textsuperscript{rd} IUPAC Congress, Puerto Rico, 29 July – 5 August 2011
Oral paper: The Global Water Experiment – Developing a Truly Global Water Treatment Activity
\textit{E Steenberg and MF Ostrowski}

22\textsuperscript{nd} International Conference on Chemical Education, Rome, 15-20 July 2012
Oral paper: Learning from the Experience – the Global Water Experiment in Developing Countries
\textit{B Bell, JD Bradley and E Steenberg*}

Inquiry-based Science Education for Girls, Zimbabwe Academy of Science, Harare, 19\textsuperscript{th} July 2012
Lecture: The Kinds of Curriculum Resources and Pedagogies which Appeal Particularly to Girls
\textit{A Chikochi}

27\textsuperscript{th} Annual Conference of the Comparative and International Education Society, New Orleans, 10-15 March 2013
Oral paper: Microscale Science: from Conference to Classroom
B Abegaz, JD Bradley and MJ Cosentino*
AAS-IOCD Round-Table Discussion and Microscience Demonstration, Nairobi, 15-16 May 2013
Lecture: Basic Concepts of Microscience
JD Bradley
Workshops: Microscale Biology (J Ovens), Microscale Chemistry (JD Bradley), Microscale Electricity (M Lycoudi)

AVU Teacher Education Curriculum Workshops, Nairobi, 23 May 2013
Plenary lecture: Basic Concepts of Microscience
JD Bradley

1st African Conference on Research in Chemical Education (ACRICE-1) and Pre-Conference Workshops, Addis Ababa, 2-7 December 2013
Workshop: Microscale Chemistry
JD Bradley

Oral paper: Microscience and the RADMASTE Centre – Meeting the Challenge of Access to All
JD Bradley

Pan African and South African Conference and Summit on Crystallography (IYCr2014), 12-17 October 2014, Bloemfontein
Oral paper: Crystallography for All
B Bell, CH Roberg, JD Bradley*, M Lycoudi and R Basson

8th International Symposium on Microchemistry, 24-30 May 2015, Mexico City
Plenary lecture:
JD Bradley
Workshops:
JD Bradley
MICROSCIENCE EDUCATION AND TRAINING ACTIVITIES

in cooperation with UNESCO and Ministries of Education
MICROSCIENCE EDUCATION & TRAINING ACTIVITIES IN
COOPERATION WITH UNESCO AND MINISTRIES OF EDUCATION

1998: UNESCO-IUPAC Introductory Workshops in Microchemistry
Nairobi, Windhoek, Maseru, Sofia, Moscow, Krasnojarsk, Tripoli, Chisinau, Minsk,
Johannesburg

Yaoundé

1999: UNESCO-IUPAC Introductory Workshop in Microchemistry
Maseru

1999: Ivory Coast Ministry of Education National Microscience Training Workshop
Abidjan

2000: UNESCO-IUPAC Introductory Workshops in Microchemistry
Bamako, Ougadougou, Kaunas, Vilnius, San’a, Niamey, Teheran, Tartu, Tallin,
Bujumbura, Dakar, Banjul, Conakry, Georgetown, Kingston, Port of Spain

2000: SA Ministry of Education National Microscience Implementation in Primary Schools
Training of Education Development Officers from 4 provinces, Johannesburg
Training of 100 Teachers each in NW, EC, KZN and L Provinces

2001: UNESCO-IUPAC Introductory Workshops in Microchemistry
Cotonou, N’Djamena, Yerevan, Tbilisi, Rabat, Bissau, Praia, Hong Kong

2002: UNESCO-IUPAC Introductory Workshops in Microchemistry
Freetown, Monrovia, Khartoum, Asmara, Riga, Tashkent, Maputo, Lisbon

2003: UNESCO-IUPAC Introductory Workshops in Microchemistry
Manzini, Maseru, Gaborone, Windhoek, Brazzaville, Victoria (Seychelles), Donetsk,
Kiev, Almaty, Issik Kul, Port Louis (Mauritius), Baku, Ufa, Kazan, Abidjan, Lomé,
Djibouti, Malabo

2003: UNESCO & Senegal Ministry of Education National Microscience Consultation,
Dakar

2004: UNESCO-IUPAC Introductory Workshops on Microchemistry
Port Louis, Harare, Bergen, Stockholm, Helsinki, Istanbul, Lilongwe

2004: UNESCO Microscience Project Evaluation Meetings
Johannesburg, Windhoek

2005: UNESCO-IUPAC Introductory Microchemistry Workshops
Lusaka, Kinshasa, Dhaka, Malé, Bangkok

2006: UNESCO Introductory Microscience Workshops
Kuala Lumpur, Jakarta, Copenhagen, Reyjavik, Paramaribo

2006: Ministry of Education National Microscience Training Workshops
Kigali (Rwanda), Bafoussam (Cameroon)

2006 UNESCO IBSP Pilot Project for Microscience in Mozambique: Training workshops for
school teachers from Mozambique, Johannesburg
2007: UNESCO Introductory Microscience Workshops
Ramallah, Brunei

2007: Mozambican Ministry of Education National Microscience Consultation, Maputo

2008: ECC (Sud Kivu, DRC) Introductory Microscience Workshops, Bukavu

2008: UNESCO-INIDE Angolan Ministry of Education National Microscience Workshops, Luanda

2009: Centre for Distance Education, CUM (Beira) Microscience Training Workshops

2010: UNESCO Microscience Global Programme Consultation, Paris


2011: UNESCO & Tanzanian Ministry of Education Microscience Training Workshops, Morogoro

2012: UNESCO & Tanzanian Ministry of Education Microscience Training Workshops, Morogoro