



THE WORLD BANK

**Secondary Education In Africa (SEIA)**

**Developing Science, Mathematics and ICT (SMICT)  
in Secondary Education:  
Patterns and Promising Practices**

**Wout Ottevanger, Jan van den Akker, Leo de Feiter  
Vrije University Amsterdam and University Twente  
SEIA Thematic Study #7 (2005)**



Copyright © January 2006  
Human Development department  
Africa Region (AFTHD)  
The World Bank

The views, findings and interpretations expressed herein are those of the authors and do not necessarily reflect the opinions or policies of the World Bank or any of its affiliated organizations

Cover design: Jacob Bregman (SEIA)  
Cover photo: Jacob Bregman (SEIA)

Africa Region Human Development  
Working paper series (SEIA Thematic Study Report #7)

Vrije University Amsterdam  
University Twente  
Netherlands

**Secondary Education In Africa (SEIA)**

**Developing Science, Mathematics and ICT (SMICT)  
in Secondary Education:**

**Patterns and Promising Practices**

**Wout Ottevanger, Jan van den Akker, Leo de Feiter**

**Vrije University Amsterdam and University Twente**

**SEIA Thematic Study #7 (2005)**

## Acknowledgements

This SEIA Thematic Study report “*Science, Mathematics and ICT Secondary Education in Africa: Patterns and Promising Practices.*” is based on the work of many. We would like to thank the many researchers in our SMICT case study countries in Africa for the compilation of the country profiles, the promising practices, and the feedback on the various drafts of this SEIA-SMICT study report.

They are: Francis Adesoji, Gbenga Adewale, Kwame Akyeampong, René Almekinders, Hayley Barnes, Paul Béré, Ed van den Berg, Ken Chavunduka Andrew Clegg, Papa Youga Dieng, Michel Durand, Joseph Ghartey Ampiah, Norbert Gnamou, Marianne van der Graan, Chaya Herman, Sarah Howie, Janneke van der Hulst, Rien Kool, Anthony Koosimile, Mariska Leliveld, Ramon Leyendecker, Annemarie van Loggerenberg, Fidelis Mafumiko, Sanry Mapile, David Mtetwa, Pai Obanya, Silas Oluka, Iroegbu Thomas Orji, Funja Osaki, Pai Obanya, Maarten Pieters, Robert Prophet, Jimmy Ramorogo, Joseph Sar, Oumarou Sawadogo, Emmanuel Tambo, Lesego Tawana, Annette Thijs, Frank Tilya, Julien Yougbaré.

The various drafts of the SEIA-SMICT thematic study have been discussed with the SEIA team. Preliminary conclusions and the methodology for the country case studies and the overall objectives of this SMICT thematic study were presented at the SEIA Regional Conferences in Uganda. A draft of the final SMICT report was presented and discussed at the SEIA Regional Conference in Senegal. Comments from Sub-Saharan Country representatives provided feedback and comments, which were subsequently incorporated in the final version of the SEIA-SMICT report.

The SEIA team members provided extensive feedback and comments on the drafts as the study progressed. These were Jacob Bregman (SEIA Task Team Leader and Lead Education Specialist, Africa Region, World Bank), Nicole Lawrence, Lina Stulpinaite (Research Consultants SEIA), and Adrian Verspoor (Senior Consultant, SEIA).

The country case studies accompanying this SMICT thematic report can be found at the SEIA website.

## Foreword

Sub-Saharan Africa (SSA) GDPs grew by an estimated 3.8 percent in 2004 and 4.1 percent in 2005 as the benefits from past reforms and a more peaceful environment play out in expanded economic activity. The World Bank's Africa Action Plan aims to accelerate progress toward the Millennium Development Goals (MDGs), based on economic growth. Progress reports by the UN on efforts to achieve the MDGs and the World Bank's Global Monitoring Report – attest to a renewed commitment on the part of the international community, as well as on the part of Africans, to defeat global poverty and disease. Since June 2002 the Education for All- Fast Track Initiative (EFA-FTI) partnership, now involving more than 30 bilateral, regional and international agencies and development banks, has gradually made important strides. In the coming years, the key challenges are to continue the efforts towards achieving universal primary education, to expand secondary school access in response to demands from growing African economies, and to improve quality, relevance and equity of learning across the board. The Africa Region's multi-year **Secondary Education in Africa (SEIA)** study initiative ([www.worldbank.org/safr/seia](http://www.worldbank.org/safr/seia)) is under completion. We worked with our partner ADEA, SSA country teams, African Educators and international institutions. Two regional **SEIA** conferences (in Uganda and Senegal) emphasized the need for IDA support in secondary education and training. The SEIA study initiative includes eight thematic studies on specific topics. These thematic study reports contribute to the knowledge base for Africa's secondary education and training systems.

This thematic study This SEIA Thematic Study report “Science, Mathematics and ICT Secondary Education in Africa: Patterns and Promising Practices.” This thematic study was compiled by Prof. Jan Van Den Akker, Wout Ottevanger, and Leo de Feiter from the Vrije University of Amsterdam and the University of Twente in the Netherlands. The team worked closely with our SEIA team. Drafts of the SMICT thematic study were discussed at the regional SEIA conferences. This study reveals a number of huge challenges in SMICT education in sub-Saharan Africa: poorly-resourced schools; large classes; a curriculum hardly relevant to the daily lives of students; a lack of qualified teachers; and inadequate teacher education programs. The Educational for All policy has resulted in a growing and heterogeneous student population at the secondary level, creating problems of mixed ability teaching. Textbooks are often available in only limited supply; the same holds true for equipment and consumables for practical work. The policy emphasis is on learner-centered education, but many studies reveal that actual classroom practices are still largely dominated by teachers, with students silently copying notes from the blackboard. All countries report serious problems with the supply of good SMICT teachers. Teacher education is seen as the least attractive university level option and consequently attracts the weaker students into their programs.

The challenge is not only in the quantity of participation, but also in the quality and relevance of what is taught and learned. The profile of secondary, vocational and technical education graduates in Africa will need to be more demand-driven, and based on both local and international economic needs. Post-primary education tends to be poorly diversified and typically offers limited opportunities to acquire knowledge and skills to anticipate the patterns of labor market demand in modernizing economies. Reforms will be unavoidable on a continent where SE & VTET has largely remained unchanged for several decades, where access has been limited to those with high household incomes, and where mass participation is only likely with more efficient and more effective patterns of expenditure. The results of the SEIA study initiative respond to the growing demand from our Clients for technical assistance and information about options and strategies for SE & VTET.

*Jacob Bregman  
Lead Education Specialist and SEIA Task Team Leader  
Africa Region Human Development  
The World Bank*



# Executive Summary

## Introduction

This report presents the results of the SMICT study on **Science, Mathematics, and ICT** in secondary education in sub-Saharan Africa. It is one of the thematic studies under the SEIA program of the World Bank and has been carried out in ten sub-Saharan countries: Botswana, Burkina Faso, Ghana, Namibia, Nigeria, Senegal, South Africa, Uganda, Tanzania, and Zimbabwe.

While this report is primarily written for decision makers at the central and local level, teachers and researchers may also be interested. The study has focused on two questions:

1. *What is the state of science, mathematics and ICT in secondary education in sub-Saharan Africa?*
2. *What lessons for improvement can be learned?*

Both questions have been addressed through the analysis of country profiles of SMICT education. These profiles have been compiled by local research teams in the ten countries and included a number of specific themes in SMICT education: curriculum, instructional practices, practical work, SMICT teacher education, ICT in education, and national strategies for improvement.

In addition, insight into potential improvements has also been gained through fifteen case studies of selected promising practices in SMICT education in the countries included in the study.

## SMICT Education at the Secondary Level: A Bird's-Eye View

This study reveals a number of huge challenges in SMICT education in sub-Saharan Africa: poorly-resourced schools; large classes; a curriculum hardly relevant to the daily lives of students; a lack of qualified teachers; and inadequate teacher education programs. The Educational for All policy has resulted in a growing and heterogeneous student population at the secondary level, creating problems of mixed ability teaching. Textbooks are often available in only limited supply; the same holds true for equipment and consumables for practical work. The policy emphasis is on learner-centered education, but many studies reveal that actual classroom practices are still largely dominated by teachers, with students silently copying notes from the blackboard.

The SMICT teaching force is largely inexperienced and teachers tend to have a limited understanding of SMICT subjects, despite statistics suggesting that most teachers are qualified. All countries report serious problems with the supply of good SMICT teachers. Teacher education is seen as the least attractive university level option and consequently attracts the weaker students into their programs. Both at universities and at teacher colleges, subject as well as pedagogical knowledge is often dealt with inadequately. Upgrading programs with the aim to produce more qualified teachers and attract more qualified individuals into the profession do exist in all countries. However, teacher professional development is often short-term and mostly connected to donor-funded projects. The expansion of secondary education as it is planned in some of the countries, adds an extra dimension to these challenges.

The following section focuses on these trends in more detail.

---

## Major trends

### *Curriculum Policies, Instructional Practices and Assessment*

*Education for All*—The EFA policy has led to a growing and heterogeneous student population at the secondary level, creating problems of mixed ability teaching in most countries.

*Localization*—All countries have localized curricula and examinations or are in the process of localization.

*Learner-centered education*—In all countries active learning approaches are strongly emphasized in curriculum policies, but rarely applied in classroom practices.

*Inclusion of societal issues*—Inclusion of HIV/AIDS-related themes, environmental education, and issues related to science and technology in the curriculum.

*Integration of science topics*—Integrated science courses contain at least a combination of biology, chemistry, and physics, and can also include agricultural and environmental topics.

*Inclusion of ICT*—In most countries, Computer Studies has been introduced as an optional subject, or as part of existing subjects, at both the junior secondary and senior secondary levels, but there are numerous implementation problems.

*New ways of assessment*—There are some efforts to introduce criterion-referenced assessment systems and continuous assessment as part of the examination process.

### *School context and instructional resources*

*Class size*—Classes are often large due to the combining of classes, while teaching loads are often relatively low.

*Instructional time*—Science and mathematics are compulsory at the junior secondary level in all countries. The instructional time for SMICT is considerable and dependent on the various syllabus options available.

*Time on task*—Time on task is often limited due to late coming students (and teachers), extra-curricular activities, and absence of teachers.

*Textbooks*—Availability of textbooks is often limited so students must share textbooks. Many countries develop local textbooks, some with the involvement of teacher associations. Marketing of local textbooks against those published by international publishers is sometimes problematic.

*Practical work resources*—A considerable variety of science curricula (e.g. purposes of practicals) are found in the study from the high cost A-level program in some countries to the low cost Life Science program in Namibia. These require varying levels of materials in terms of facilities, equipment, and maintenance.

*Resources for ICT*—ICT resources have found their way into schools. In some countries this is the case in almost all schools, while in other countries this has happened only to a limited extent.

*Cost of practical work*—The general trend noted, not only for purposes of reducing cost but also for pedagogical reasons, is away from the restrictive expensive fixed serviced bench laboratories towards the more flexible—and cheaper—option of a serviced room.

*Cost of ICT*—Currently, most of the initial purchase cost ICT facilities is met by donations from donor-funded projects and SchoolNet organizations, while much of the running cost of ICT is born by schools. However, interesting partnerships with private businesses are beginning to emerge.

*Optimizing resources*—Resource Centers and special science schools have been established in several countries as a way of concentrating resources for practical work and ICT in order to use

them more efficiently. In a number of countries, promising public private partnerships for funding SMICT resources exist.

### ***Teacher Education and Development***

*Enrolment in teacher education programs*—Teacher education is seen as the least attractive university level program. Consequently teacher education programs attract the weakest students entering higher education, i.e. students who cannot be admitted to medicine, engineering, and other more attractive options.

*Subject content coverage*—At both teacher colleges and universities content is dealt with inadequately. At the colleges, it is often a repeat of the A-level/senior secondary material, while at universities subjects move quickly towards more advanced topics and formalized (and mathematized) theoretical frameworks with little attention paid to science and conceptual deficiencies at the secondary school.

*Pedagogical content knowledge*—At both teacher colleges and universities pedagogical content knowledge is dealt with inadequately. Various countries have teacher education programs that are dominated by subject content instead.

*Teaching in teacher education programs*—Teacher colleges are often isolated and quality control is difficult. Universities tend to be too academic and students cannot link the ‘higher science’ in laboratories to day-to-day practical science. At both teacher colleges and universities instruction occurs in a teacher-centered way (i.e. lecturing).

*Teaching practice*—To bridge the theory-practice gap, students have a practice period in secondary schools. This practice is increasingly school-based and requires a lot of manpower, budget and logistics.

*ICT in teacher education*—The systematic use of ICT for teaching and learning purposes is still low. Students are mainly learning basic computer skills and some principles of computer operation. A lack of equipment also limits the practical experience for students and many well-trained ICT students leave the teaching field behind for business and industry jobs.

*Upgrading programs*—In most countries, upgrading routes for teachers exist as a means to tackle the shortage of qualified teachers, and also as an incentive to make the teaching profession more attractive, thus drawing better qualified individuals into the profession. However, upgrading programs seem not very efficient and cost-effective. Crash programs (e.g. to increase enrolment in degree level programs) are likely to be more cost-effective. Other programs (often at the Masters level) for further development in leadership functions exist in various countries.

*Teacher professional development*—Many professional development programs for SMICT education are associated with the implementation of curriculum reforms or with efforts to improve practice in schools. INSET programs are mostly donor-funded and short-term. Little cooperation is observed between institutions and agencies involved in INSET (government, universities, NGOs) while expertise may be complementary. Some other problems are as follows:

- Many INSET initiatives are isolated workshop-based events at a central venue.
- Peer coaching and teacher collaboration are potentially effective methods for INSET programs, but considered innovations themselves and, therefore, problematic to implement.

Many INSET programs use a cascade model for training activities. This model has proved to be helpful in situations with a large number of teachers and few trainers, but it has been observed that training is often ‘diluted’ to unacceptable levels down the cascade.

*ICT in professional development*—Countries also report on the use of ICT as a platform for communication between teachers

---

## Recommendations

### *4.1 Recommendations for SMICT Curriculum, Instructional Resources and Assessment*

#### *On curriculum aims and content*

- A critical review of the SMICT program's aims in view of the changing needs of the student population is needed, as well as a careful distinction between general science courses for all students and more specialist science courses.
- The curriculum overload should be addressed by prioritizing topics based on a clear vision on what would be an appropriate balance between subject-related and academic needs, societal needs, and student-related needs for the different SMICT programs.

#### *On teacher support for curriculum implementation*

- More comprehensive teacher support programs involving in-service workshops, materials, and in-school support should be provided. They should focus on innovative and challenging characteristics of the SMICT curriculum such as learner-centered teaching, multidisciplinary and thematic approaches to science education, mixed ability teaching, and the use of formative assessment.
- More attention to similar themes should also be provided in pre-service teacher education programs.
- More emphasis should be placed on the development of curriculum materials with specific guidelines on the use of learner-centered and multidisciplinary SMICT approaches. Materials should also use relevant local and real-life examples.

#### *On assessment*

- A reinforcing relationship should be established between the curriculum and the assessment system in which the two jointly develop learner-centered and meaningful SMICT education.
- School-based assessment and assessment as part of the national examination should be geared to one another to avoid unnecessary overlap.
- The development of relevant assessment methods that help teachers improve the teaching and learning process should receive more attention.

#### *On class size and instructional time*

- Class size should be examined in relation to teaching loads to optimize the efficiency of teaching. This is particularly important for practical subjects such as SMICT. It will be useful, in this respect, for teachers to be able to teach at least two SMICT subjects.
- Because so much time is lost at both the beginning and end of lessons, and because lessons are sometimes not taught at all, time-on-task should be investigated and increased.

#### *On textbooks*

- The production of quality local textbooks and teacher support materials should be stimulated to provide opportunities and support for teachers and other educators who develop these tools.
- In-service and pre-service programs must stress the effective use of textbooks in the classroom.

#### *On SMICT resources*

- Re-assess the physical provision needed to promote 'good' science. The use of simple equipment like micro-science kits in many countries is an example of this.

- 
- The use of teaching and learning resources, in particular equipment for practical work and ICT, needs to be optimized through the following:
    - the use of Science Resource Centers (e.g. Ghana) and special science schools (Senegal, South Africa, and Nigeria);
    - extensive programs of teacher support (both in-service and pre-service) in the effective use of ICT equipment in practical science;
    - longer opening hours for schools and community-school cooperation to provide access to ICT for the community.

*On funding of SMICT resources*

- Funding possibilities outside of government funding need to be explored. School funds, industry funds, tripartite arrangements between a private sponsor, commercial education service providers and an education institution (schools or ministry), and cost sharing (e.g. religious foundations managing state aided schools and company schools built and partly run by large industries), are all examples of potential public private partnerships.

***Recommendations for SMICT Teacher Education and Development***

*On supply and demand of SMICT teachers*

- There is a need to collect and maintain data for an overall assessment of the supply and demand issues for SMICT teachers. Currently data are scarce or non-existent.
- In regard to this, the extent to which a lack of qualified candidates for SMICT teacher education programs plays a role in different countries should be assessed.

*On entry criteria for students entering teacher education programs*

- SMICT teacher education requires bright students. Therefore, clear selection criteria need to be set for admission to SMICT teacher education programs at both the teacher college and university level.
- In areas where only a limited number of candidates with sufficient subject knowledge are available, remedial measures should be established to safeguard against a fall in standards or decline in numbers for some subjects.

*On the pedagogy component in teacher education*

- Teaching and learning take different forms in different subjects. The pedagogy component in teacher education therefore should be organized in subject-related approaches.
- Teacher education programs should aim for qualification in two science subjects as this qualifies the teacher better for teaching general science, integrated science, or simply cooperation between science disciplines.
- Teaching methods promoted—in almost all countries student-centered education in schools is intended—should be realistic and take country and school conditions into consideration. There are many possibilities for inspired SMICT teaching with limited resources.

*On the subject-based teacher education curriculum*

- The subjects as they appear in the school curriculum should form the organizing principle in a more practice-oriented and demand-led teacher education curriculum.
- As a temporary measure in transitional situations, additional subject content study in non-core subjects for teacher education candidates may be necessary to optimize employability. Such

additional study may also be necessary if school subjects change through curriculum reform and teachers must facilitate its implementation.

*On cooperation between teacher education institutions and schools*

- Experimental models for cooperation between schools and teacher education institutions should be designed and piloted to investigate the feasibility of alternative forms of teacher education in different country contexts.
- Teaching practice, crucial but expensive in its present form, could be organized as a natural part of such a cooperation between schools and teacher education institutions, with school-based mentors taking part of the responsibility for supervision of student-teachers

*On strengthening the role of schools in teacher education*

- It is recommended that teacher leadership programs for experienced teachers are developed to strengthen schools.
- The selection of teachers for such programs should be based primarily on performance and commitment.
- For training institutions it may then be recommended they redirect part of their pre-service teacher preparation towards in-service support of teachers and the training of educational leaders.

*On teacher upgrading routes*

- The common practice of upgrading routes for teacher qualifications from diploma to degree level deserves close scrutiny in terms of actual effects and cost implications. A special program or strategy to increase the number of teacher education students at the degree level is likely to be more cost-effective.
- Current upgrading programs often serve as a route out of the teaching profession when they open other career avenues. Therefore, career development programs more closely tied to professional skills are preferable.

*For on-going in-service teacher support*

- As part of initiatives for curriculum reform and long-term development, a system and related infrastructure (both human and material) should be designed for on-going support for schools and teachers.
- A link to leadership development programs and teacher career development (see above) is therefore recommended.

*On the use of ICT in teacher education*

- To support the introduction of ICT in schools, the use of ICT should be introduced as a priority in all teacher education programs. The International ICT driving license (as used in some countries) could be used for this purpose.
- As ICT is simultaneously a promising vehicle for distance support for teachers and a platform for teacher communication, its use in a school support infrastructure may also be considered, depending on the overall country infrastructure for ICT.

***Towards a Strategy for Development of SMICT Education***

SMICT education reform plans need to have a strong implementation orientation, ensuring that ambitious aims are actually realized. Sensitivity to the context in which the reforms are

---

implemented will be of utmost importance. *One size does not fit all* is thereby an important credo. The report argues for two interlocking core activities in such a strategy: *curriculum reform* and *teacher development*. For these two domains the report has formulated the sets of recommendations above. These are illustrated in a number of case studies of promising practices in SMICT education from countries covered by the study. It is observed that many promising practices are carried out as pilot projects and experimental programs. Up-scaling and sustainability are problems when these promising practices are attempted at a national level. It points at two crucial aspects of a strategy for development of SMICT education: the need for major investments and the need to build capacity at all levels.



## Table of Contents

<b>Executive Summary .....</b>	<b>i</b>
Introduction .....	i
SMICT education at the secondary level: a bird-eye view .....	i
Major trends.....	ii
Recommendations.....	iv
<b>List of Abbreviations .....</b>	<b>xi</b>
<b>List of Tables and Figures .....</b>	<b>xii</b>
<b>1 Introduction .....</b>	<b>1</b>
1.1 SMICT Study.....	1
1.2 Methodology of the study .....	2
1.3 Countries in the study .....	3
1.4 Structure of the report .....	6
<b>2 Curriculum Policies, Instructional Practices, and Assessment .....</b>	<b>9</b>
2.1 General trends in curriculum policy.....	10
2.2 Aims and content of SMICT education .....	11
2.3 Instructional processes .....	16
2.4 Assessment.....	18
2.5 Concluding remarks: the way forward.....	19
<b>3 School Context and Instructional Resources .....</b>	<b>21</b>
3.1 Context in which resources for SMICT are used .....	21
3.2 Instructional resources .....	23
3.2.1 Textbooks and teacher support materials .....	23
3.3 Cost of Instructional Resources .....	27
3.4 Optimizing opportunities and resources.....	28
3.5 Funding science and ICT resources .....	29
3.6 Concluding remarks: the way forward.....	31
<b>4 SMICT Teachers, Teacher Education, and Teacher Support .....</b>	<b>33</b>
4.1 SMICT Teachers.....	34
4.2 SMICT Teacher Education .....	37
4.3 Teacher upgrading, teacher career progression, and alternative teacher education policies .....	46
4.4 Teacher in-service support and development.....	50
4.5 Discussion.....	54
4.6 The way forward.....	56
<b>5 SMICT Education– towards a strategy for development .....</b>	<b>59</b>
5.1 National strategies in development of SMICT education .....	59
5.2 Towards a strategy for SMICT education development .....	59
5.3 Curriculum reform: the need for coherence .....	61
5.4 Teacher education and teacher support.....	63
5.5 Upscaling and sustainability of promising practices.....	65
<b>6 References .....</b>	<b>67</b>

---

**Annex 1 Summary Country Profiles**

**Annex 2 Summary of Promising Practices**

**Annex 3 Outline for Country Profile**

**Annex 4 Framework for Promising Practices in SMICT Education**

---

## List of Abbreviations

ACE	Advanced Certificate of Education
B. Sc.	Bachelor of Science
B.ed.	Bachelor of Education
BST	Specialized Schools in Senegal
CA	Continuous Assessment
CIE	University of Cambridge International Examination
CIS	Centre of International Cooperation, Vrije Universiteit Amsterdam
CP	Country Profile
CPD	Continuing Professional Development
DipSciEd	Department of Science Education
DMSE/INSET	Department of Mathematics and Science of the University of Botswana In-Service Team
EFA	Education for All
EMIS	Education Management Information System
FEMSA	Female education in Science and Mathematics, Promising Practice Uganda
GAST	Ghana Association for Science Teachers
GEEP	Groupe pour l'étude et l'enseignement de la population (Group for study and teaching of Population, Promising Practice Senegal)
GES	Ghana Education Services
GNI	Gross National Income
HDI	Human Development Index
ICDL	International Computer Driving License
ICT	Information and Communication Technology
IGCSE	Senior Secondary Education level
INSET	In-Service Training for Teachers
INSTANT	IN-Service Training and Assistance of Namibian Teachers
M.Ed.	Master of Education
MASTEP	Mathematics and Science Teachers' Extension Program, Promising Practice Namibia
MUSTER	Multi-Site Teacher Education Research Project
NGO	Non-Governmental Organization
PGCE	Post Graduate Certificate in Education, Promising Practice South Africa
PP	Promising Practice
RESAFAD	Réseau Africain de Formation a distance. African Network for Distance In-Service Training, Promising Practice Senegal, Burkina Faso
SA	South Africa
SEIA	Secondary Education for Africa
SEITT	Science Education In-Service Teacher Training, Promising Practice Zimbabwe
SESS	Science Education in Secondary Schools, Tanzania
SMICT	Science, Mathematics, and Information Technology
SRC	Science Resource Center, Promising Practice Ghana
SSA	Sub-Saharan Africa
STAN	Science Teacher Association of Nigeria, Promising Practice Nigeria
TE	Teacher Education
TRC	Teacher Resource Center
UK	United Kingdom
UNESCO	United Nations Educational, Scientific, and Cultural Organization
WAEC	West African Examination Council

---

## List of Tables and Figures

Table 1. GNI for the countries in SMICT study (2000).....	3
Table 2. HDI rank for the countries in SMICT study (2000).....	4
Table 3. Costs per student in various SMICT countries (US \$), 2001.....	5
Table 4. Expenditure on education .....	6
Table 5. Example of two days of a timetable of a typical Grade 10 (junior secondary) learner's timetable in South Africa.....	22
Table 6. Practical work cost spectrum-showing examples of typical requirements. ....	25
Table 7. Some characteristic figures on computer penetration .....	26
Table 8. Specific recommendations for SMICT curriculum.....	61
Table 9. Summary of recommendations in teacher education .....	63
Figure 1. Strategy for development of (SMICT) education.....	3
Figure 2. Strategy for development of (SMICT) education.....	60
Figure 3. Curriculum spider web .....	64

# 1 Introduction

The World Bank has initiated a study entitled *the Secondary education for Africa (SEIA) study*. The SEIA study is a regional study initiative by the World Bank, in co-operation with Sub-Saharan African countries and other donors, to review international secondary education reform experiences and provide a forum for educators, decision-makers, and donor agencies to discuss and develop secondary education in Sub-Saharan Africa.

The SEIA study has been launched to address a growing demand for more access and better quality of lower secondary education by the progress in achieving Education for All (EFA). Currently less than one-third of Sub-Saharan African youth attend secondary education and considerably fewer graduate. While achieving the EFA targets for primary education remains the top priority of all sub-Saharan governments, economic and social growth requires a balanced sector development, with a critical mass of secondary and higher education graduates.

The SEIA study currently focuses on eight themes:

- Access, financing, and equity
- Relevance and quality of curricula, learning, and assessment
- Transition processes
- The link between health and social issues at the secondary level
- Gender Studies
- Governance, management, and accountability
- Secondary school teachers and school principals
- Secondary science, mathematics, and ICT education (SMICT)

These themes are explored in separate studies and will together provide a summary of best practices and sustainable development.

## 1.1 SMICT Study

As part of the SEIA study, the study on Science, Mathematics, and ICT education in secondary education, the SMICT study, investigates the status of and promising practices in these subjects in a number of countries in sub-Saharan Africa. The World Bank has requested the Center for International Co-operation (CIS) of the Vrije Universiteit Amsterdam to take the lead in the execution of the SMICT study.

The SMICT study set out to investigate the status of science, mathematics, and ICT (SMICT) education in sub-Saharan Africa. The general research question for this study has been formulated as follows:

*What is the state of science, mathematics, and ICT in secondary education in sub-Saharan Africa?*

*and*

*What lessons for improvement can be learned?*

The study focuses on a number of specific themes considered to be important aspects of SMICT education in sub-Saharan Africa. These are curriculum, instructional practices, practical work,

teacher education, ICT in education, and national strategies for improvement. Specific questions for these themes have been formulated as follows:

1. What are the (intended) *curriculum* characteristics?
2. What are *instructional practices*?
3. How is *practical work* used?
4. How do *teacher education* programs prepare teachers?
5. How is *ICT education* used in teacher education and in secondary schools?
6. What are the *national strategies* for improvement?

In addition, the study aimed to identify promising examples of practices in each of the themes.

## 1.2 Methodology of the study

### *Country profiles*

The study has tried to answer the specific questions by developing profiles on the current status of SMICT education for each of the countries in the study—Botswana, Burkina Faso, Ghana, Namibia, Nigeria, Senegal, South Africa, Uganda, Tanzania, and Zimbabwe. In the case of Tanzania, only a limited data set was available. The outline of the profile was piloted and subsequently adjusted in cooperation with educational researchers in Namibia. This outline, included as annex 3 to this report, was used as the basis for the development of a *country profile* (CP) in each of the countries in the study.

Local research teams in the ten countries compiled the country profiles. Drafts were discussed with the coordinators of the study, and clarification and further information was gathered in many cases. This has resulted in a database of 10 country profiles on the current status of SMICT education in sub-Saharan Africa. A summary of the 10 country profiles included in this study can be found in annex 1.

### *Promising Practices*

In addition to the 10 country profiles, the study conducted 15 case studies of promising examples of SMICT education in the countries included. These case studies, called *Promising Practices*, (PP), focused on a number of promising initiatives for improvement of SMICT education, including issues of effectiveness, sustainability, and the potential of transfer to different contexts and countries. They were developed through the combined effort of local and external researchers. A total of 15 summaries of PPs have been included in the summary in annex 2. Annex 4 provides the framework for the compilation of the PPs.

### *Co-operation with Local Researchers*

The SMICT study has been executed in cooperation with local researchers at every stage of the study. Communication with researchers in the countries in the study was considered of vital importance, although this was at times difficult despite the availability of e-mail facilities. Besides the one-on-one communication with local researchers and the coordinators of the study in the Netherlands, preliminary conclusions of the study were put forward via e-mail and visits for discussion at a seminar at the University of Pretoria, organized by the South African counterparts in the study, in August 2003. Presentations of the preliminary results of the study were made at

the first SEIA conference in Kampala in June 2003 (see <http://www.worldbank.org/afr/seia/>) and at the annual meeting of the Southern African Association for Research in Mathematics, Science and Technology education (SAARMSTE) in Cape Town. Both occasions have provided opportunities for meeting local researchers and receiving feedback on the study from science educators.

This report is based on information from the SMICT country profiles from the 10 countries, case studies of promising practices in SMICT education in the same countries, feedback from the various sources, as well as our own insights and experiences from many years of international cooperation in the development of science and mathematics education in sub-Saharan Africa.

### 1.3 Countries in the study

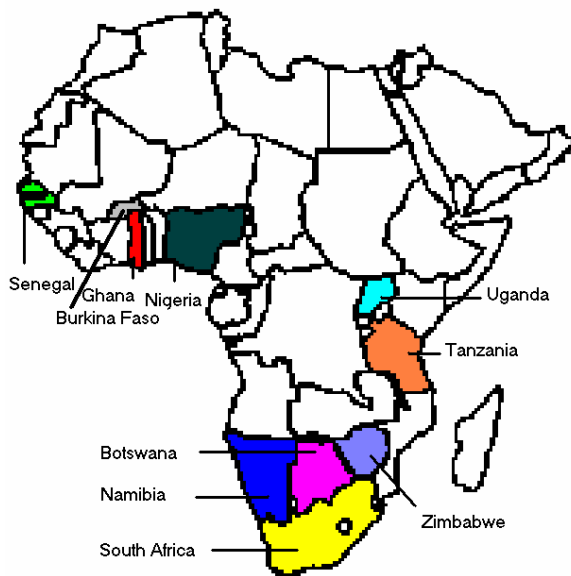


Figure 1. The 10 countries in the SMICT study

The study on Science, Mathematics, and ICT (SMICT) in secondary education in sub-Saharan Africa has been executed in 10 countries—Botswana, Burkina Faso, Ghana, Namibia, Nigeria, Senegal, South Africa, Uganda, Tanzania, and Zimbabwe. The countries are located in West Africa (Burkina Faso, Ghana, Senegal, Nigeria), East-Africa (Uganda and Tanzania), and Southern Africa (Namibia, Botswana, Zimbabwe and South Africa). Figure 1 indicates the location of the 10 countries. With the exception of Burkina Faso and Senegal, which are Francophone, all countries in the study are Anglophone. Although the countries in this SMICT study are presented as one group of countries, a

comparison of a number of socio-economic indicators shows that there are similarities and differences between them. The next section looks at some of the important indicators.

#### 1.3.1 Important Socio-economic Indicators

Economic indicators separate the countries in the study into two different groups (table 1 and table 2). The first group of countries is comprised of South Africa, Namibia, and Botswana. Their GNI ranks them in the middle income countries. The rest of the countries are in the group of low-income countries. The human development index (HDI) puts these three countries (South Africa, Namibia, and Botswana) together with Ghana and Zimbabwe in the Medium HDI countries.

Table 1. GNI for countries in SMICT study (2000)

Countries	GNI/Capita (US\$)
Upper Middle-Income Countries*	
Botswana	3300
Lower Middle-Income Countries	
South Africa	3020
Namibia	2030
Low Income Countries	
Senegal	490
Zimbabwe	460

Ghana	340
Uganda	300
Nigeria	290
Tanzania	270
Burkina Faso	210

\*Based on the classification of the World Bank

Table 2. *HDI rank for the countries in SMICT study (2000)*

Countries	HDI* (2000)
Medium HDI	
South Africa	107
Namibia	122
Botswana	126
Zimbabwe	128
Ghana	129
Low HDI	
Nigeria	148
Uganda	150
Tanzania	151
Senegal	154
Burkina Faso	169

\* The Human Development Index measures a country's achievements in three aspects of human development: longevity, knowledge, and a decent standard of living. Longevity is measured by life expectancy at birth; knowledge is measured by a combination of the adult literacy rate and the combined gross primary, secondary, and tertiary enrolment ratio; and standard of living is measured by GDP per capita (PPP US\$). The HDI rank is based on 173 countries.

### *Population*

There are large differences in population among the countries in the study, ranging from 1.5 million in Botswana to 132 million in Nigeria. A large portion of the population in all ten countries in the study is under the age of 15 (35-49%). A large share of the population (31-54%) lives in urban centers, with the exception of Uganda where most people (88%) live in rural areas. There are also large differences in annual population growth between the countries in the study, from 0.77% in South Africa to 3.19% in Uganda.

A relevant indicator for this report is the percentage of HIV/AIDS infected in the countries. In Senegal the HIV/AIDS epidemic is of minor proportion and is limited in the three other West African countries in the study. The Southern African countries are the worst hit with infection rates up to 39%. Life expectancy has decreased considerably in these countries, with Botswana having a life expectancy of 36 years.

### *Enrolment in Education*

Several countries are achieving Education for All to a large extent at the primary level (Zimbabwe, Uganda, South Africa, Botswana, and Namibia). Enrolments in secondary school are problematic (<10%) in several countries (Uganda, Tanzania, and Burkina Faso). The enrolments in tertiary institutions are generally lower than 5%, with the exception of Zimbabwe and Namibia (both 7%) and South Africa (17%).

Based on the number of students sitting for SMICT examinations at the end of junior secondary education, it can be concluded that the number of enrolled students has increased over the last

number of years in some countries (Burkina Faso, 37%; Ghana, 41%; Uganda, 47%; and Zimbabwe, 22%), but has slightly decreased in other countries.

### 1.3.2 Structure of Secondary Education

Secondary education in the ten countries included in the study can be divided into two phases. Each country has its own terminology for these phases (e.g. Lower/Upper Secondary, O-level/A-level, Enseignement Moyen/Enseignement Secondaire, or Junior and Senior Secondary). This report uses the terms *junior secondary* (JS) and *senior secondary* (SS) to refer to these two phases. If the text only uses the term secondary it includes both junior and senior secondary levels.

The duration of compulsory education varies among the countries from 6/7 to 9/10 years. In four countries (Senegal, Nigeria, Tanzania, Uganda) only primary education (6 or 7 years) is compulsory. In Zimbabwe primary education and one year of pre-primary is compulsory. In the other countries, education is compulsory for 9 or 10 years. This can either be compulsory education until the end of JS or until students reach the age of 16. The senior secondary phase is not compulsory in any of the countries.

Five of the countries in the study have 6 years of secondary school, divided into 3 years JS and 3 years SS, or 4 years JS and 2 years SS. Botswana, Namibia, and South Africa have five years of secondary education. The two Francophone countries—Burkina Faso and Senegal— have a 7-year program for secondary education. Senegal, Burkina Faso, Uganda, Tanzania, and Zimbabwe have the O-level and A-level type of system. This system has a highly selective senior secondary school (A-Level), preparing students for a university education.

In a number of countries primary education combines with junior secondary into (nine or ten years) Basic Education (e.g. in Namibia and South Africa). A possible consequence of this trend is that, as in various OECD countries, education is increasingly seen as 9-10 years of Basic Education followed by two to three years of senior secondary education. In the SMICT domain, Basic Education would cover ‘science for all’ whereas senior secondary would be much more selective and focus on the academic aspects of SMICT subjects in preparation for science-based studies at tertiary institutions.

### 1.3.3 Costs and Funding of Education

#### *Costs per student*

Table 3 indicates the costs per students in the four countries for which data were available. The figures show that this increases significantly from primary to JS and SS, with the exception of Namibia, where the increase is only about 10%.

Table 3. *Costs per student in various SMICT countries (US \$), 2001.*

<i>Education</i>	<i>Ghana</i>	<i>Namibia</i>	<i>Senegal</i>	<i>Uganda</i>
Primary	51	280	63	19
JS	84	310	123	122
SS	207	310	323	122

## Funding

Governments are the main funders of education in all SMICT countries. The expenditure on education ranges from 1.4% of GNI (Burkina Faso) to 8.4% in Namibia. Annual government expenditure on education (% of the total budget) ranges between 6.7% in Nigeria and 33.1% in Senegal. Table 4 also shows the percentages of the total education budget spent on secondary education, ranging from 10% in Ghana to 43% in Senegal.

Table 4. *Expenditure on education*

	Botswana	Burkina Faso	Ghana	Namibia	Nigeria	Senegal	South Africa	Tanzania	Uganda	Zimbabwe
Education expenditure as a percentage of GNI*	7.8	1.4	4.4	8.4	8.0	3.4	6.9	3.4	2.2	7.5
Annual government expenditure on education**	24.6	21	20	25	6.7	33.1	20.3	15.3	32	18
Percentage of education budget spent on secondary education***	no data	38	10	31	no data	43	30	no data	12	26

\* Based on most recent available data per country of UNSD

\*\* Based on most recent available data per country of UNESCO

\*\*\* Based on information in country profile (various sources)

School costs are mainly covered by the government. The number of private and government aided schools varies considerably in the countries in the study, from 3% in South Africa to 75% of the secondary schools in Uganda.

## 1.4 Structure of the Report

The report on the SMICT study is divided in four parts. After this introductory part, chapter 2 looks at the issues in curriculum, instructional practices, and assessment in SMICT education. Chapter 3 focuses on school context and instructional resources for SMICT education, especially textbooks, resources for science practical work and for ICT. The next chapter, chapter 4, addresses the many issues related to SMICT teacher education. Each chapter focuses on the current situation in SMICT education in the countries included in the study, considers the issues against the background of general views on SMICT education. Also included in the chapters are short summaries (in separate textboxes) of promising practices in SMICT education. At the end of the chapters suggestions for the way forward are provided. The closing chapter, chapter 5, puts these suggestions for improvements into a larger framework and uses the promising practices to illustrate how these suggestions may work in practice and what possible problems there may be. More detailed background information on the issues addressed in the report can be found in the summary of country profiles, in annex 1, and in the summary of case studies of promising practices in annex 2.

The report, annexes, and all country profiles and case studies of promising practices are available on the websites of the World Bank ([www.worldbank.org](http://www.worldbank.org)) and the Centre for International Cooperation (CIS) at Vrije Universiteit Amsterdam ([www.cis.vu.nl](http://www.cis.vu.nl)).

Hopefully, this report will prove to be a useful document for senior policy makers and SMICT educators and researchers in sub-Saharan Africa and elsewhere.



## 2 Curriculum Policies, Instructional Practices, and Assessment

This chapter aims to describe and discuss major patterns, trends, and issues in SMICT curriculum policies and instructional and assessment practices in the investigated 10 sub-Saharan countries. A few central concepts and perspectives (cf. Van den Akker, 2003) are helpful for interpretation of the text:

- There are numerous definitions and conceptions of the term 'curriculum', but in essence it refers to a 'plan for learning'. Curricular activities include a variety of processes such as policy-making, design and development, evaluation, and implementation. These activities occur at different levels of the education system, including the national level (*macro*), school level (*meso*), or classroom level (*micro*). The tension and gaps between these levels will be addressed in this chapter.
- Curriculum problems can be approached from various perspectives: *substantive*, *technical-professional*, and *socio-political*. Although the emphasis is on the first perspective, the other two will also be addressed.
- Curricula may have various representations:
  - intended curriculum, referring to both the policy ideals and vision, or philosophy underlying a curriculum (*ideal curriculum*), as well as the intentions specified in curriculum documents and materials such as syllabuses or textbooks (*formal curriculum*);
  - implemented curriculum, comprising both the curriculum as viewed by teachers (*perceived curriculum*) and the actual process of teaching and learning in the classroom (*operational curriculum*);
  - attained curriculum, addressing both learning experiences (*experiential curriculum*) and learning outcomes (*learned curriculum*).

The focus in this SMICT analysis is on the patterns of and discrepancies between the intended curriculum, instructional practices (or operational curriculum), and assessment (or learned curriculum).

- More broadly, a curriculum may include principles and choices about ten different but interdependent components—Rationale, Aims, Content, Learning Activities, Teacher Role, Materials & Resources, Grouping, Location, Time, Assessment. The (lack of) consistency between these components will receive especial attention in this chapter.

This chapter looks specifically at the following aspects of curriculum, instructional practices, and assessment:

- General trends in curriculum policy (section 2.1)
- Aims and content of SMICT education (section 2.2)
- Instructional processes (section 2.3)
- Assessment (section 2.4)
- Concluding remarks: the way forward (section 2.5)

## 2.1 General Trends in Curriculum Policy

In all sub-Saharan African countries SMICT education is offered to a growing number of students at junior and senior secondary level. Science and mathematics are compulsory subjects at junior secondary level in all countries, which means that every secondary school student takes three to four years of science and mathematics. At senior secondary level mathematics is compulsory in half of the countries (Burkina Faso, Botswana, Ghana, Nigeria, and Senegal). Science is compulsory in Ghana and Nigeria (with a choice of Chemistry, Physics, or Biology), and within specific streams in Senegal and Burkina Faso. At this level a variety of elective science courses are offered, including such subjects as biology, physics, chemistry, physical science, and science & technology. At this level a variety of elective science courses are offered, including such subjects as biology, physics, chemistry, physical science, and science & technology.

The following major trends in curriculum policy can be observed in the different countries:

- *Localization of syllabi and examinations:* all countries have localized curricula and examinations or are in the process of localization (Namibia). In Namibia and Botswana, ties with the University of Cambridge International Examinations (CIE) board remain, while Ghana and Nigeria conduct their examinations under auspices of the West African Examination Council (WAEC). In Nigeria, examinations are also conducted by a National Examination Council.
- *'Education For All' policies,* which have led to a growing and diverse student population, creating problems of mixed ability teaching in most countries, in junior secondary level but also at senior secondary level to some extent. To deal with this problem, Botswana, Namibia, and Zimbabwe offer core and extended level programs within the SMICT subjects.
- *Inclusion of societal issues:* new topics have been added to the SMICT curriculum, including HIV/AIDS related themes (in all Anglophone countries), environmental education, and issues related to science and technology (South Africa).
- *Integration of science topics:* in all countries a move towards the integration of science topics within the SMICT curriculum can be observed, both at junior and senior secondary level. The integrated science courses contain at least a combination of biology, chemistry and physics, and can also include agricultural and environmental topics (Ghana, Namibia).
- *Inclusion of ICT:* in most countries Computer Studies has been introduced as an optional subject at both junior secondary and senior secondary level, but there are numerous implementation problems.
- *Emphasis on learner-centered education:* in all countries active learning approaches are strongly emphasized in curriculum policies, but are rarely applied in classroom practices.
- *New ways of assessment:* most countries have introduced continuous assessment as part of the examination process. Changing the norm-referenced examination practices into a wholly criterion-referenced assessment system is currently being considered, and has been made a policy priority in three countries (Botswana, Namibia, and South Africa).

The country profiles give an insightful description of the many changes and developments that have taken place in the domain of SMICT education and the major achievements in terms of

reaching out to an increasing number of students. At the same time, however, there are serious concerns regarding the quality and relevance of this education. The Senegal report, for example, speaks of national “*disenchantment with science*”, while Zimbabwe notes that “*scientific literacy and technological operacy are still distant goals*”.

The patterns described in the different country profiles point to two major areas for concern regarding the SMICT curriculum: (1) the huge gap between policy intentions and classroom practice and (2) the lack of coherence in curriculum policy making. These gaps and inconsistencies present important challenges for the future, as will be discussed in the following sections, with a focus on (combinations of) various curriculum components.

## 2.2 Aims and Content of SMICT Education

### *Trends in student population and achievement*

The philosophy of ‘Education for All’ figures high on policy agendas in all countries. Emphasis has been put on widening access to schools and on automatic promotion, leading to an increasing number of students in junior secondary education, while senior secondary education is more selective. In most countries, junior secondary examinations are used to select students for entry into senior secondary level. As science and mathematics are compulsory subjects in junior secondary education, a growing number of students are enrolled in SMICT programs. The majority of these students take the integrated or combined science courses. In most countries (with the exception of Botswana) more boys than girls are enrolled in the SMICT courses, both at junior and senior secondary level.

The increasing number of students in junior and senior secondary education has led to a large degree of heterogeneity in the student population enrolled in SMICT programs. Problems of mixed ability teaching are present in all countries, and the examination results show that the curriculum aims are not within reach of the majority of students. Although pass rates vary considerably between subjects and countries, a few general trends can be observed:

- Student performance in junior secondary mathematics appears to be particularly problematic as compared to results in science courses at this level. In Namibia, for example, 18% of the students obtained a pass rate in junior secondary mathematics in 2000. Pass rates in junior secondary core science courses range from 93% in Nigeria (1993) to 28% in Zimbabwe (2001).
- In senior secondary education, student performance in the combined or integrated sciences is generally lower than in the elective science programs. In 2002, in Botswana, 11% of the students using the ‘single science’ (an integrated science) syllabus passed with a grade of C or better, while 80% of students passed the physics course, which is one of the electives. It is especially true that more capable students pick elective courses, unlike in single science courses. The latter syllabus, aiming at a lower ability range of students, is still very academic and often too difficult for students who take that course.
- Regarding the elective courses, student scores in biology tend to be lower than in chemistry or physics, which could be explained by the fact that biology is often taken as an optional subject by students who follow a non-science field of study.
- In most courses, gender difference in pass rates is observed. While boys generally perform better, there are a few cases of comparable performance and courses in which girls have

achieved better results (senior secondary biology in Zimbabwe, and junior secondary mathematics in Namibia).

- The country reports mention a variety of problems that may contribute to students' limited performance including language problems, automatic promotion, poor foundations provided at primary and junior secondary level, ambitious content of the curriculum, and problems with mixed ability teaching. Studies by FEMSA in Uganda have shown that additional problems contributing to girls' relative poor performance include the lack of gender-sensitive teaching methods and examples in the curriculum, the lack of encouragement at home, and the poor sanitary facilities at school.

### *Shifting aims*

With rapidly increasing numbers of students, not only have the ability levels of students become more diverse, but also students' future aspirations and interests in participating in SMICT curricula. With the current student population, preparation for continued science education and for a science-based career is no longer the exclusive aim. In line with worldwide trends, developing a general scientific literacy is more important for the majority of students, especially at lower secondary levels. At the same time, however, the need to educate qualified scientists and engineers remains.

The crucial challenge for curriculum policy-makers will thus be to make science knowledge more accessible to more students without lowering standards for those who will become the scientists of tomorrow. In other words, how to accommodate both goals of providing a basis for citizens to engage with science and technology and to prepare students for the next level of science education? This question needs thorough consideration and discussion. While 'science for all' is generally emphasized in educational policy in the surveyed countries, it is also noted that the curriculum is not relevant to the majority of students, leading to poor results and lack of interest in science. The perspective of science for further studies still seems to be dominant in the SMICT curricula.

In order to enhance the relevance of science and mathematics programs for all students, two issues are important. First, a clear definition of 'scientific literacy' is needed. Although the attainment of scientific literacy is considered desirable in the international arena, there is little clarity and agreement about its meaning. Second, based on a clear vision of the meaning of scientific literacy in terms of curriculum provision, a careful distinction should be made between SMICT courses that are aimed at all students (core courses) and those that are chosen by a part of the students (elective courses). If junior secondary programs aim to provide a broad base of scientific literacy to all students and to motivate interested students to pursue in-depth science studies at senior secondary level, they should pay more attention to generating curiosity and creating enthusiasm in science and helping students to understand scientific phenomena in the world around them.

Another critical area for concern is the observed curriculum overload in most countries, which is seen as contributing to students' poor performance in SMICT subjects. Teachers do not know what balance to strike between such divergent aims and objectives as acquisition of scientific knowledge and practice of the scientific method, and how to implement this in classroom practice. Teachers also need more support in prioritizing different curriculum elements. Especially in countries where attainment targets are included in the syllabus rather than content specifications

(South Africa, Botswana), teachers need guidance with specification of outcomes in the classroom.

More extensive teacher support is also needed in dealing with mixed ability groups in classroom practice. Teachers face many challenges in this respect, such as making the aims and content accessible to students with divergent intellectual abilities, addressing individual learning needs in classes with 40 students or more, and doing so with limited material resources. In some countries, core and extended levels have been introduced to deal with the growing diversity of ability levels, but in practice students are often not streamed accordingly. Teachers thus face the additional challenge of organizing lessons such that core and extended content is covered at the same time.

### *Trends in content*

International movements towards science for all have led to a stronger emphasis on the importance of the utility of science to the individual and society at large. This is also the case in the countries involved in this study. All ten countries mention lack of relevance as a major area of concern related to the SMICT curriculum.

In all countries, societal problems are constant reminders of the need to make the SMICT curriculum more responsive to local needs. Issues such as environmental degradation, narrow industry bases, low agricultural productivity, high infant mortality and morbidity, and the HIV/AIDS epidemic constantly place new demands on the SMICT curriculum, thus bringing its relevance into question.

There is also a widespread concern that the SMICT programs are too difficult for the majority of students and lack relevance to their everyday lives and future needs. As noted in the previous section, the growing number of students in junior secondary education has resulted in a heterogeneous student population both in terms of ability levels and in future aspirations in the SMICT domain. This raises new questions about what content is most relevant for the SMICT curriculum. In addressing these concerns, three curriculum questions are of importance: (1) which elements of the academic and cultural heritage should be included in the curriculum?; (2) which issues are important from a societal point of view?; and (3) which issues should be included to address the personal and educational needs and interests of individual learners? It will be crucial to strike a proper balance between these issues; this thinking needs more attention in curriculum policy-making.

A relevant SMICT curriculum can only come about if countries have a clear vision on what society-related needs (preparing for future employment, addressing socio-economic problems), student-related needs (developing personal skills, relevance of content to everyday life), and subject-related needs (preparing for higher education levels) are. This needs to be addressed in the different junior and senior secondary programs, as well as a sound reasoning as to 'why' these needs should be addressed. As the interests of junior secondary students differ from those at the senior secondary level, the needs that should be addressed at both levels will not be the same. It could be argued that student-related needs and societal needs are of most importance in junior secondary programs, while subject-matter perspective will be more prominent at the senior secondary level.

Besides creating a better curriculum balance, providing more emphasis on skills to solve real-life problems in syllabi and including more life-related examples and applications in textbooks is another way to contribute to the relevance of SMICT education. The junior secondary syllabi in

Botswana and Namibia (Life Science, see textbox 1) and the mathematics syllabus in South Africa are promising examples in this respect.

In all countries, societal developments have led to the inclusion of a variety of new topics and issues in the SMICT curriculum. The general tendency to add these topics without replacing and omitting less relevant ones has led to the widespread complaint that the curricula have become overloaded. Syllabi tend to contain too many aims and topics to be covered within the available time, making it unclear to teachers where and how to focus. A striking example comes from Botswana where the time allocation for science classes was reduced by more than half without corresponding changes in the amount of content in the syllabus. It should be noted that curriculum overload is not typical for the surveyed countries in SSA. Worldwide, it appears to be easier to get things into the curriculum than to take them out.

*Textbox 1 Promising Practice - Life Science, a new junior science subject in junior secondary schools in Namibia*

The Life Science curriculum was developed by the Ministry of Education and Culture in Namibia in collaboration with the donor-funded Life Science Project. Development of the curriculum was based on the ZimSci syllabus in the 1980s in Zimbabwe and the notion of 'education with production' and 'self-reliance'. The curriculum is seen as a combination of biology (emphasis on human physiology), agriculture (emphasis on animal husbandry), and environmental education. The curriculum advocates a learner-centered pedagogy, provides for the use of simple equipment, and addresses both relevant skills and academic knowledge.

The development and implementation of a new curriculum was at the core of the activities of the project. All other components of the project were developed in support of the implementation of the new curriculum, including teacher education and the development of a national INSET infrastructure with training of regional facilitators. The curriculum development activities of the project included the development of the formal curriculum: syllabus for grade 8-10 of junior secondary level, textbook and teacher support materials, equipment kits, and assessment.

(See promising practices *Life Science in Namibia* in Annex 2 for further details).

Obviously, the curriculum overload presents serious threats to possibilities for learner-centered teaching to happen in the classroom. Moreover, it reinforces the phenomenon of 'teaching to the test'. Teachers rush to cover all topics mechanically in order to finish on time for the examinations, rather than striving for in-depth student understanding. So to allow for meaningful learning, the problem of curriculum overload should also be addressed.

Moreover, the philosophy underlying the selection of topics should be scrutinized. A choice can be made between having an in-depth focus on a few relevant topics or including a large number of topics, which are not necessarily relevant and are covered more superficially. Although the former is considered desirable, especially within a learner-centered approach, the latter philosophy is often taken as the basis of the syllabi in the different countries.

In all countries, moves towards more integrated science approaches can be observed, especially at lower secondary levels. This type of movement, which is line with international trends in science education, can be considered promising both in view of enhancing the relevance of the SMICT curricula as well as in an attempt to address the observed curriculum overload. The major benefits of integrating the separate science disciplines into broader science learning areas include providing a more holistic picture of science, allowing to focus on real-world problems that cut across disciplines, and promoting science reasoning skills across a range of learning contexts. This is especially vital at the junior secondary level where it is most important to provide a broad base to students, which helps to interpret and solve phenomena and problems they experience in everyday life, rather than offering specialist academic knowledge. In order to fulfill the mentioned potentials, the integrated science programs should include multidisciplinary themes, rather than

unrelated fragments from each of the different science domains, as is currently the case in a number of countries. The Botswana report, for example, notes that the integrated senior secondary science syllabus "*was constructed by simply cutting-and-pasting topics from the three pure science syllabi which were designed for the highest ability senior secondary students and it is thus highly unsuitable for its target population*". Fortunately, promising examples of integrated science syllabi, structured around multidisciplinary themes, can also be found in the ten countries. These include the previously mentioned junior secondary science syllabus in Botswana, the Life Science syllabus in Namibia, and the science and mathematics programs in South Africa. The GEEP materials in Senegal also provide a promising example of how family life education can be approached in a multi-disciplinary way, combining insights from the various science domains and relating to issues in everyday life.

While most countries offer integrated science courses, the implementation in schools is reported to be problematic. Major problems include the lack of adequate teacher preparation and the availability of relevant teaching and learning materials. In many countries teacher pre-service programs include separate subject streams and do not offer specific courses for integrated science teachers. Combined with limited opportunities for in-service education, the use of a thematic approach has become a serious challenge for teachers. As a consequence, the teaching of integrated science courses is often split up between biology, chemistry, and physics teachers. More emphasis on integrated science approaches in pre-service education, and more in-service support for existing teachers can thus be recommended.

The place of ICT in the curriculum of the surveyed countries deserves some separate remarks:

- Computer studies have found their way into the formal curriculum, but in most educational practices their existence is embryonic, mainly due to lack of computers, connections, and staff expertise. Exceptions are mainly clustered in resource centers, pilot schools, and teacher training institutes. Most successful in the implementation of ICT in practical use are a few, often donor funded projects, such as SchoolNet Africa and WorLD. They stand out because they are active in several countries and combine support in three layers—infrastructure (ICT hardware), general and educational software, and the training of teachers. Often the projects focus on ICT centers or resource centers (Ghana, Zimbabwe) or a small network of pilot schools. The focus of ICT as a means to enhance the quality of education is often very vague, with such exceptions as activities by SchoolNet Namibia and the GEEP project in Senegal which help teachers with the implementation of new teaching methodologies in class.
- In most survey countries Computer Science is taught in secondary education. Some countries have introduced it as a separate subject with its own syllabus and (in most cases) its own assessment. Most of these courses focus on the computer as a tool for office functions, presentations, acquiring information on Internet, and communication through e-mail. Also, the place of ICT in society is generally addressed.

In several countries, ICT is mentioned as a cross-curricular issue, without however finding its way into syllabi, textbooks, and classroom practice other than in a separate subject like Computer Science. The Computer Awareness program in junior secondary schools in Botswana is an exception. The course is cross-curricular and non-examinable.

### 2.3 Instructional Processes

All countries have emphasized including more active learning approaches in the SMICT curriculum. Learner-centered education, participatory teaching, inquiry-based approaches, problem solving and critical thinking are some of the keywords that feature prominently in curriculum policy documents. This is in line with international literature on science education, which makes a case for science education in which student learning is not a passive activity, but an activity in which students actively construct their own knowledge through interaction with their existing knowledge, and ideas provided by materials, other students, and the teacher.

The country reports are very clear and consistent in their description of the type of pedagogy that actually dominates the classrooms in sub-Saharan Africa. It is perhaps best illustrated by a quote from the Ghana country document:

*“Largely very traditional, teacher-centered and content-driven, with note taking and sometimes a practical especially in preparation for the practical exam at the end of secondary. Whole class teaching at all levels, in spite of the curriculum advising otherwise. Nice jargon in the curriculum documents but nothing to be seen in the classroom”.*

Thus, overall, there is very little evidence of the often ambitiously formulated curriculum ideals. That situation seems to be the norm for SMICT classes in all countries in the study.

The reports from the various countries use different wordings to express one and the same thing: there is a huge gap between the intended curriculum and what is implemented in the classroom. Three main reasons are offered to explain this:

- Lack of teaching materials and other resources (South Africa: *“because of the lack of resources in many schools, the teacher is often the learners' only resource to learning”*).
- Overloaded curriculum (Uganda: *“pressure to complete the syllabus competes successfully with teachers using more co-operative strategies in teaching”*). Very little room seems to have been created in the curriculum for adopting a learner-centered teaching approach.
- Lack of teacher confidence with the subject matter prevents teachers from using a more learner-centered teaching pedagogy. This refers back to the often-poor initial preparation and qualifications of teachers as well as the lack of structured support while in post.

The picture of what happens in the classroom is indeed rather sobering. However, it is useful to put the observations in perspective.

- The change in pedagogy from teacher-led to more active student participation is problematic everywhere, not just in sub-Saharan Africa. Teachers in Europe, America, and Asia struggle with such proposed changes as well.
- School systems are at different stages in their development, and the higher the development stage the better the chances of success for curriculum implementation. Looking at the stage of development of many schools in sub-Saharan Africa, one must come to the conclusion that the chances of successful implementation of an innovative science and mathematics curriculum will be slim. The South African report observes that implementation of Curriculum 2005 was successful at the Model C schools (best-equipped schools with qualified teachers). But it is less successful in schools at a much lower stage of development, where the curriculum was intended in the first place.

- In the curriculum reforms emphasizing a more participatory role for students, learner-centered education, outcomes-based education, and active methods, very little attention is given to the support for teachers in the implementation process, besides the occasional workshop. Support in the classroom is often completely absent from in-service programs accompanying the implementation of the new curriculum. The results suffer accordingly.
- Queries have been raised about the idea of a learner-centered pedagogy in schools in 'traditional societies' where the authority of the teacher is unquestioned. Tabulawa (1996) makes a clear case for careful introduction with great sensitivity to cultural issues that may play a role in the school, in order to avoid what he calls 'tissue rejection'. Others have suggested trying to improve on what is already there, and to focus on improving more 'traditional' forms of teaching with an open eye for possibilities to gradually introduce learner-centered pedagogy (de Feiter et al., 1995).
- Another constraint limiting possibilities for learner-centered education in practice is *language mastery* of both students and teachers. In the Anglophone and Francophone countries, the language of instruction, English or French, is different from the mother tongue of the majority of the students and the teachers. In Ghana, 9.6% of the primary school leavers achieved basic mastery of English in 2000, which shows that the great majority of students have a weak base when entering junior secondary school. In other countries language mastery of students as well as teachers is also considered a major impediment to educational improvement, both in science and in mathematics (cf. Howie, 2002).

A number of measures are needed to improve teaching and learning processes in schools. These include: (i) policy specification and coherence; (ii) a critical review of curriculum content; (iii) more comprehensive teacher support programs.

The lack of clarity about what is expected from teachers is a major factor contributing to the limited implementation of learner-centered approaches in all countries. At the macro-level, curriculum documents (syllabi, policy papers) should express a clear vision of the type of learner-centered pedagogy that schools should strive for. However, considering the huge gap between policy and practice, a more careful definition of what is feasible within the existing conditions in schools (capacities, materials) and appropriate within the existing cultural context is needed. Moreover, the consistency between the different curriculum components needs more attention. If a learner-centered philosophy is at the heart of the curriculum, it should be clear how this approach is reflected in other components of the curriculum such as instructional materials and assessment. Regarding the content of the curriculum, learning less information in greater depth is preferable to covering a large number of facts with limited understanding ('less is more') (Fraser & Tobin, 1998). This emphasizes once again the need to address the curriculum overload that is present in the various countries.

To further facilitate the implementation of learner-centered education, more relevant curriculum resources are urgently needed at the school and classroom level (textbooks, teacher guides, and student materials), combined with other opportunities for teacher support. The introduction of learner-centered approaches is a formidable challenge to teachers, and this innovation is bound to fail if there is not sufficient support (van den Akker, 1998; Black & Atkin, 1996). In developing such support, the provision of specific and detailed ('how-to-do') guidelines for use of the approach in practice should be considered as a major point of attention. Studies conducted in Namibia (Ottevanger, 2001) and Botswana (Thijs, 1999) show that exemplary curriculum

materials including such advice can be a powerful means to help teachers utilize learner-centered approaches, especially when combined with in-service workshops and in-school support.

## 2.4 Assessment

Assessment plays an important role in the education system in all countries. National examinations in SMICT subjects take place at the end of junior secondary and senior secondary education and are used for selection purposes. These examinations usually consist of three papers: one with multiple choice questions; one with essay-type and short answer questions; and a practical paper. The practical examinations tend to be written papers at junior secondary level and in integrated science courses at senior secondary level, while the elective courses usually involve a hands-on practical examination.

The examinations have a profound impact on the teaching and learning process in all countries. There is a lot of 'teaching to the test', i.e. teachers focusing on topics and skills that are included in the examinations and devoting a lot of time to acclimatizing students to examination-type questions. In the core science courses, practical work is hardly done and often theorized, because of the absence of a practical examination. Zimbabwe reports that "*aspects of the curriculum that are seen not to be periodically examined tend to be skipped whilst those that are periodically examined are taught in ways that facilitate students to answer particular questions. The absence of a practical examination leads to a theorizing of practical work and a lack of hands-on practical activities*". In Botswana "*SMICT teachers invariably copy questions from national examination papers and sometimes mimic their questioning style as the papers are seen by many as defining the standards to be attained and maintained in assessment.*"

Considering the strong impact of examinations on teaching and learning in the classroom, there should be a sound relationship between the nature of the assessment and the curriculum. Various country reports voice their concerns in this respect. Despite much advocacy of the need for learner-centered approaches, examinations tend to focus on knowledge and understanding, while practical skills, reflective skills, local application, and attitudes are often hardly assessed. More careful thought should thus be given to ways to strengthen the link between the examinations and the curriculum. The move towards criterion-referenced and outcomes-based assessment, which is considered by a number of countries, could be promising in this respect (cf. Lewin, 2000). In Namibia, Botswana, and South Africa, criterion-referenced testing has become a policy priority, but all three countries report implementation problems in practice, pointing to the need for more teacher professional development.

In most countries school-based continuous assessment has been introduced as part of the final examination. In Botswana, South Africa, and Ghana, school-based assessment results amount to, respectively, 20%, 25%, and 30% of the examination marks. The Ghana report is most specific on what is expected of teachers: four class assignments, three class tests, and four projects should be conducted every term. In South Africa various assessment tasks (pen and paper tests, closed and open type investigations, lab reports, and projects) form part of a portfolio in science, to be moderated at the end of each year. Assessment activities in mathematics include investigations, group work, and journal entries.

While there is emphasis on school-based continuous assessment at the policy level, there are many obstacles limiting a smooth implementation in schools. These include (1) lack of correlation between results of school-based assessment and end-of-year national examination results (Ghana,

Nigeria, Namibia, South Africa); (2) teachers' lack of insight in what skills and knowledge to assess, and what techniques to use, are major problems in many countries; and (3) risk of over-assessment is mentioned as a concern. Botswana, Ghana, and South Africa all point at the large amount of teaching time that schools now devote to collecting and recording data on student performance in certain areas of the curriculum, while some of this knowledge and skills feature again in the national examination.

Addressing these implementation problems can be considered important, as the inclusion of more school-based assessment has the potential to yield positive benefits in terms of providing a more relevant and valid basis for selection of students (cf. Briseid & Caillods, 2003). It could provide a more holistic picture of student performance, as it allows for the use of a variety of assessment methods other than written tests that could assess a larger range of skills on a more continuous basis. To realize these benefits, the school-based assessment approach needs more specification, support, and elaboration. Examination policies and documents should be clear on the role and moderation of continuous assessment in the overall examination. School-based assessment could be used to finalize certain parts of the curriculum that will not be assessed in the final examination. Moreover, more guidelines and support should be provided to teachers on how and what to assess. This support could include in-service workshops, as well as manuals and teacher guides. An example of the latter is coming about in Namibia, where a continuous assessment manual for SMICT teachers is currently being developed with practical guidelines, good practices in terms of assessment tasks, assessment criteria, and guidelines for recording summative marks.

Besides the use of continuous assessment for summative purposes, its foremost strength lies in the potential to monitor student learning on a regular basis and thus provide input for improving the teaching and learning process. The literature clearly outlines how such formative assessment can be a powerful means to improve student learning (Black & William, 1998). In the ten countries, testing at the school-level is very much summative in nature, and is hardly used for instructional purposes or to provide feedback to the learners. More emphasis on the formative nature of assessment can thus be recommended. As Briseid and Caillods (2003, p. 91) note, more weight should be given to assessment methods that "*keep students in the system rather than selecting them out*". This will require the development of relevant assessment methods that can be used to improve students' learning experiences. In this respect, it will be interesting to learn from experiences with portfolios in South Africa as well as the diagnostic tests and worksheets that are currently developed in Ghana. Whatever methods used, teacher support will be a key to the success of formative assessment. Preliminary results of a study into formative assessment in science education in Botswana show that exemplary materials can be a promising means to support teachers, but also point at the need for comprehensive teacher support scenarios in order to affect the full potential of formative assessment as a vehicle for classroom improvement (Motswiri, 2004).

## **2.5 Concluding Remarks: the way forward**

The discussion of the main trends and challenges regarding curriculum policies, instructional practices, and assessment has revealed several important insights regarding SMICT education. Based on these insights the following pointers for future policies on SMICT education can be summarized.

- A critical review of the aims of the SMICT programs in view of the changing needs of the student population is needed, as well as a careful distinction between science courses for all students and more specialist science courses.
- The curriculum overload should be addressed by prioritizing topics based on a clear vision of what would be an appropriate balance between subject-related and academic needs, society-related needs, and student-related needs for the different SMICT programs.
- More comprehensive teacher support programs (in-service workshops, materials, in-school support) should be provided, focusing on innovative, challenging characteristics of the SMICT curriculum such as learner-centered teaching, multidisciplinary and thematic approaches to science education, mixed ability teaching, and the use of formative assessment.
- More attention to similar themes should also be provided in pre-service teacher education programs.
- More emphasis should be placed on the development of curriculum materials with specific guidelines on the use of learner-centered and multidisciplinary SMICT approaches, with relevant local and real-life examples.
- A reinforcing relationship should be established between the curriculum and the assessment system in which the two jointly aim towards developing learner-centered and meaningful SMICT education.
- School-based assessment and the assessment as part of the national examination should be geared to one another, thus avoiding unnecessary overlap.
- The development of relevant assessment methods that help teachers to improve the teaching and learning process should receive more attention.

### 3 School Context and Instructional Resources

In the previous chapter, the large gap between the intended curriculum and the curriculum in operation in the classroom was related to poor teacher qualifications, the overloaded curriculum, the large classes, and the lack of Instructional Resources. This chapter looks at resources such as textbooks, laboratory resources for practical work, facilities for ICT at schools, and the school context in which the use of these resources may lead to improved quality of education. The effectiveness of inputs for SMICT is largely dependent on how and in what context (school and class) these inputs are used (cf. Scheerens, 1999).

This chapter specifically looks at the following aspects of resources for SMICT:

- Context in which the resources are used (section 3.1)
- The different kinds of instructional resources (section 3.2)
- Cost of resources (section 3.3)
- Optimizing opportunities and resources (section 3.4)
- How resources are paid for (section 3.5)

Section 3.6 suggests possible ways forward.

#### 3.1 Context in which resources for SMICT are used

In many schools, resources for science, mathematics, and ICT education are inadequate. Although it is difficult to get systematic data on the resource level at schools, local studies and anecdotal evidence suggest that the resource level is low in view of the demands of the various SMICT syllabi. Both the supply of equipment and the replacement of faulty equipment are often very limited. In many cases there seem to be no proper and clear systems for these. Procedures on how to order are often not known to teachers, and the times before orders are delivered at schools are often very long and discourage putting in further orders at all.

The few resources for SMICT that are found in schools are often left un-used, underused, or used in the wrong way. Perhaps with the exception of schools which have lab technicians (e.g. Botswana), inappropriate storage and poor maintenance of equipment often renders equipment unusable. Teachers' lack of understanding of how equipment works often results in a small missing screw being the cause of malfunctioning equipment. Few schools have lab assistants, and if these are present they might not have been adequately trained for the job. Generally, there seems to be little support for teachers in the classroom in this area, nor have teachers been trained at the College or at University to appropriately deal with issues of maintenance of equipment.

##### *Instructional time*

SMICT subjects are well represented in the junior secondary curriculum, from 21% in Uganda to 39% in South Africa. Both mathematics and science are compulsory at junior secondary level. Mathematics is also compulsory at senior secondary level. At that level, the time taken up by science and mathematics subjects may increase up to more than 90%, depending on the science options taken. However, the *actual* time spent on the various SMICT subjects in the class seems difficult to establish. No systematic information was provided in the country reports on the actual time devoted to SMICT, but other reports as well as anecdotal evidence suggest that much time is lost due to late arrival of teachers and students, and change of classrooms between lessons. Many classes are cancelled because of teacher absenteeism due to illness; taking care of family due to

the HIV/AIDS endemic, in-service workshops and other school activities at times taking preference over classes.

Most junior and senior secondary schools have a school year of more than 200 days and have around 27 hours of classes. Most classes have periods of 35-40 minutes. These figures might differ from the actual school year, because days might be lost by, for example, late reporting of students and teachers during each term, such events as sporting days and Anniversaries. Table 5 gives an example of a typical school day in a junior secondary in South Africa.

Table 5 . *Example of two days of a timetable of a typical Grade 10 (junior secondary) learner's timetable in South Africa*

Time	Activity	Time	Activity
7:20	School starts	7:20	School starts
7:20	Class registration	7:20	Class registration
7:30	Period 1: Art	7:30	Period 1: Test period
8:15	Period 2: Art	8:15	Period 2: Test
9:00	Period 3: French	9:00	Period 3: Science
9:45	Period 4: French	9:45	Period 4: Second language
10:30	Break	10:30	Break
10:55	Period 5: Second language (Afrikaans or Sepedi)	10:55	Period 5: French
11:40	Period 6: English	11:40	Period 6: English
12:20	Break	12:20	Break
12:30	Period 7: Science	12:30	Period 7: Art
13:15	Period 8: Mathematics	13:15	Period 8: Mathematics
14:00	School day ends	14:00	School day ends
14:15 – 16:30	Optional extra mural activities	14:15 –	Optional extra mural activities

Classes in secondary education are generally large. This is so in junior secondary schools and to a lesser extent in classes in the senior secondary sections. There are large differences though between countries (Namibia and Ghana: 20-35; Uganda and Nigeria: 60 and more) as well as within countries. Classes are especially large in urban areas, and class sizes of well over 100 have been reported. In rural areas the class sizes are usually smaller. Classes that prepare students for university are usually much smaller (e.g. 16 students per class in Senegal, 12-20 in Zimbabwe).

Pressure for placement in secondary school has resulted in large classes in junior secondary. From the country profiles, it appears that there are organizational reasons for large classes as well. There is a tendency towards combining large groups of students (e.g. from different classes) together in one class, rather than more but smaller classes. Also, grouping students from different science options together in one class (e.g. in Botswana) creates problems for teachers. As a result, teachers in many countries appear to have relatively low teaching loads in terms of scheduled hours.

Large classes are seen as one of the deterrents to the implementation of a learner-centered curriculum. Teachers are often overwhelmed by sheer numbers and find maintaining order a mammoth task, let alone facilitating students' conceptual development. There is therefore a need to improve the balance between teaching loads and class sizes. The ability of teachers to teach two or more subjects would also be a great help in the attempts to improve the human resource inputs in schools, especially small rural schools. In addition, timetabling is a technique not necessarily always mastered by schools, thus requiring development.

## 3.2 Instructional Resources

### 3.2.1 Textbooks and Teacher Support Materials

#### *Development*

In many of the countries in the study, there are attempts to develop textbooks locally. In some of the countries (Ghana and Nigeria), all textbooks are developed in country. In those two countries textbooks are developed and published locally (by consortiums of international and local publishers) and with the involvement of teachers through the science teacher associations (GAST and STAN, see textbox 2), respectively. In other countries, especially in less densely populated ones (Botswana and Namibia), textbooks are produced locally for JS but are imported for SS mainly because the very small markets make local development economically unattainable. However, there are recent efforts to produce a senior secondary science book for use in both Botswana and Namibia. Still, in other countries, very little local development of textbooks is observed, although very first initiatives can be observed (Senegal, Uganda, Tanzania), parallel to the liberalization of the market.

On-the-job training of textbook writers by UNESCO and donor funded projects has helped the development of local textbooks (Namibia, Botswana). A group of experienced teachers has received training to develop textbooks under the supervision of an editor. This has resulted in a good set of local textbooks at junior secondary level.

#### *Informal learning materials*

The use of the informal learning materials is widespread. Teachers develop supplementary materials in Ghana, Uganda, Nigeria, and Senegal (in BST schools) in the form of so called *pamphlets*. These pamphlets are often used as alternatives to books. They are cheaper (but not very cheap) but also varying in quality (content, layout, paper, and binding). The pamphlets are mostly examination-focused and therefore limited in their approach to teaching and learning.

Textbox 2. Promising Practice – Science Teacher Association of Nigeria (STAN) and its role in science curriculum development

Since the late 1960s STAN has been involved in curriculum development activities. One of its main achievements has been the development of the Integrated Science syllabus.

The Association adopted a model for curriculum development involving relevant stakeholders, teachers, and examination board. The model included five steps: problem identification and formation of curriculum teams, stating objectives, determination of content and the development of instructional materials and identifying writers, trial testing, modification and installation of materials, summative evaluation and revision cycle.

STAN has produced an extensive number of textbooks, teacher guides and pupils workbooks, in integrated science, agricultural science, and mathematics, both for junior secondary and senior secondary levels, many of which in co-operation with the local branch of Longman and Heinemann. The royalties from the textbooks and other curriculum materials were received in the name of the Association. This has helped STAN to organize training workshops for teachers to familiarize themselves with new methods and techniques essential for the successful and effective implementation of the new curricula.

STAN has put Nigeria on the map of integrated science. Through the association's efforts the country can produce learning materials for all science subjects and mathematics. STAN has produced books with essentially local content. These materials are very popular and widely used.

STAN has a membership of about 3000.

(See promising practices: *Science Teacher Association of Nigeria (STAN) and its role in science curriculum development* in Annex 2 for further details).

In addition, in some of the countries there have been efforts to develop teacher support materials and teacher guides. These may be well-prepared teacher materials—prepared with the help of donor funds, e.g. in Namibia with the help of INSTANT Project (Physical Science) and Life Science Project (Life Science). Uganda Links provides promising teaching materials developed for Diploma courses at teacher education colleges: it has a strong focus on low cost materials and it provides examples of investigations which can easily be adapted for use by pupils in schools.

### *Selection*

In most of the countries in the study, the Ministry of Education produces prescribed lists of textbooks suitable for use by students. In some countries, there is a textbook evaluation committee set up by the science panels (e.g. Namibia, Botswana) that advises which of the available books should be on the prescribed list. Such evaluation committees are often shrouded in a cloud of obscurity resulting in a lack of clarity in the evaluation process. The stakes are high in the process of textbook selection and evaluation. There is pressure from the publishers to get their books on the list of prescribed books, and interference with the selection process is not completely impossible.

### *Provision and use*

To get a local book on the Ministry's list of prescribed books is often difficult. The problem noted in Botswana is the fact that a different kind of local textbook, supporting a learner-centered teaching approach, is not necessarily understood and valued by those on the evaluation committee. In addition, marketing local textbooks against imported books is a problem (again noted in Botswana), and this defies the curriculum localization efforts as local books usually include relevant local examples often missing from imported books. The supply of textbooks to schools is often insufficient to have a textbook for every student. Schools and parents (via school fees) need to buy extra textbooks. In almost all countries, students share textbooks and make use of the extra copies in the library.

The availability of textbooks is not a guarantee that they are (effectively) used in class. Unfortunately, as noted in some of the country reports, it has not put a stop to note dictation and copying. Similarly, country reports raise the question of whether available teacher guides are really used. For instance, in Namibia the availability of such guides in Teacher Resource Centers has largely gone unnoticed by the teaching force.

## **3.2.2 Resources for Practical Work**

A considerable variety of science curricula (e.g. purposes of practical) are found in the study. These require varying levels of materials in terms of facilities and equipment and maintenance. Table 6 provides an overview of four typical science syllabi and their required equipment.

Curricula that explicitly seek to take science outside the traditional confines of the laboratory tend to be less reliant on expensive facilities and their cost is lower. It is interesting to note that most expensive are the older style selective academic programs such as A-levels. These A-level curricula are typically offered often in the 12th and 13th year. In this program, only 3-4 subjects are studied in greater depth than the more usual wide spectrum of 6-8 subjects. This depth takes science, particularly physics, into new and much more expensive programs of study requiring a markedly higher level of facilities and equipment. Some countries in the study, such as Ghana and Nigeria, have abandoned A-level studies in recent years in favor of a broader curriculum.

At the other end of the cost spectrum is one new program, the Namibia Life Science program. This program is specifically designed to link science with everyday life and requires very little in terms of equipment and facilities. Column 3 of the table shows what is currently a largely hypothetical program in Africa—but common elsewhere—that takes ‘Science for All’ to the end of senior secondary schooling.

Table 6. *Practical work cost spectrum-showing examples of typical requirements.*

Syllabus	A-level physics	Grade 12 ‘selective intake’ syllabi	Grade 12 ‘science for all’ syllabi	Grade 10 LifScience (Namibia)
Typical practical requirements	Class size - 24 <ul style="list-style-type: none"> <li>• Secure storage room</li> <li>• Laboratory with mains electricity</li> <li>• 6-12 low-voltage packs or outlets</li> <li>• 6-12 sets of equipment covering all main topics, including multi-purpose oscilloscopes</li> <li>• Demonstration models of expensive items</li> </ul>	Class size - 36 <ul style="list-style-type: none"> <li>• Secure storage room</li> <li>• Serviced laboratory, including gas</li> <li>• 6-12 Low voltage power packs or alternative sources</li> <li>• 6-12 sets of basic equipment and materials covering key curriculum areas</li> <li>• 6 microscope</li> <li>• Access to demonstration equipment related covering specific topics</li> </ul>	Class size - 40 <ul style="list-style-type: none"> <li>• Secure storage room or large cupboard</li> <li>• Serviced room, preferably with gas</li> <li>• 6-12 power packs or a supply of batteries</li> <li>• Supply of basic materials, much of which will be commonly available locally</li> <li>• Equipment for using outside (gardening, simple magnifying glasses, long tape measures, etc)</li> </ul>	Class size - 40 <ul style="list-style-type: none"> <li>• Storage</li> <li>• Room with a working sink</li> <li>• Class sets of simple equipment such as dissecting kits, magnifying glasses, or improvised equivalent.</li> <li>• Heating equipment and some common chemicals</li> <li>• Gardening equipment and secure garden area</li> </ul>
Notional equipment costs US \$ k (*)	36	30	10	3

(\*) based on data from UK and local Southern African suppliers of school science equipment

### 3.2.3 ICT Resources

#### *Infrastructure*

ICT resources have found their way into schools. In some countries this is the case in almost all schools (Namibia, Botswana, and South Africa), in other countries this has happened only to a limited extent (Ghana, Uganda). Precise data on computers in schools are hard to come by, but if the number of computers per 1000 inhabitants is anything to go by, Botswana, Namibia, Zimbabwe, and South Africa top the list (see table 7).

Table 7. *Some characteristic figures on computer penetration*

Country	Computers per 1000 people	Internet users per 1000 people
Botswana	40.7	29.7
Burkina Faso	1.6	2.1
Ghana	3.8	2.3
Namibia	70.9	26.7
Nigeria	7.1	1.7
Senegal	20.4	10.7
South Africa	72.6	68.2
Tanzania	4.2	2.3
Uganda	3.3	2.8
Zimbabwe	51.6	42.9

Source: International Telecommunications Union, ITU (2002), [www.itu.int](http://www.itu.int)

These figures are averages. There is quite a divide between urban and rural areas. Even in countries with many computers, some rural regions have no computers in schools or at best one computer for administrative purposes. Figures on schools without computers go from 70% to 90% of the countries' schools. Besides the availability of computers, electricity and connectivity to the Internet cannot be taken for granted.

Access to an electricity grid cannot be counted on for the average school in sub-Saharan Africa. In remote areas, electricity is often supplied by generators, and usually in the evenings. In some regions, however, schools have solar powered electricity. In Namibia, SchoolNet has developed a solar-powered computer suite for use in schools beyond the reach of the electricity grid.

Once a school has a power supply, connectivity to the Internet is in principle not a big technical problem. Some schools simply use the telephone net, some use radio connections, of various kinds and prices, others use satellite connections, provided by sponsored projects. Namibia has installed a fast optical communications backbone, and all parts of the country are beginning to see the benefits of it. SchoolNet Namibia is currently putting up a wireless system via a narrow-band radio network to reach those areas in the country where the backbone does not reach, in particular in the northern part of the country. Namibia is on track to becoming the first country in Africa with 100% Internet access in schools.

#### *Software: general*

The main problem is the current limited availability of relevant software and Internet use in schools, which is currently mostly restricted to teachers. Most of the general software helps students learn how to use the Internet and email, word-processing, spreadsheets; CD-ROMs often bundled with computers have electronic encyclopedia such as *Encarta*, or *Encyclopaedia Britannica*. Most countries in the study have computer science as a subject in senior secondary level, or integrated in other subjects as Integrated Science (Ghana) in some cases, including programming in languages such as Logo and Pascal. In most countries and projects, the operating system and most applications are from Microsoft, although a move towards the use of Open Source software can be observed. In Namibia, SchoolNet has developed the free, stable and fast

Linux-based operating system X-Windows, and schools run this on diskless computers using Star Office in a Microsoft-free environment.

*Software: subject specific*

An overall observation in many countries is that few teachers are regular computer users, and those that are, are generally unaware of what software is relevant and available for science and mathematics and what it can do. A pessimistic South African observation is that even where computers are being used in specific learning areas, there is a tendency to rely on software that is oriented towards drill and practice activities as opposed to a more problem oriented approach. However, in networks around Resource Centers or projects, there is science-related software and hardware, and teachers learn to use it in an appropriate way.

Specific for the use of computers in science education is the availability of sensors, actuators (lamps, switches, electromotors etc.), and interfaces or data loggers to connect sensors to computers or to store data collected during field work; all of these together with appropriate processing software. These tools form a relatively cheap extension of practical work facilities, under the assumption that computers are already available. These provisions appear rare in secondary schools. Schools can have access to the limited quantities of this type at Science Resource Centers (Ghana), or borrow them from Teacher Resource Centers (Namibia). However, an observation from Namibia is that even where these are available, they are largely unused.

The limited use of scarce resources can partly be traced back to the fact that many teachers are not familiar with its use. Programs are active in several countries to update the skills of teachers in the use of ICT. Examples are (among others) the Educators' Network in South Africa, World Links for Development in several sub-Saharan African countries, and the RESAFAD/GEEP initiative in Senegal and Burkina Faso combining SMICT teacher professional development and ICT.

### **3.3 Cost of Instructional Resources**

*Cost for practical work*

Table 6 in section 3.2 provides an overview of the four main science programs and related demand on resource provisions, from the high cost A-level program to the low cost Life Science program in Namibia. The general trend noted (at least in a number of countries), not only for purposes of reducing cost but also for pedagogical reasons, is away from the restrictive expensive fixed service bench laboratories and towards the more flexible—and cheaper—option of a serviced room. This trend is accompanied by a widening of science activities and a general move away from traditional work that required expensive and difficult-to-maintain class sets of equipment that characterized the era of the 1960s to 1980s.

*Cost for ICT*

It has been observed that not much discussion takes place on whether the acquisition of ICT skills should be the responsibility of schools, as a public provision, or whether this should be the result of private providers such as Internet Cafes and (partly) paid by parents. Arguments in favor of ICT in the school curriculum include the observation that exposure to ICT provides students with better chances in the labor market. At the moment much of the initial cost of ICT facilities is met by donations from donor-funded projects and SchoolNet organizations.

The capital costs of ICT infrastructure are mentioned in several of the country profiles. The recurrent costs should also be taken into account. The country reports have not been made with

the aim of a systematic and comparative analysis of these kinds of costs, but exemplary figures can be found throughout the reports. Based on figures from the literature and analysis of schools and telecenters in regions in Zimbabwe and South Africa recurrent cost categories including housing, equipment (hardware and software), running costs, training of teachers, technical and pedagogical support, and learning materials can be indentified (Cawthera, 2000). These costs result in a total ICT cost of about *six* times the initial layout for the purchase of the computers. The cost for operating system licenses and applications (mostly from Microsoft) can add substantially to the operating costs. In reaction, SchoolNet Namibia has developed a Microsoft-free environment.

### 3.4 Optimizing opportunities and resources

#### *Resource Centers*

Several countries report initiatives that concentrate limited resources in specialist centers. These are often intended to act as hubs for professional development and in some cases for exposure of learners from neighboring schools to practical elements. Examples of such centers are the Teacher Resource Centers in Namibia and Botswana, which are used as structures, separate from schools, with library facilities, equipment, duplicating facilities, and computers. Teachers (and sometimes students) can go there to consult books, to borrow equipment, and to make photocopies. The above centers are also used for professional development activities, like workshops and teacher meetings. Success in both these endeavors is reported to be limited but not entirely unpromising.

*Textbox 3. Promising Practice – Science Resource Centres in Ghana as a cost reducing measure in the provision of science and ICT equipment to schools*

The Science Resources Centre concept in Ghana was designed as a solution to the problem that many senior secondary schools in Ghana have no laboratories; yet such facilities are a pre-requisite to taking part in the final science examinations.

The Ghana Education Services (GES) was tasked with putting the plan into practice. Six teachers were trained in the UK by Philip Harris (who had also provided the equipment for the 107 centres located throughout the country). These teachers in turn trained other science teachers.

The Centres attached to, but not owned by, schools were supplied with liberal quantities of science and ICT equipment. Students from surrounding schools are bussed to the Centre (every Centre has its own bus) initially every week, then later every fortnight, and are engaged in science practical activities for the afternoon. Trained teachers conduct the lessons, not teachers from the other schools.

The Centres were perceived as a cost-reducing measure, as expensive equipment could now be used by many students from several schools. An analysis of the functioning of the Centre reveals that the Centres received an enormous patronage by schools. However, with the passage of time discrepancies between the original intentions and practice emerged. Problems observed relate to finances, transport, number of students involved, type of equipment present in the Centres, maintenance, and organisational arrangements of students visiting the Centres.

The strength of the model lies in the fact that it has provided a better environment for the teaching and learning of science in the schools that host the Centres. The weakness of the model stems from the logistics and the financial needs to run the Centres, something which was not budgeted for. This has made the model unsustainable. The analysis suggests adapting the model to include activities for SMICT teacher professional development.

(See promising practices: Science Resource Centres in Ghana in Annex 2 for further details).

A similar development in several countries, the loan of expensive and infrequently used materials from resource centers, where expertise is also available, has been reported with similarly mixed comments. Very often, the materials are not borrowed, either because distances are too great or it

costs money to get them there, because TRCs do not open after school time, or because teachers are unfamiliar with the materials and are reluctant to use them. A multi-country evaluation of TRCs (Knamiller, 1999) suggests improving the effectiveness of TRCs by attaching them to existing schools rather than by housing them as separate structures. Such centers exist in Ghana, where over 100 Science Resource Centers (SRCs, see textbox 3) are attached to schools. They have an extensive inventory of science and mathematics equipment, including ICT facilities. The SRCs are very much integrated into the operation of the schools to which they are attached and are certainly beneficial to the schools. They should also benefit the surrounding schools, and indeed students from neighboring schools are at times bussed to the SRC for practical science sessions. However, the benefits of the satellite schools seem much more limited. This has mainly to do with organizational problems and the lack of funding affecting the transport of students to the Centers (see promising practice 2). The SRCs in Ghana therefore seem to function more as special SMICT schools, with better provision of equipment and better-trained teachers.

#### *Special SMICT schools*

Similar intentions and developments of special SMICT schools are observed in the Dinaledi project in South Africa, the BST schools in Senegal, and the Federal Government Colleges and Federal Government Girls' Colleges in each of the 36 states, and Abuja in Nigeria. Such schools are used as models in SMICT education for staffing, equipment and teaching, and quality output. The study has not collected data on any of these, but Caillods et al. (1997), reflecting on special science schools in Malaysia and Nigeria, indicate that they produce students with high science qualifications. However, whether the achievement gain was cost-effective compared to those in ordinary schools with fewer facilities and operating at lower cost remained to be seen.

#### *Efficient use of ICT facilities*

Besides pooling resources, it is clear that much money is saved when the efficiency of computer use is increased, i.e. when more people use computers, and when computers are used for a longer period during the day. This can be done by extending the time that students use computer labs (e.g. in double shift schools) much like Internet Cafes that are open for long hours and in some cases for 24 hours per day (e.g. in urban centers in Ghana). A reasonable standard for a school day is five hours of teaching time. Many schools encourage students to use facilities after school and during lunch times. A total of 10 hours per day should be attainable for most schools that wish to have good usage of their computers and are prepared to devise a strategy to attain this.

Such a strategy could well include the use of the computers by members of the community and students from other schools until the early evening. When schools open their ICT facilities to other users the costs can be shared. The benefit of school-community co-operation is twofold: it provides more cost-efficient ways to use available computers, and it facilitates a more encompassing development of 'unfreezing schools'. School-community co-operation may also be approached from the other end, i.e. when a public or commercial community provision such as an Internet cafe is hired partially for formal education purposes. This is perhaps under-explored, except for an interesting development that has been seen in Dar es Salaam in Tanzania. Schools allocate a commercial training company a room for offering ICT instruction. Parents pay the company directly.

### **3.5 Funding Science and ICT resources**

All countries report a steady increase in the number of students taking SMICT subjects through all the grades. This has raised the issue of the cost of the subjects, particularly in relation to

provision for practical work. In some countries this is being addressed through an increase in the numbers of private secondary schools where the costs are being met by parents and others who support such schools, in an often very limited way. In other countries, particularly in the South, expanded state provision is the norm, but the expanding salary bill increasingly precludes significant support for SMICT subjects (except in Botswana). In these countries, forms of cost sharing with parents and the private sector are emerging. Currently these are unsystematic and tend to favor the already elite establishments, but there are moves to spread this support more equitably. Because support for practical SMICT subjects is a relatively small element of the education bill, and because it is a highly visible one (particularly if ICT is involved), promising cost-sharing initiatives are emerging.

The following categories of sponsors for SMICT can be distinguished:

- *Governments* - government contribution to SMICT materials are generally small, except in Botswana.
- *Parents* - their contribution is mostly through school fees. Schools use these fees in particular to purchase relatively inexpensive consumables and for maintenance and replacement of equipment. School funds are also used to enter into cost sharing activities. These take the form of private subsidies to allow state-run education to function more effectively through input (both financial and expert) from the private sector.
- *Local private sector* – this can take the form of support in kind or in money. Examples are industry funds (such as mining and petroleum companies) which support activities in subjects important for the operation of the industry that do not replicate the normal government operation of schools. Such activities can also be in the form of tripartite arrangements between a private sponsor, commercial education service provider, and an education institution such as one or more schools, or ministry. Examples of these include SchoolNet organizations in several countries which install internet in schools and science fairs and mathematics Olympiads, organized by science and mathematics teacher associations, both with the support from local industry.

*SchoolNet Namibia* - One particular interesting development is the SchoolNet movement, especially the SchoolNet Namibia, a not-for-profit company which provides hardware, software, and internet connectivity to schools at affordable rates (see textbox 4). Figure 2 indicates that mass provision of personal computers is unaffordable without radical cost-cutting interventions. Schoolnet Namibia aims to reach a target of US \$ 100 per school through the use of sustainable support from local industries and through a series of cost-cutting measures. These include the use of volunteers for installation and maintenance (carried out partly remotely), the use of refurbished computers,

Textbox 4. *Promising Practice – SchoolNet Namibia: affordable ICT infrastructure for schools in Namibia.*

SchoolNet Namibia is a not-for-profit company managed by a board of directors that includes the Ministry of Education and Namibia Telecom. It is a major player in the process of promoting ICT in schools. It has negotiated sustainable tripartite arrangements with local donors on the one hand and the Ministry of Education and schools on the other. It provides hardware and software to schools. It also provides affordable (i.e., matched to ability to pay) permanent internet connectivity, web and mail services to the education sector through a virtual private network leased from Telecom at a special educational rate. It organises web-based competitions for school students and is negotiating with external providers to mirror relevant educational sites. Currently about 250 schools are connected, representing 20% of the total, a figure somewhat lower than its target.

SchoolNet Namibia is a volunteer organisation; it provides on-the-job training to out-of-work youth, and volunteers rotate around its various activities—refurbishing, web maintenance, LAN maintenance, school support etc. Seventy percent of volunteers subsequently get employment or enter Polytechnic programmes with exemptions for certain modules. Over 1200 volunteers have been trained over the last 3 years. This element of its brief has become a major feature of its operations; it offers a significant free service both to out-of-school youth on the one hand and to the Polytechnic on the other.

(See promising practices: SchoolNet Namibia in Annex 2 for further details).

coupled with the use of Open Sources software which does not require licensing fees.

*Other examples* of cost sharing include:

- Secondary education in Tanzania, where around half of secondary education is managed by non-government institutions and private companies.
- Religious foundations that manage state aided schools
- *International donors* – these provide in particular capital items, usually leaving the running costs to the local partner. This usually creates sustainability problems as soon as the international donor pulls out.

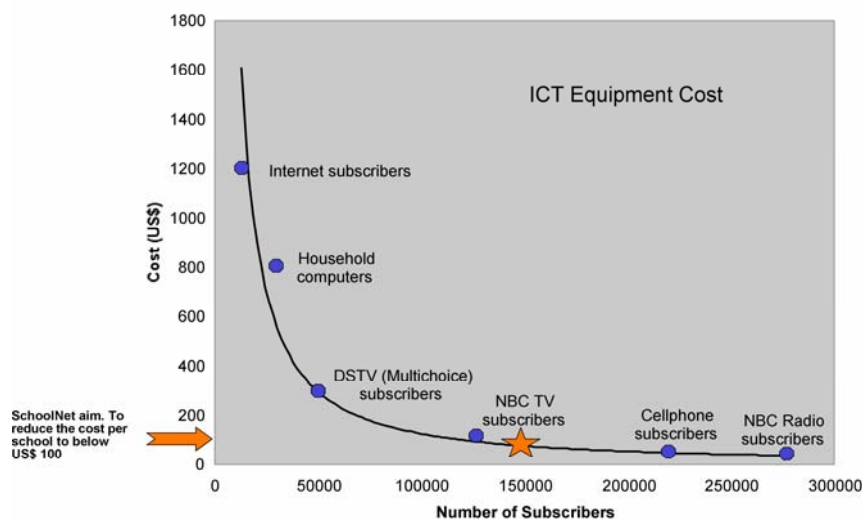


Figure 2. ICT equipment costs

### 3.6 Concluding remarks: the way forward

The previous sections have revealed several important insights regarding school context and Instructional Resources in SMICT education. Based on these insights the following pointers for future policies on SMICT education can be summarized.

1. *Class size* - There is a need to examine class size in relation to teaching loads, to optimize the efficiency of teacher input, both in junior secondary level (often very large classes) and senior secondary level (often very small classes). This is particularly important for practical subjects such as SMICT. It will be useful in this respect that teachers are able to teach at least two SMICT subjects.
2. *Instructional time* - The indications are that time on task is limited and that much time is lost at the beginning and at the end of lessons. In addition, many lessons are not taught for all sorts of reasons, because of teacher illness, teachers attending funerals and in-service education activities. Some data are available, but there is a need to investigate this further.
3. *Textbooks* – As part of the curriculum reform process there is a need:
  - to stimulate the production of quality local textbooks and teacher support materials, and to provide opportunities and support for teachers and other educators in developing these

materials. Reference is made to the involvement of science teacher associations (Ghana and Nigeria) in the production of textbooks.

- for both in-service and pre-service programs to pay attention to effective use of textbooks in the classroom.
4. *Provision of SMICT resources* - Considerable differences in cost exist between the various science options, requiring a re-assessment of the physical resources needed to promote 'good' science. The use of simple equipment in kits (in junior secondary classes) and micro-science kits (in senior secondary) are promising examples used in many countries.
  5. *Optimizing resources* - The use of teaching and learning resources, and in particular, equipment for practical work and ICT needs to be optimized through:
    - the use of Science Resource Centers (e.g. Ghana) and special science schools (Senegal, South Africa, and Nigeria), both at junior and senior secondary level.
    - longer opening hours of schools and community-school cooperation in providing access to ICT to the community. These are ways to optimize the ICT resources of schools.
    - extensive programs of teacher support (both in-service and pre-service) in the effective use of ICT and of equipment in practical science.
  7. *Funding of SMICT resources* – Funding possibilities other than government funding need to be explored. School funds, industry funds, tripartite arrangements between a private sponsor, commercial education service provider and an education institution (such as one or more schools, or ministry), cost sharing (e.g. religious foundations managing state aided schools and company schools built and partly run by large industries) are all examples of promising public private partnerships. A promising example in this respect is SchoolNet Namibia, which provides ICT infrastructure to schools without any financial contribution from the Ministry of Education, but through a sustainable arrangement with local industries.

## 4 SMICT Teachers, Teacher Education and Teacher Support

In the preceding chapters, several needs and challenges for science education improvement in SMICT countries have been identified, particularly:

- a more focused science education for different student target groups,
- narrowing the gap between curriculum intentions and actual practice,
- better actual use of instructional resources, both existing and newly supplied.

The teacher is one of the key factors in addressing these needs and challenges. Most educational investments fail if the teacher factor is not included. For example, schemes to distribute new and better textbooks fail when teachers keep dictating as if there were no books (Montagnes, 2000, 2002). Curriculum changes, promotion of different teaching methods, and other educational reforms fail if they are introduced without a very substantial teacher education component. In the words of Hargreaves (1992):

*We have come to realize in recent years that the teacher is the ultimate key to educational change and school improvement. The restructuring of schools, the composition of national and provincial curricula, the development of benchmark assessments – all these things are of little value if they do not take the teacher into account. Teachers don't merely deliver the curriculum. They develop, define it and reinterpret it too. It is what teachers believe and what teachers do at the level of the classroom that ultimately shapes the kind of learning that young people get. Growing appreciation of this fact is placing working with teachers and understanding teaching at the top of our research and improvement agendas.*

In low-income countries this is just as true as it is in high-income countries. In all country profiles the poor quality of teaching and teachers is considered one of the principal causes for poor student achievement in SMICT subjects. Teacher education and support for teachers in improving and in innovating their teaching are therefore of paramount importance in addressing the challenges of science education improvement. Teachers, teacher education, and teacher support will be addressed in this chapter.

In looking at the teacher's role and the ability of teachers to cope with the needs and challenges for improving practice, three main aspects need to be taken into account:

- a) Teacher understanding of the content that needs to be learned by students ('subject content knowledge');
- b) Teacher understanding of how students can learn the content and their ability to translate this understanding into an appropriate plan for teaching particular topics, knowledge, and skills to students ('pedagogical content knowledge');
- c) Teacher ability to perform adequately in the classroom and learn from their experiences in teaching ('practical knowledge').

The overall issue addressed in this chapter is whether existing teachers and teacher education and support systems are able to cope with the needs and challenges in improving SMICT education, with a focus on the three main aspects mentioned above. More specifically, four main themes are addressed:

- Teachers in SMICT subjects (section 4.1)
- Preparation of teachers for teaching SMICT subjects (section 4.2)

- Opportunities for teachers to further their qualifications towards higher levels of competence during their career (section 4.3)
- Teacher support for learning (section 4.4)
- Section 4.5 and 4.6 will discuss the above mentioned themes and offer suggestions for the way forward

## 4.1 SMICT Teachers

### *Subject content knowledge*

From the data in country profiles it might appear that teachers for SMICT are largely qualified. While this may be true in a formal sense, it does not guarantee that teachers do in fact have adequate content mastery of the SMICT subjects they are teaching. Dissatisfaction with the actual SMICT subject matter understanding of teachers is widespread, and official statistics may paint a much more optimistic picture on qualifications than the situation on the ground shows. There can be many underlying reasons for this, and the situation requires careful analysis at the country level to clarify causes. There is a lack of detailed information to make a solid evaluation on teacher qualifications and at what institutions and when they were acquired. Prominent factors are as follows:

- Official statistics often do not distinguish well between being qualified as a teacher and being qualified in the subject that is being taught. For example, in South Africa, although 85 % of mathematics teachers are said to be qualified, only 50% had specialized in mathematics as a subject.
- Criteria for content mastery may be inadequately or inappropriately defined. For example, EMIS statistics in Namibia suggested that most science and mathematics teachers were qualified. However, a baseline study on science and mathematics teacher qualifications (INSTANT, 1996) concluded that two thirds of those teaching SMICT were unqualified—if the content criterion was that the teacher needed to have three years more content exposure than the year he or she was teaching, in addition to a teaching qualification (i.e., a grade 9 teacher needs to have content covered up to grade 12, etc.).
- Due to teacher shortages in some subjects, considerable out-of-subject teaching may take place by qualified teachers, or teachers may teach their subject beyond the level that they are qualified for. For example, anecdotal evidence indicates that any teacher might at some point be asked by the school principal to teach science or mathematics. In the words of a subject advisor in Namibia: *‘the main qualification to teach mathematics is if you haven’t taught it for 5 years, it’s your turn.’*
- The teacher qualification structure (and teacher education program structure) is sometimes not aligned to the structure of the secondary curriculum. This plays a particular role in situations where senior secondary education and teacher education is highly specialized (like in systems with A-level senior secondary education) and teachers only become qualified in one or two science subjects. However, if junior secondary education has a more general function with integrated subjects—or is changing towards such a new function—changing teacher qualification structures and programs does not automatically follow. If schools are large,

different teachers may teach parts of the integrated subject, thereby defeating the purpose of integration. This is a problem in all countries where subjects like general science or integrated science are taught. If schools are small—as they often are in expanding systems where junior secondary education is opened up as extension of the basic education cycle—out-of-subject teaching is almost inevitable, and/or underutilization of teachers may result.

- The content that is learned in pre-service preparation programs may not be adequate as preparation for teaching. This will be treated in the next section on teacher education programs.

The problem of teachers' inadequate mastery of subject-area content is likely to contribute to the often very poor examination results, in particular in mathematics, as is found in a number of country reports, notably in Namibia and South Africa.

### *Pedagogical content knowledge*

Inadequate content knowledge of science and mathematics teachers also puts limitations on the successful implementation of new curricula with intended new content and teaching methodology. It results in a lack of teacher confidence reported as one of the factors hindering the change to a more learner-centered SMICT curriculum. More 'open' forms of teaching also mean less predictability of events in the classroom like, for example, questions raised by students. Explicit in several reports, and implicit in most, was the view that one of the main reasons practical work tended to be rare and ineffective was that teachers did not have sufficient self confidence, either to demonstrate concepts in front of the class or to supervise class practicals. In both cases, they did not have sufficient confidence in their ability to deal with matters if something went wrong, and in the second case, there was an additional underlying worry related to maintaining classroom control.

Science and mathematics have always been considered difficult subjects. Many science and mathematics concepts are counter-intuitive and therefore difficult to learn; in fact, often students do not succeed and are then stuck with misconceptions. Teachers need to be aware of where and when students are prone to make mistakes. They need to be able to diagnose misconceptions and have an extensive repertoire of remedial techniques, which need to be very specific for the concepts and subject (so-called *pedagogical content knowledge*, Shulman, 1987). Over the past 25 years there has been a flood of research on the typical difficulties of students with science and math concepts. As concepts become tools to interpret new information, misconceptions also negatively affect the learning of other concepts later on. Thijs and Berg (1996) have shown that the hard-core misconceptions in Physics are universal with respect to countries, language background, and history. The misconception studies have not led to universal recipes for avoiding or curing misconceptions. However, they have shown that teaching methods have to be highly subject specific and that teachers need a strong subject matter background and much additional pedagogical knowledge about typical student errors and misconceptions.

Little direct information is available about the pedagogical content knowledge and related behavior of SMICT teachers, but small-scale published research and anecdotal evidence generally suggests a very teacher-centered methodology, and that much drill-and-practice teaching of algorithms and verbal knowledge is taking place. Such teaching styles, coupled with lack of awareness and knowledge as to how to address students' conceptual errors, leads to superficial learning based on recall and not on comprehension. As science and mathematics learning and the curriculum are spiral in the sense that at higher educational levels content is treated at higher

levels of formalization and abstraction, SMICT education is built on shaky foundations and students experience problems in applying their knowledge in practical contexts. Paradigmatic in this sense are well-known examples of university students who still have major problems with basic mathematical operations like fractions and decimal points, although they may have—more or less successfully—gone further with much more advanced topics.

### *Practical knowledge*

Much of the knowledge for effective teaching—including issues of student understanding of concepts—can be, and often is, learned through experience on the job. However, this requires the attitude and ability to learn ('reflective practitioner'), a commitment to the profession, staying in it for a considerable time, and an environment that supports learning and trying out new ways of teaching.

Statistics on the level of experience of SMICT teachers generally show that most are relatively young and inexperienced, although there are such exceptions as Senegal where 62% of SMICT teachers in senior secondary education have more than 10 years experience, as is the case for most of the chemistry teachers in Uganda. A relatively inexperienced teaching force can be partly caused by the expansion of secondary education whereby young and newly qualified teachers are filling up new vacancies. In addition, in a number of countries the Ministry of Education has instituted an early retirement package for serving teachers. This has also kept the age and experience level of teachers on the low side. However, a major cause is the high attrition of teachers, particularly in SMICT subjects. The factors causing attrition and retention of teachers form part of another SEIA study on teacher supply and demand, so this will not be extensively treated here. However, it should be noted that the situation for SMICT teachers is often more serious than for other subjects and requires special consideration. Graduating students from SMICT-based programs, including teacher education particularly at the degree level, often have more career opportunities, making teaching frequently a profession 'of last resort' taken up while graduates are looking around for other career opportunities. In fact, although no specific study on this is as yet known, anecdotal evidence from teacher educators in various countries suggests that nowadays trained teachers at degree level often have an edge on the labor market for jobs in business and industry above graduates with a straight general science degree. This holds particularly true for jobs that require communication and other 'people skills' besides a good foundation of science knowledge. In some cases a situation appears to have arisen where trained teachers go into business and industry, while general science students end up teaching without specific preparation for it. Tracer studies of graduates of science based programs are required to inform program policies in higher education, particularly in situations where tertiary education is expanding and labor market conditions are rapidly changing.

In spite of the internationally recognized importance of teaching experience, there is little hard evidence that experienced teachers teach differently or more effectively than inexperienced ones. An overriding issue here is the influence of the school context, the pressure to conform to current practice, and the lack of support for innovative ways of teaching. This will be further treated below in discussing the role of 'practice teaching' in teacher education programs.

### *Supply and demand of SMICT teachers*

The above issues in teaching force composition directly relate to overall planning and policy in teacher supply and demand. Other important factors in teaching force composition (e.g. teacher

gender, HIV/Aids) require extensive consideration and a country-specific study of supply and demand dynamics. Lewin and Stuart (2002) note in the MUSTER study (Ghana and South Africa are included in this study) that for primary teachers planning supply and demand is largely absent or policies are deficient, and the impression is that this definitely holds for secondary teachers. Although the MUSTER study focused on teacher education for the primary education cycle, many of the issues and problems in teacher education are relevant also for teacher education for the secondary cycle, particularly where it takes place in teacher colleges. An important difference is the knowledge of subject matter, which is a more prominent key issue in secondary teacher education and also the main reason for higher complexity in terms of levels, programs, and institutional contexts in secondary teacher education.

Various countries (e.g. Ghana, Senegal) reported that there is no effort to match supply and demand in teacher education. Some of the country profiles provide clear indications about the numbers of teachers that might be needed. Burkina Faso needs, for example, 500 mathematics teachers and Ghana had a deficit of 357 elective science teachers in 2001. Some countries (e.g. Uganda, Tanzania) that are preparing new secondary education policies have started to address the issue. However, all countries report serious problems with the supply of good SMICT teachers.

Although supply and demand of SMICT teachers is difficult to address on its own without looking at the overall situation for secondary teachers, specific measures for SMICT subjects are possible and can be successful. For example, in gender composition, only a small portion of the SMICT teachers is female (8% in Senegal, one-third in Zimbabwe). In Namibia, Nigeria, and South Africa, however, there are more female than male SMICT teachers in junior secondary education, but not in senior secondary schools. SMICT subjects in many cases still radiate the aura that they are specifically suited for male students, which is perpetuated in schools by the fact that most teachers are male. However, a relatively simple change in admission criteria and a special short pre-entry preparation program for female students in sciences at the University of Dar es Salaam in Tanzania, successfully raised the percentage of female science students in a small number of years, particularly also in teacher education programs. This is an example how adaptations in teacher education can be instrumental in addressing supply and demand concerns, in spite of overriding issues in schooling culture, working conditions, and labor markets that negatively affect the teaching profession.

## **4.2 SMICT Teacher Education**

### *Levels, structures and admission policies*

In most countries of the world, teacher education for the secondary level has two distinct traditions—one originally based in the school system itself ('normal schools') and one in universities. Different original models often come together, but the origins remain visible in institutional contexts and the type and content of programs. Special teacher colleges, although mostly post-secondary nowadays (at least for the preparation of secondary teachers), have often retained definite characteristics of secondary schools.

Most countries in the SMICT study still have a dual track system with large enrolments in Certificate or Diploma courses at teacher Colleges (usually 2 or 3 year programs) and smaller enrolments in degree programs at the university level (3 or 4 year programs). However, the situation is gradually changing like in Zimbabwe where teacher colleges have started to offer

degree-level programs and in South Africa where colleges have recently merged with universities. Teacher college graduates at Certificate or Diploma level are certified for primary education and/or junior secondary education. The university trains teachers mostly at first-degree level and they are certified for teaching in senior secondary education and often for teaching at teacher colleges as well.

A main structural issue in (SMICT) teacher education is whether subject content studies take place before the study of education and pedagogy and before specific teacher preparation is embarked upon ('consecutive model'), or whether the study of content and education takes place simultaneously in programs ('concurrent model'). Both models, and some mixture between them, can be found in the countries in the study. At university level both models can be found simultaneously, either through a B.Ed or B.Sc.Ed. Degree where content and education are studied concurrently or through a subject degree (B.Sc.) followed by a postgraduate Diploma of education. The latter route is usually one year longer and therefore more expensive than the former. Some mixture of the models is possible through the streaming of students after first or second year of subject studies into different directions. At college level, the program is usually more a concurrent model, but nowadays it follows subject content studies at senior secondary level, whereas in the past teacher education was parallel to senior secondary schools ('normal schools').

The premise regarding subject content studies, and also one of the overriding issues in practice, is that a teacher needs to have studied the content he or she is teaching at a higher level of abstraction and generalization, and therefore in a spiral curricular situation, at a higher education level than his/her students. The greater breadth and depth of a teacher's subject understanding should enable him/her to handle student problems and questions with confidence. Although this principle is widely accepted internationally, there is little solid evidence as to what the required breadth and depth of subject understanding should be, nor of the specific content knowledge that teachers should have in order to teach at a particular level. In practice, therefore, mastering and passing subject content studies at some higher education level beyond what one is teaching is taken as a proxy measure for required teacher subject mastery.

A rule of thumb here is that the teacher should master the subject being taught at a level of 2 to 3 years beyond the level he or she will be teaching, but interpretation of this is obviously fraught with difficulties and rather dependent on how specialized the curriculum is, particularly at senior secondary level: A three or four year degree level study (including subject content plus educational studies) would be a requirement to teach at senior secondary level. There is an international trend to make teacher education for secondary education largely postgraduate after a full first degree in subject content, followed by either a postgraduate Diploma or a Master's degree to prepare as a teacher.

The subject content in the senior secondary curriculum (for junior secondary teachers) or in a general subject degree study (for senior secondary teachers) is taken as the paradigm for this, without much consideration of whether this provides the adequate content for teacher preparation. The way this influences teacher education will be further discussed below.

Especially for SMICT subjects, in spite of official levels and structures, teacher education is highly influenced by actual practice in student admission, and by the fact that the results and outcomes of secondary education in these subjects are often highly unsatisfactory. Although official policy for admission into teacher education is most often the passing of senior secondary

education examinations, particularly in the intended teaching subjects, the practice is often less optimal for SMICT subjects. The country reports do not provide much information with regard to admission criteria and incentives for entering SMICT teacher education, but indications are that in situations where large numbers of SMICT teachers are trained at college level (e.g. Uganda) the entry criteria are not very stringent. Also, in Namibia, teachers qualified for general entrance to teacher education with an acceptable average but with low SMICT grades, might still end up as SMICT teachers.

Generally, entrance requirements to teacher colleges are lower than those for university based SMICT Teacher education. Similarly, entrance requirements for the latter are often lower than entrance requirements for more popular and more potentially rewarding university studies. In most countries of the world, teacher education is often considered as the least attractive university level program. Consequently, teacher education programs attract the weakest students entering higher education, i.e. students who cannot be admitted to medicine, engineering, and other more attractive options. This also seems to be the case in most of the SMICT countries studied; for example, Ghana reports that teacher education is the lowest on the preference list of prospective students, and in South Africa admission requirements for teacher education are the lowest compared to other professional fields. This is in spite of the fact that teachers in South Africa are relatively well paid (Crouch & Lewin, 2000).

#### 4.2.1 Subject Content Studies

The way subject content studies are handled in either teacher colleges or universities, and the respective problems that ensue, are rather different, and therefore need separate treatment. A common issue, however, is the way the weak subject background from secondary school is addressed in either situation. Even if students have managed to successfully pass their senior secondary education examinations, their actual grasp of concepts may be deficient and their learning may have been characterized by a high emphasis on memorization.

##### *Teacher colleges*

Originally, teacher education for junior secondary education took place in special streams or schools parallel to genuine senior secondary student streams (for primary education this is still the case in some countries, particularly those with A-level senior secondary education). In those streams, further content study at senior secondary level took place concurrently with preparation for teaching. In practice, the weaker students ended up in those teacher streams and tried to acquire a qualification at par with a senior secondary student and thus still gain admission to tertiary education. In most countries, admission to secondary teacher education now takes place after students have completed senior secondary education, and teacher education programs now mostly contain only the education and teacher preparation part. In this situation, subject content studies in teacher education would be predominantly *pedagogical content* study, integrating study of the subject content together with consideration on how to teach it, maybe with some extension of secondary school knowledge towards first year university level. However, again in practice, the senior secondary school knowledge of admitted students, particularly in SMICT subjects, is often deficient, and teaching is frequently focused on remedying this, thus repeating what should already have been mastered in school and neglecting the pedagogical content element. If, as is often the case (see section 4.4.), graduated Diploma teachers can gain admission into a degree

program (maybe after some years of service as a teacher) the teacher education program may still function as a second chance route into higher education.

### *Universities*

Whereas in teacher colleges the emphasis in content studies is often predominantly on the secondary school content, in universities the secondary school knowledge, including its possible conceptual deficiencies is often neglected. In universities, the responsibility for certain types of courses is usually distributed to Faculties along disciplinary boundaries. Responsibility for teacher education programs, a typical multi-disciplinary field geared towards preparation for a specific profession, is thus often distributed over different Faculties and Departments. Content studies for SMICT teachers usually fall under the responsibility of Science Faculties, while Faculties of education are responsible for educational and professional studies. Within Science Faculties, student teachers study their foundational subject content together with students in general degree courses or other specialist programs. As students are usually selected on the basis of having good marks in science subjects in secondary school examinations, secondary school content knowledge is often taken for granted and the emphasis is on typical disciplinary content that quickly moves towards more advanced topics and formalized (and mathematized) theoretical frameworks. However, having studied more advanced material does not imply sufficient mastery of basic concepts in practice.

To some extent the need for good foundational disciplinary knowledge applies to all students, whether they are enrolled in pure sciences, Engineering, or Teacher Education. However, there are differences as well. Prospective science/maths teachers need more conceptual emphasis and a deeper qualitative understanding and less emphasis on sophisticated computation. They also need more explicit attention for secondary school concepts. This means that at least some of the science content courses should be specially designed for prospective teachers. Prospective teachers will have to restudy the subject matter they are going to teach, particularly its conceptual foundations.

Some university based programs, particularly those in Botswana, Ghana, and Uganda, appear to have strong subject matter components (cf. Prophet, 2002). Over 50% of the student course work consists of science and mathematics courses. At the University of Botswana, for some teacher education streams, content studies are under the responsibility of the Faculty of Education, thus allowing for specially selected content. At the University of Dar es Salaam in Tanzania specially designed content courses for student teachers were developed between the Faculty of Science and science educators from the Faculty of Education as well as some educators from the Netherlands.

### *Bridging school and universities*

In the 1980s, several universities in the southern African region developed with the assistance of Dutch co-operation projects remedial and bridging programs in between secondary school and university to improve the quantity and quality of student intake in science based programs (Cantrell et al., 1992). As universities tend to stick to stringent entry criteria for science based studies, and the secondary school output in science subjects is often inadequate, universities looked for ways to increase student enrolment in science-based studies. In recent years, similar strategies have been employed in South Africa where universities face the same problem, particularly in raising the number and percentage of students from disadvantaged sectors of the population. Although extensive research on the effectiveness and efficiency of these strategies is lacking, the following tentative observations can be made:

- Specially designed and intensive full-time programs for one semester or a full year can be quite successful in remedying conceptual difficulties and instilling a different learning attitude and behavior in students. Also, students with rather deficient school knowledge and low passing grades can become successful university science students, although students have to be specially selected for such programs on the basis of aptitude and interest in science based studies. However, such specially-designed and carefully- implemented programs are rather costly.
- As such programs leave main stream education in either senior secondary school or university programs untouched, they are difficult to institutionalize and can only work well for a limited period to boost the numbers of students in science-based programs. However, discontinuities between secondary school education and higher education in SMICT subjects should be simultaneously targeted in a structural manner in either of the two, or both. For an alternative resource-concentration strategy, special science schools that get extra resources, good teachers, and specially selected students, Caillods et al (2000) reach similar conclusions. Special science schools are costly, and if they do not follow a special program, are also rather ineffective. If they are treated separately and follow a special curriculum, they are difficult to institutionalize as they get an elite status, which conflicts with other main policy intentions in educational provision.

#### 4.2.2 Pedagogical and Educational Studies

*“Science/math teachers teach the way they were taught science/math when they were students.*

*They do not teach the way they were told to teach in teaching methods courses!”*

*A teacher educator to his student teachers:*

*“Please note – and you better write this down, because it is important in your examination –*

*In the modern conception of education, so-called student-centered education, we do not lecture anymore to students, but students have to find out things for themselves’*

The above two statements capture key aspects of the theory-practice gap in teacher education. The effectiveness of teacher education in promoting a more student-centered education in schools is often in doubt, particularly for teacher education that is based in universities.

##### *Teacher colleges*

Whereas teacher education at universities is often plagued by a lack of identity, low status, and distribution of responsibility over different faculties, teacher education at colleges could in principle have a clearer profile and identity, as teacher education is their chief function. However, teacher colleges reportedly suffer from isolation and neglect, are often under-resourced, and quality control is problematic (Lewin & Stuart, 2002). These problems occur even more where there are many colleges, as for example, in Ghana with 41 colleges, 17 of which offer science and mathematics specialization. Efforts in Ghana to change subject teaching methodology in teacher colleges report major difficulties that echo much reported change factors in the school system (overloaded curriculum, excessive student-tutor ratios exacerbated by insufficient tutors per subject, over-enrolment, high staff turnover, and lack of classroom facilities, combined with pressure to cover the syllabus and prepare for examinations). Teacher colleges tend to copy the

type of practice found in secondary schools, particularly if college tutors are primarily trained as secondary teachers and have not undergone a specific preparation or further development as a teacher educator, which is often the case. As observed in Ghana: “...*although some training colleges had a good supply of teaching and learning materials, many teachers were not using them. Instead they preferred to lecture and dictate notes*”.

To what extent the Ghana college problem applies to other countries can not be deduced from the country profiles, but the MUSTER studies on teacher colleges, with an emphasis on primary teacher education, also confirm the rather bleak picture of the quality of those institutions, notwithstanding the fact that there will be exceptions to this general statement. South Africa recently dismantled teacher colleges due to lack of quality. All teacher education programs in South Africa are now organized and supervised by universities.

On the other hand, graduates of teacher colleges may be more likely to stay in rural or remote provinces than graduates of Universities who studied in the city; study at colleges is usually cheaper than at universities. A closer alignment and co-operation between teacher colleges and universities in teacher education is an important improvement strategy that will also be considered below.

### *Universities*

Traditionally, university studies are removed from direct practical concerns and directed towards theory in the disciplines and learning the foundations of disciplinary knowledge. As for subject content studies, this was already treated in the previous paragraph, but the teaching methodology used in Faculties of Science further influences the pedagogical formation of future teachers in, for example, the type of practical work they will do. The typical practical work of B.Sc. programs tends to be closed recipe-following exercises on key experiments in the discipline rather than open-ended investigations that would promote student independent reasoning skills. Student views on what science is, and how to learn it, therefore tend to be steered toward ‘high science’ in typical laboratory environments with sophisticated equipment. Often absent is a view of science that entails building on more generic human reasoning and problem-solving skills formalized in scientific communities and taken to greater heights. Students’ decontextualised and abstract view of science, already developed in their school history, is thus not corrected much in university based studies.

The academic nature of university studies is also present in many education faculties, education in university settings is usually conceptualized as a branch of the social sciences, and many teacher education programs are traditionally built from introductory courses in so-called educational foundations (e.g. history, sociology, psychology, philosophy of education), followed by more applied courses (e.g. curriculum development, educational methods, educational assessment, education management). It is not unusual that method programs tend to reflect, in their delivery, the prevailing university didactical culture of lecture presentations rather than the learner-centered ideal that the programs are ostensibly trying to promote following modern conceptions of teaching and learning. It is thus not surprising that when student teachers enter schools they tend to teach in the only manner they have experienced. In country profile descriptions, a reform of both these aspects of teacher education was seen as urgently necessary. The typical university educational philosophy of separating the academic formation and the development of specific professional skills is changing in many expanding higher education systems in the direction of curricula that are designed on the basis of competency profiles (output-orientation). Teacher

education is a high-priority professional field that all too often is neglected in universities. Teacher education programs tend to be a collection of individual courses that are ‘thrown together’ without a clear curriculum conception or thought-out structure and content.

Two further aspects of pedagogical studies in teacher education programs require additional mention. First, it was argued above that teaching methodology in SMICT subjects requires close integration with specific SMICT content, as many student difficulties are very content specific, and teachers need to learn the *pedagogy of subject matter* (Shulman, 1987). The extent to which this occurs is rather varied—in some cases most education courses are generic for all subjects, whereas in other cases the methods courses are strongly differentiated according to subject. For example, in Botswana and Ghana, on top of an already strong subject component (see above), there are substantial content pedagogy courses as well. However, most colleges and universities may not have the knowledge and expertise to offer practical courses in subject specific pedagogy. This is related to staffing policies. University lecturers are often recruited in their student days on the basis of their intellectual potential for academic work. However, for roles in teacher preparation, solid experience as a teacher would be an important advantage (in this case with a SMICT background plus a background in educational studies). Teacher educators are often in between cultures: if they are academics they have usually little regard for practice in the schools, if they are practitioners they usually have a low standing in the academic environment. Few teacher educators manage to bridge these cultural gaps.

A second important aspect, also related to the theory-practice gap, concerns the ideals of student-centered education as they are portrayed in teacher education programs. Ideals of teaching are often presented as if they would (or could) be found in the average classroom in most weekly lessons, while in practice such images usually stem from research literature under optimal conditions in specially designed lesson sequences. ‘Open’ forms of teaching are often highly complex and require a considerable amount of teacher skill (and learning). Furthermore, they require mastery of the basics of teaching and classroom control first, before more complex forms can be added and tried out. In reference to the second citation that opened this section, one may state that there are very few teachers in the world who no longer lecture to students. There are more, however, who besides traditional lecturing formats employ other more complex methods and who bring variation to their teaching in line with different types of objectives pursued, practical conditions, and characteristics of their students. In teacher preparation courses, student teachers should be confronted with more challenging forms of teaching and experiment with them, but should also learn the basics of classroom teaching. If one considers the restricted didactic modes found in many schools and classrooms, an emphasis on effective teacher-centered teaching (in contrast with ineffective rote learning strategies) is an important requirement for teacher education programs, especially considering the fact that many school contexts are not conducive to highly complex and resource intensive teaching methodologies. A key component of teacher education should be a close alignment with practical contexts and actual application in classrooms, which will be treated below.

### **4.2.3 Teaching Practice**

It is necessary to bridge the theory-practice gap in teacher education particularly in an embedded practice period in schools and classrooms during the pre-service preparation program. In fact, a general international trend is to make teacher preparation increasingly school-based. The Ghana case study on the new In-In-Out structure (see textbox 5) of teacher education, with an extended practice period in the schools, reflects this trend. However, in order to be effective, this requires a close integration of course-based and institution-based program components with the practice lessons, and intensive supervisory arrangements through cooperation between school-based tutors and teacher educators. At present, it is questionable whether schools form an appropriate training environment for new teachers, as new teachers will all too easily conform to the existing ineffective teaching practices found in schools (Lewin & Stuart, 2002).

Country profiles provide some information on the duration of Teaching Practice but little or nothing is known about the nature and quality of supervision. The Ghana study of the In-In-Out program reports the difficulties surrounding effective supervision and the training of school based mentors. Our own experience is that even in teacher education programs with intensive and up-to-date teaching methods, courses, and model-taught SMICT courses, student teachers tend to fall back into the worst secondary school practices they experienced as a student and in their practice school. Teaching Practice is the most important course but also the most expensive in terms of required manpower for supervision. Many curricular, professional, budgetary, and logistical problems exist in the organization of school practice in teacher education programs. For universities, some common limiting factors and experienced difficulties are:

- The difficulty of blocking off periods in the university calendar during term-time so that teaching practice ends up having to take place in holiday periods;
- The lack of a sufficient number of schools in the neighborhood of the institution, so that student teachers and university supervisors have to travel long distances, often to the home areas of students;
- The high status difference between university lecturers and schoolteachers, and the lack of trust and rapport between them.
- The lack of feedback from teaching practice experiences into university based methods courses, also because teaching practice supervision is infrequent and not subject-specific.
- A lack of distinction between different potential purposes and phases in the teaching practice experience, particularly between 'learning from practice and reflection' and 'assessment of competence'.

*Textbox 5. Promising Practice – The In-In-Out system of teacher education in Ghana*

Following the observation that earlier attempts to improve SMICT teacher education resulted in trainees 'being crippled into inaction', the In-In-Out programme at the Teacher Education Colleges is creating the right conditions to place learning in a practical context, thus providing opportunities for teachers to adopt effective instructional approaches.

In the In-In-Out programme, trainees spend two terms in the Out segment, working closely with teachers to develop their practice and understanding of teaching. Tutors are linked to trainees to discuss experiences and help shape their 'own' theories of learning. During the Out period mentoring and supervision takes place by the colleges.

Monitoring of the Out component provides a mixed picture. The programme provides teachers to schools especially in rural areas. It motivates students and reduces dropout. Each trainee is assigned a mentor. These are themselves inexperienced, and the short in-service training provided does not make them effective classroom mentors.

*(See promising practice: The In-In-Out system of teacher education in Ghana in Annex 2 for further details).*

It is unusual to find specific training programs for school-based mentors for practice teaching, such that expectations and professional opinions between schools and training institutions are aligned, although there are some exceptions.

In principle, the arrangements in teacher colleges for teaching practice are often easier to make (colleges are more often spread around the country; their curriculum is specifically designed for teacher education only; they often have more contact with schools, and there is less professional distance between college lecturers and teachers), but financial and logistical difficulties often abound. Furthermore, Lewin and Stuart (2002) note that a coherent and common vision and program concept is often lacking in teacher colleges, also with respect to the role of 'practice teaching' in programs.

A better organization of in-school teacher education and supervised practice is a high priority area for improvement of teacher preparation. This, however, requires cooperation between schools and teacher institutions (colleges, universities), in possible conjunction with other decentralized structures and staff (e.g. resource centers, school inspectors, or regional advisory staff). Such cooperative arrangements will be more necessary if teacher education changes towards different models, including less emphasis on front-loaded training and more emphasis on learning during the teaching career (see below). An integration of teacher education strategies and school improvement strategies is then necessary to make schools a proper place for teacher learning.

#### **4.2.4 Computer Science in Teacher Education**

The status of ICT in teacher education concerns three main aspects: the extent to which future teachers become ICT literate during their training, the way teacher education programs produce teachers for teaching ICT as a subject in secondary education, and the extent to which ICT is used as a potential tool in the teaching of other curriculum subjects.

##### *ICT literacy*

Teacher students are generally prepared in the use of ICT like secondary school students, by learning basic computer skills and some principles of computer operation. This, however, is probably more common and intensive in university settings. Like the schools, many teacher education colleges suffer from the lack of sufficient equipment, which sets limits to practical experience. A good framework for ICT literacy is the International Computer Driving License that can also be used for in-service training of teachers, as takes place in the South African SCOPE project (See annex 1, table 6.6).

##### *Computer science as teaching subject*

In Namibia, computer science can only be taken by student teachers in mathematics. In Botswana, computer science is a minor course for students who major in any regular subject. The course has content and professional studies components. The professional studies element covers teaching and learning theories, classroom management, assessment and record keeping, as well as study of the whole junior Certificate (basic education) syllabus with special emphasis on the role that computer aided learning can play. The content component equips teachers with the necessary skills to use a computer, manage hardware and software, and acquire the knowledge to understand the past, present, and future developments associated with IT and its applications.

### *ICT as tool in subject teaching*

In Ghana and the University of Pretoria, South Africa, similar courses are available for all students who prepare as mathematics or science teachers. In these cases, part of the ICT programs also focus on application of ICT in the major subjects. The extent to which ICT is being used in teacher education to learn science and mathematics content can not be deduced from the available information. The overall impression is that the systematic use of ICT for teaching and learning purposes is still low in higher education institutions, with the exception of computer studies and informatics as higher education subject areas.

In spite of all the training, the unavailability of qualified ICT teachers remains a central issue. As a short-term measure in Botswana, formal training in computing is a key requirement for ICT teachers while a teaching qualification is an *added advantage*.

A threat to all ICT education is that many future teachers, once trained, leave the field of education because of better remuneration in ICT related fields outside education. The aforementioned phenomenon that trained teachers are particularly interesting for business and industry because of their foundation in both science and social skills, could be particularly strong in ICT related professions.

#### **4.2.5 Balance and integration in Teacher Education programs**

Emphasis has been placed in the previous sections on three main components in teacher education programs, namely subject content studies, education and pedagogic studies, and supervised practice teaching. In modern conceptions of teacher education, all three are considered as indispensable components of effective programs, but their relative weight and importance, and their interrelationship is subject to many debates between different interest groups and schools of thought. Particularly in universities, teacher education is often a battlefield, as vested interests in certain program components are situated in different Faculties and Departments. Program change then becomes very difficult and highly politicized. Suffice it to say that a well-balanced and integrated program is required to prepare teachers for a difficult profession in difficult circumstances. Programs need to be scrutinized with respect to their actual effectiveness in preparing for competent teaching after graduation. A high-level policy commitment in governments and higher education institutions is required to break through ineffective policies and practices, as they are often visible in many circumstances.

#### **4.3 Teacher upgrading, teacher career progression and alternative Teacher Education policies**

In all countries in the study there are in-service programs for secondary SMICT teachers. A summary of what country reports indicate on in-service education is included in annex 1, table 5.2. Botswana has quite an array of different professional development activities available for serving teachers, both at junior and senior secondary, including SMICT teachers. From the summary of the development programs in the table one can see that there are basically two types of in-service education activities, the formal ones which lead to a certificate, diploma, or degree, and the less formal continuing in-service education, in the form of workshops, cluster meetings, and the occasional school visit. The second type is treated in the next section as part of teacher support.

### *Teacher upgrading*

In most countries, college graduates can upgrade their qualifications through university degree programs. Some countries (Botswana, Uganda) even offer in-service versions of their university degree programs. Other examples of this include the MASTEP program at the University of Namibia in which junior secondary trained teachers upgrade their qualifications to teach at senior secondary (IGCSE) level. In Uganda, untrained teachers can upgrade in formal courses to diploma and degree level.

Two main arguments are at the root of the widespread phenomenon of upgrading routes for teacher qualifications. The first is that often an insufficient number of teachers are produced at degree level to satisfy the need for degree-level senior secondary teachers; this is due to the general shortage of qualified science-based higher manpower. In practice, therefore, many college graduates teach beyond the level they are trained for, and upgrading their knowledge and skills is an important way to improve teaching quality at the secondary level. Similarly, schools may hire high school graduates (often with low qualifications) if an insufficient number of college graduates is present. Providing those unqualified teachers with an opportunity for formal teacher education is possibly a cost-effective way to produce teachers. A second reason is that the opportunity for further study during the career with consequent higher qualifications and rewards is an important means to make the teaching profession more attractive, might attract better qualified individuals to begin with, and might induce teachers to stay in the profession, particularly if this study is subsidized by the employer.

The policy and practice of teacher upgrading requires scrutiny, particularly if systems have been in place for a long time. Experience in various countries shows potentially undesirable side effects, and market conditions for choosing a teaching career may change, making certain engrained policies potentially counterproductive. The following are reported phenomena:

- As in teacher colleges the academic level often does not go much beyond senior secondary education, and in universities, mastery of academic content is usually the main selection criterion. Further study after a college diploma to a university degree often requires the full length of a degree study, or only a minimal reduction of study time is granted. This adds the cost of a Teacher Diploma to the cost of producing a degree level teacher, rather than optimizing training costs by providing further training to already committed teachers. Special programs to increase the number of science degree students after high school, although also expensive, might then be more cost-effective.
- As students in teacher colleges originally did not have sufficient high school qualifications to enter university, the teacher college Diploma can become an alternative route to gaining university admission. Enrolment and teaching in colleges may become dominated by this possibility and may aim primarily at fulfilling the university admission criteria, rather than at providing a good preparation for teaching (see also above).
- For Diploma level teachers who satisfy the formal criteria (usually a certain level of pass at the College and some further years of actual teaching experience) entry to university may come to be considered as an automatic right, irrespective of actual performance as a teacher or commitment to the profession. If for degree level teachers other popular job opportunities are present, teacher upgrading may become a (subsidized) route out of the profession, rather than a route for professional enhancement.

- Providing unqualified teachers (high school graduates hired as teachers) with a teacher education program may attract teachers who originally did not meet the admission criteria to enter a teacher education program, thereby potentially lowering the standards of teaching in the longer run.

Careful consideration is required of respective entry criteria for colleges and universities, of the teacher education curriculum at colleges and universities, and their potential alignment, and of the supply and demand dynamics of teachers at the diploma and degree level. Especially if higher education systems are expanding and labor markets become less favorable for science-based graduates, upgrading routes may not be very effective or efficient. If no reduction of study time is possible during the degree, because the difference in level between diploma and degree is too big academically, it is a highly expensive strategy and special measures to increase the enrolment in degree level teacher education streams are likely to be more cost-effective.

As a means of career progression, higher qualifications remain an important incentive for teachers, but programs can also concentrate on improving the competence of teachers in the subjects and at the education level they are already qualified for. The Advanced Certificate of Education (ACE) offered by several universities in South Africa is an example of a program that upgrades the qualifications of teachers in a formal way from diploma level to a level equivalent to a first degree. It usually provides the teachers with an extra salary notch after they have received the new qualification. However, in the South African situation this possibility for career advancement through higher qualifications does not necessarily mean qualification to teach at a higher education level. Teachers can also do an ACE for the primary or junior secondary level, and these programs usually have a study load of approximately one-year of full-time study. They form part of an overall National Qualifications Framework in which different levels are defined for all professions and qualifications.

#### *Further career progression*

Other programs for further development towards leadership functions also exist in various countries. In Ghana teachers are provided the opportunity to enroll in Master's Programs after a number of years of teaching in secondary schools. This seems to be a huge incentive for teachers to go into the profession in the first place. Through residential courses during holiday periods at the University of Cape Coast, teachers enroll in the Master's program for Educational Management. A similar program exists at the University of Dar es Salaam for teachers who want to be in positions of educational leadership. These programs are providing teachers with the opportunity to move on in their careers and become the headmasters of schools, subject advisors, and trainers, curriculum developers, and so on. Another interesting program is the Diploma program for INSET, offered as a Postgraduate diploma program at the University of Zimbabwe. The program is part of the SEITT program, and it trains teachers to become INSET facilitators at Teacher Centers around the country. In post-independence South Africa (1994), the number of teachers enrolled in Master's programs expanded tremendously (Laugksch, 2003).

Most of these programs are offered in a distance education mode intertwined with residential courses during school holidays so that students maintain their teaching positions at school. The M.Ed. program in Dar es Salaam is currently a full-time program, but in the future it might also be offered as a distance education option. Very often, teachers pay for (part of) the course themselves.

Offering scholarships and the incentive of paid (or subsidized) further studies such as in Ghana might attract better students to the teaching profession in the first place, but a drawback may be that it potentially promotes good teachers out of the classroom or even out of science and mathematics education. From the outset, most Master's programs are focused either on educational management and administration (in preparation for management functions in schools or educational bureaucracies) or on research. Few programs exist that focus on education in subjects and on development of teaching and teachers. This can be considered a priority area. The programs in Zimbabwe and Tanzania are examples in this regard, as are some programs in South Africa that focus on education in the subjects.

#### *Alternative policies*

Lewin and Stuart (2002) speculate on alternative models of teacher education that invest less heavily in up front pre-service teacher education, but spread the investment over a career path by having a shorter pre-service and more on-the-job training in schools and in-service. The latter model could embed new teachers more firmly into the educational system while on the other hand it could make teacher education less attractive to good students. Various mixes of pre-training in-school experience, full-time training periods, supervised induction in schools after training, and further in-service development would be possible. Important considerations in moving to a different model are as follows:

- a) Teaching is learned in the classroom; courses on "how to teach" are only successful if directly linked to concurrent classroom practice. Experiences in the classroom before and after training may be as important as the training itself.
- b) Training in the school environment has the extra advantage of socialization in the profession. In some countries many teaching graduates do not enter the teaching profession or leave rather quickly. Concentrating training funds on those teachers in and committed to the profession is more cost-effective.
- c) Further training during the career could potentially make use of distance education technologies that may further enhance cost-effectiveness.

The MUSTER studies of Lewin and Stuart concerned teacher education for primary education. For junior and senior secondary SMICT teacher education there are some other considerations. First is that SMICT subjects themselves should be offered to teachers in a residential setting either in regular study at the university or a college, or even more expensively, in in-service programs. The many misconceptions of secondary school graduates and untrained teachers cannot easily be corrected through distance education. This is necessarily a front-loaded activity, as teachers should know their subject before anything else. Second, models which invest more in professional development and less in traditional pre-service teacher education require complex coordination between Colleges/Universities, schools, and government bureaucracies. A critical condition for effectiveness will be in-school supervision and quality control. Thus far, experiences with in-school improvement of teaching cast doubt on the possibility of easily effecting standards of teaching in schools (see also below). Finally, experience with many untrained SMICT teachers has shown that both pre-service and in-service require *selection* of students or teachers who are most likely to make progress in SMICT subjects. The possibility of selecting on the basis of aptitude and ability in SMICT subjects is sensitive to overall labor market conditions for SMICT graduates.

In general, it can be stated that the possibility for alternative policies needs to be evaluated in the context of overall supply and demand issues. Critical factors to consider are the expected growth in the secondary system and the need for teachers, the overall size of higher education systems with respect to labor market demand for graduates, and the main limiting factors in increasing the percentage of students taking science-based studies in higher education. In some countries a general oversupply of graduates (but maybe not in science subjects) is already present or not far off. If such a situation is reached, as is the case in a number of southern African countries, upgrading the quality of teachers and teacher education becomes easier. For example, selecting students for teacher education at a later stage (for example, after completing a few years of straight science study) then becomes an attractive option and may give teacher education a clearer professional identity. As mentioned above, in South Africa teacher colleges have been closed and merged with universities, and in Zimbabwe a number of colleges have been upgraded to university status and are now offering degrees. These countries follow the general international (but long-term) trend towards an all-graduate teaching profession.

A long-term vision for teacher education, and the long-term nature of the effects of policy decisions, is an important policy issue in its own right (Eraut, 2000). As teachers can stay in the profession for 30 or more years (although many will not) recruitment and training decisions can have long term effects. So-called ‘crash programs’ for teacher education— often employed when rapid expansion is taking place—can put severe limitations on quality-improvement efforts later on, as teachers have been recruited who can be virtually untrainable at a later stage. For example, Tanzania is still feeling the effects of the Universal Primary education policies of the 1970s and 1980s, when teachers were recruited who had themselves only just completed primary education (and probably not very well as they would have otherwise entered secondary education). Special and alternative programs have been established in many instances in African countries, particularly through donor funding targeted at specific problems or institutions. An uncoordinated and often inconsistent system of programs and qualification levels has sometimes resulted. In South Africa, as part of an overall national system of qualification levels and quality assurance, a new system of norms and standards in teacher education has been established in recent years. Other countries are currently considering new quality systems in order to cope with expansion, diversification, and privatization in tertiary education.

#### **4.4 Teacher In-service Support and Development**

There are many examples of professional development programs for science and mathematics teachers from the countries participating in the SMICT study that directly try to influence teaching in the schools. These programs may be associated with the implementation of specific curriculum reforms or with general efforts to improve practice in schools. Most of these programs are executed by donor-funded projects, and by default this means that they usually have a limited lifespan. The Science Education Project in South Africa, running for more than 20 years as an NGO, is a notable exception. Once the project ends, the program also comes to a close. Efforts to continue are there but financial means are often insufficient for the program to continue. The provision of continuing professional development programs seems most often made on a short-term basis, and mostly does not form part of an overall national strategy to develop a sustainable support infrastructure. Furthermore, INSET programs can be initiated and offered by government agencies (or by several of them simultaneously, like inspectorates and curriculum departments), by universities or training institutes, or by NGOs, but one hardly ever sees joint initiatives across

these types of organizations. An exception must be made for the DMSE-INSET program at the University of Botswana, which operates in close partnership with the Ministry of Education. This is perhaps where much gain can be made. Universities are good in designing and evaluating programs, but usually do not have the staff to execute professional development programs. On the other hand, Ministries have the human resources for the organization of continuing professional development, but not necessarily the know-how. For in-service education to become less one-off and ad-hoc, it is important that it becomes more integrated in the regular education and development of teachers. Within the different options forwarded by Lewin and Stewart (2002, see above), there are possibilities for such an integration. However, other key concerns regarding the impact of in-service development programs will also need to be addressed.

Although only limited data on the effects and impact of in-service teacher development programs are available, existing evidence and anecdotal information does not paint an optimistic picture. Of the different levels of effect as distinguished by Guskey (2000), measurement is often limited to impact on teacher perception, knowledge, and skills gained from workshops or courses. It does not usually extend to classroom implementation or organization in and around schools, let alone improved pupil learning. Existing studies that have looked into the potential deeper impact in schools and classrooms (e.g. Ottevanger, 2001; Rogan & Grayson, 2003, Thijs, 1998), point towards a number of key difficulties:

- The content of in-service development activities and the type of aimed for teaching innovations are often beyond the reach of participants and the practical conditions under which they teach. Rogan and Grayson (2003) in this respect coin the concepts 'zone of feasible innovation' and 'levels of practice' dependent on the actual knowledge and skills of teachers and existing practice in schools. For large-scale in-service initiatives the amount of variation in practical contexts and teacher backgrounds also poses a major challenge for effective design of interventions.
- A critical condition for effective implementation of innovations in teaching is the availability of curriculum materials of good quality, both for direct use in the classroom and for the work and learning of teachers. The development and structural supply of such materials to teachers and schools is an issue beyond the reach of the typical project-based in-service program, and is a determinant key of sustainable effects (Ottevanger, 2001).
- Most in-service initiatives are based on workshops in central venues, and typically one-off events, although sometimes such one-off events are organized on a regular basis for teachers. Still, implementing changes in the classroom requires a learning process over time, and follow-up after an initial workshop is needed to reflect on experiences, to solve typical problems after first attempts to change, and to gain further confidence. A series of events is therefore recommended, but often difficult to organize in practice due to resource constraints, distances involved, and high teacher mobility.
- Active support and coaching in the school environment are needed to enhance the chances of actual implementation in the school. Schools and teachers differ and the impetus for change is often quickly lost if practical problems are encountered in the school context. Direct in-school support, or in-service workshops that are organized in or close to schools is a recommended strategy to make change actually happen. However, this has large resource and manpower implications for in-service programs.

- The school community has to support changes in teaching, not only in material and physical conditions, but also socially. Individual teachers can easily meet resistance in starting to do things differently on their own, and need to have active support from school leadership and colleagues. “Peer coaching” and other forms of “teacher collaboration” are potentially powerful methodologies for in-service programs, but are themselves innovations in schools that can not easily be brought about by an external in-service program (Thijs, 1998). In-service programs have to be embedded in comprehensive strategies for school development that include leadership development and department building in schools.

#### *Cascade model of INSET provision*

Many in-service education programs use a *cascade model* for their training activities. In the cascade model a group of national in-service trainers is trained first. They in turn train provincial trainers, and there might even be another cascade to district or school levels. Usually there are large numbers of teachers involved in such programs, but only few staff available for the organization and execution of activities. The cascade has proved to be a helpful model in such a situation and many programs use it. It provides the opportunity to reach many teachers with few trainers, but it also presents the danger that the training gets diluted to unacceptable levels with every step down the cascade. Critical factors in the cascade approach are as follows:

- The position of trainers and the support they get to perform a training and coaching role;
- The competence of trainers in SMICT matters and their confidence to teach teachers;
- The competence of trainers in issues regarding teacher learning and educational change.

A number of programs in the countries of the study acknowledge the vulnerability of the cascade model and the importance of the facilitators in the cascade model. They have developed special programs for facilitator training. The SEITT program at the University of Zimbabwe has developed a postgraduate Diploma program for facilitators in their in-service education program. (See promising practice on SEITT, in annex 2). The DipSciEd (INSET) provides facilitators with a theoretical basis for professional development combined with hands-on activities on how to execute activities with teachers and how to evaluate them. The SESS program in Dar es Salaam is looking at competency profiles for facilitators as a first step to make their training and their functioning more efficient (see textbox 6 on SESS).

In-service education is expensive, particularly in large, sparsely populated regions. Cheaper alternatives are evolving that make use principally of self-help models based on teachers working

#### Textbox 6. *Promising Practice – Science Education in secondary schools (SESS) project in Tanzania*

The SESS project in the Ministry of Education and Culture uses a multi-pronged approach to the development of O-level teachers and schools. It provides in-service education and support to teachers in 28 schools in three regions. In addition, it organizes ‘Whole School Development’ activities monitoring and supporting departments and Heads of schools, the My Body-My Life to promote awareness around Health issues, like HIV/AIDS. As part of the project schools have been supplied with textbooks and equipment.

The project uses a cascade system for its INSET provision: facilitators are trained and selected for involvement in national workshops as well as in cluster meetings of teachers in the region.

The success of the project depends on the effectiveness of the facilitator training. The project has recently put together a competency profile for facilitators and a possible curriculum for a diploma program for facilitators and other teachers in similar leadership roles. In addition, the development and use of exemplary curriculum materials in facilitator training was considered.

(See *promising practice: The Science Education in secondary schools (SESS) project* in Annex 2 for further details).

together at school or local levels. Developments in teacher education that lead towards structures of much greater longitudinal support in the classroom, and towards self-financed distance upgrading programs will add support to this trend.

*Support infrastructure and the use of ICT in professional development programs*

Teacher Resource Centers in Namibia, Botswana, and other countries are centers of support to teachers. These centers are housed in buildings separated from schools and have library facilities, equipment, duplicating facilities, and computers. Teachers (and sometimes students) can go there to consult books, borrow equipment, photocopy teaching materials and the like. The centers are also used for in-service education activities, like workshops and teacher meetings. The Science Resource Centers (SRC) in Ghana are different in setup from these Teacher Resource Centers. They are physically attached to schools and are mainly used for students from their associated schools, but also for students from neighboring schools. However, these SRCs should also play a role in the INSET training of teachers (as suggested in the case study on the SRCs, in annex 2).

ICT (Information and Communication Technology) has brought new opportunities to professional development programs, also in sub-Saharan African countries. The country reports from Senegal and Zimbabwe indicate that ICT is used to provide a platform for communication and collaboration between teachers at different schools. The activities of SEITT in Zimbabwe and the activities of RESAFAD in combination with GEEP in Senegal and Burkina Faso are examples of how this could be set up. The latter is using a common workspace for communication between teachers, with the department of *Developpement Professionnel Continu* as the moderator.

More important than what exactly is taught or trained, is how this is done in both a cost-effective and sustainable way. Several projects show that networks of teachers can be supported in a vital way by the use of ICT. The experiences in the Senegalese RESAFAD network (*Réseau Africain de Formation à Distance: African Network for Distant Learning*) support its effectiveness in changing teachers' values by *localization* and *personalization*. Face-to-face contact every now and then is indispensable for fruitful net-based exchanges. In the words of a Senegalese teacher:

*'I have learned that I can change: I don't need permission! I share my ideas with other teachers, and we develop new ideas for teaching, we do things differently.'*

On top of physical contact, e-networks offer the benefit of reduced travel costs, and of the freedom for teachers to use the provisions at times and places that fit their individual programs.

*Textbox 7. Promising Practice—Educators' Network in South Africa*

Educators' Network is an educator development program building online learning communities. Self-sustained NGOs create learning communities of teachers and learners using ICTs, and make effective use of ICTs in schools (using computers to learn, not learning to use computers).

Educators' Network is characterised by:

- Combining face-to-face training with modularised distance learning
- Materials provided for each educator on CD
- Collaborative groups of teachers with support from peers and E-mentors.
- Reflection on practice with colleagues and mentor
- Reflection on change—reflections recorded in an e-diary

Indications are that many teachers are now successfully engaged in the Educators' Network and have developed competencies as well as supportive and sound e-mail cultures. In a smaller number of cases implementation has led to change in classroom practice.

The Network forms the core part of training programs for two projects involving 300 schools and a potential of 5000 total educators. The training cost is comparable to face-to-face cost.

(See *promising practice: — Educators' Network in South Africa* in Annex 2 for further details).

Another example is the successful South-African *Educators' Network* model (*SchoolNet SA*) with many interesting features (see textbox 7). The practice can be made successful elsewhere, and a few similar international models exist. Most recently the World Bank-funded *World Links for Development* project has embarked on a pilot e-learning project with many features similar to the Educators' Network.

#### 4.5 Discussion

##### *Lack of subject knowledge*

Teacher education in general is strongly affected by the lack of educational opportunity at higher education levels and the scarcity of jobs in the formal sector of the economy in African countries. Teaching is one of the least popular and financially rewarding careers, and given the strength of economies, size of government budgets, and the size of the teaching force, it is difficult to imagine how this may change in the foreseeable future. Nevertheless, given the steep educational pyramid in most countries, a sufficient number of reasonably qualified candidates are usually present to enter teaching and teacher education. However, for SMICT teacher education this is not often the case. Although the overall results of secondary education may be such that a sufficient number of entrants at higher education levels is assured, the results in SMICT subjects both quantitatively and qualitatively, often leave much more to be desired. Higher education systems are often skewed towards the humanities and social sciences, and teacher education for SMICT subjects is therefore often confronted with too few or very weak students. This can be a serious problem with potential long-term consequences, because it promulgates a condition of deficient teacher knowledge, if it is not remedied. Lack of teacher knowledge in their teaching subjects can be considered a key factor, not only for educational quality in the short term, but also for the ability to cope with curriculum reform and the implementation of more demanding forms of instruction and assessment. A weak knowledge base also affects the ability to learn, certainly in the intellectually demanding SMICT subjects. *The extent to which the lack of qualified candidates for SMICT teacher education plays a role in different countries should be assessed on a country-specific basis as part of an overall assessment of supply and demand issues.* The situation in individual countries, and the underlying causes, can be rather different, and therefore in terms of further recommendations, only general trends are indicated here.

##### *Teacher education curriculum*

Because SMICT teacher education is often in a different position with respect to the quality of entrants compared to other subjects, curriculum problems with respect to general reform trends in teacher education are created. *The long-term trend is to concentrate teacher education on the specific professional preparation and leave the development of general intellectual knowledge and skills, including knowledge of the specific subjects to the general education system. Simultaneously therefore, there is a trend to raise the entry-level of teacher education candidates in terms of the level of general education they have reached.* This has already happened in most countries up to the end of secondary education, and is already moving further in some to include some years of general degree study, if not a full first degree. *A more demand-led teacher preparation that concentrates on those who actually are in, or are close to going into the profession, is a much-recommended general strategy* but creates problems if an insufficient number of sufficiently qualified candidates is present in some subjects but not all. If countries decide to follow such a strategy, *it is recommended that they keep a close watch on the actual*

*level of knowledge and skills of teacher education candidates, and put in place remedial measures and programs to safeguard against a fall in standards or decline in numbers for some subjects.* This particularly holds if schools hire secondary school leavers directly as teachers, due to teacher shortages, and those teachers subsequently enter special crash programs in teacher education. If special care is not taken, this phenomenon can easily lead to a fall in standards with potential long-term consequences.

If intellectual achievement in teaching subjects is largely placed outside (and prior to) the teacher education curriculum, it does not mean that teacher education should not, for an important part, be subject-based. Teacher education should be strongly oriented towards practice and teaching, and learning in practice takes place in specific subject domains. Notwithstanding the fact that generalizations about teaching and learning can be provided, they take different forms in different subjects. In particular, the understanding in SMICT subjects is very sensitive to how topics have been taught and learned. What this means for prospective teachers is that as part of teacher education they have to revisit their understanding of SMICT topics and how they can be taught and learned in alternative ways. If a more student-centered education in schools is intended, teachers have to become more proficient in probing student learning and understanding in the subjects. *The pedagogy component in teacher education is therefore best organized in a subject-based fashion.* For more general education components in the teacher education curriculum a stronger link to practice is also recommended, but this falls outside the scope of this study.

Subject-based pedagogy in teacher education is not the same as disciplinary-based. Rather than the disciplinary divisions in higher education subjects, faculties, and departments, *the subjects as they appear in the school curriculum should form the organizing principle in a more practice-oriented and demand-led teacher education curriculum.* This also requires a careful and longer term analysis of possible subject combinations, of future teacher needs in view of curriculum reform intentions, of deployment considerations including preferred and likely school size in expanding systems, and of entry criteria for teacher education. *As a temporary measure in transition situations, additional subject content study in non-core subjects for teacher education candidates may be necessary to optimize employability. Such additional study may also be necessary for serving teachers if school subjects need to change as part of curriculum reform and in order to facilitate its implementation.*

#### *Cooperation between teacher education institutions and schools*

A more demand-led teacher education that focuses on the specific professional preparation for teaching can also be shorter than the traditionally lengthy pre-service preparation, which includes study in the teaching subjects. Furthermore, it can become more flexible and school-based. This, however, necessitates close cooperation between training institutions and schools, which is notoriously difficult to accomplish, certainly in situations where schools and institutions are under-resourced and stagnant. *It is recommended that experimental models for cooperation between schools and teacher education institutions are designed and piloted to investigate the feasibility of alternative forms of teacher education in different country contexts.*

#### *In-service education: upgrading and leadership training*

A stronger role of schools in the teacher education of new entrants to the profession will require quality assurance and innovation capacity in schools, particularly in the form of educational leadership capacity in the subjects, and not just in general school management. *It is recommended*

*that programs for experienced teachers are developed to strengthen schools in this respect. However, selection of teachers for this should be primarily based on performance and commitment. If this is attached to new career roles and incentives, it may simultaneously make the teaching profession more attractive. For training institutions it may then be recommended to redirect their current capacity from heavy input in pre-service teacher preparation towards in-service further development of teachers and the training of educational leaders. This will also create a potentially more fertile target group for reflection on educational issues and fundamentals, and may provide a wider professional audience for educational innovation.*

*The oft-found practice of upgrading routes for teacher qualifications, for example, from Diploma to Degree level, deserves close scrutiny in terms of actual effects and cost implications. As a strategy to raise the number of teachers that are qualified to teach at senior secondary level it is rather expensive if different programs are not closely aligned in content. Furthermore, because the critical difference between teacher education programs at different levels often lies in the level of subject mastery that is required, further teacher education is steered away from actual preparation for teaching towards more academic prerequisite knowledge. As a strategy for providing career opportunities for serving teachers it is also questionable, as the main selection criterion is usually academic ability rather than professional competence and commitment. It may well serve as a route out of the profession if the degree level qualification opens other career avenues. Other types of programs for career development that are more closely tied to professional skills may well be preferable (see also point 6 above).*

#### *Teacher support*

Initiatives for job-related in-service support for teachers in relation to improvement and innovation of curriculum and instruction are often too fragmented, ad-hoc, short-lived, and driven by funding opportunities and supply-side interests. *As part of initiatives for curriculum reform and long-term improvement, a system and related infrastructure (both human and material) should be designed for on-going support to schools and teachers. This should then include mechanisms to articulate bottom-up needs and demands, and should be linked to monitoring implementation and evaluating impact in schools. As the critical condition for success is the quality of implementation at a decentralized level in a wide variety of circumstances, capacity development in schools, districts, and regions is essential. A link to leadership development programs and teacher career development (see above) is therefore recommended.*

#### *Use of ICT in teacher education*

As the essential factor in the successful introduction and use of ICT in schools is the competence of teachers in working with it, *the use of ICT should be introduced with priority in all teacher education programs. As ICT is simultaneously a promising vehicle for distance support to teachers and a platform for teacher communication, its use in a school support infrastructure may also be considered, dependent on the overall country infrastructure for ICT.*

## **4.6 The way forward**

The discussion of the main trends and challenges in SMICT teacher education and support in the previous sections has revealed many important insights. Based on these the following pointers for future policies on SMICT teacher education and support can be summarized.

### *1. On supply and demand of SMICT teachers*

- There is a need to collect and maintain data for an overall assessment of supply and demand issues for SMICT teachers. Currently data are scarce or non-existent.
- As part of this, the extent to which the lack of qualified candidates for SMICT teacher education plays a role in different countries should be assessed on a country-specific basis.

### *2. On entry criteria for students entering teacher education programs*

- SMICT teacher education requires bright students. Therefore, clear selection criteria need to be set for admission to SMICT teacher education programs at the teacher college and university levels.
- Where only limited numbers of candidates with sufficient subject knowledge are available, this should be addressed by putting in place remedial measures to safeguard against a fall in standards or decline in numbers for some subjects.

### *3. On the pedagogy component in teacher education*

- Notwithstanding the fact that generalizations about teaching and learning can be provided, they take different forms in different subjects. The pedagogy component in teacher education should therefore be organized in a subject-based fashion.
- In this respect, one should aim for qualification in two science subjects, as this qualifies the teacher better for teaching general science, integrated science, or cooperation between science disciplines.
- Teaching methods promoted (in almost all countries in the study, student-centered education in schools is intended) should be realistic considering country and school conditions. There are many possibilities for inspired SMICT teaching with limited resources.

### *4. On the subject-based teacher education curriculum*

- Subjects as they appear in the school curriculum should form the organizing principle in a more practice-oriented and demand-led teacher education curriculum.
- As a temporary measure in transition situations, additional subject content study in non-core subjects for teacher education candidates may be necessary to optimize employability. Such additional study may also be necessary for serving teachers if school subjects need to change as part of curriculum reform and in order to facilitate its implementation.

### *5. On cooperation between teacher education institutions and schools*

- Experimental models for cooperation between schools and teacher education institutions should be designed and piloted to investigate the feasibility of alternative forms of teacher education in different country contexts.
- Teaching practice, crucial but expensive in its present form, could be organized as a natural part of such a cooperation between schools and teacher education institutions, with school-based mentors taking part of the responsibility for supervision of student-teachers (see also 6 below).

#### 6. *On strengthening the role of schools in teacher education*

- It is recommended that *teacher leadership* programs for experienced teachers are developed to strengthen schools in this respect.
- The selection of teachers for such programs should be primarily based on performance and commitment.
- For training institutions it may then be recommended that they redirect part of their current capacity from pre-service teacher preparation towards in-service support of teachers and the training of educational leaders.

#### 7. *On teacher upgrading routes*

- The oft-found practice of upgrading routes for teacher qualifications from Diploma to Degree level deserves close scrutiny in terms of actual effects and cost implications. A special program or strategy to raise the number of teacher education students at degree level is likely to be more cost-effective.
- Current upgrading programs often serve as a route out of the teaching profession if these open other career avenues. Other types of programs for career development more closely tied to professional skills, like the once mentioned in 6 above, are therefore preferable.

#### 8. *On on-going in-service teacher support*

- As part of initiatives for curriculum reform and long-term development, a system and related infrastructure (both human and material) should be designed for on-going support to schools and teachers.
- A link to leadership development programs (see 6 above) and teacher career development (see 7 above) is therefore recommended.

#### 9. *On the use of ICT in teacher education*

- To support the introduction of ICT in schools the use of ICT should be introduced with priority in all teacher education programs. The International ICT Driving License (as used in some countries) could be used for this purpose.
- As ICT is simultaneously a promising vehicle for distance support to teachers and a platform for teacher communication, its use in a school support infrastructure may also be considered, dependent on the overall country infrastructure for ICT.

## **5 SMICT Education– Towards a strategy for development**

This closing chapter draws together the recommendations made in the previous sections on curriculum, instructional practices and assessment, school context and resources, and teachers and teacher education. To start, it looks at the national strategies for improvement of SMICT education presented in the country reports (section 5.1) and argues for an implementation focus of national strategies. In section 5.2, components for a development strategy for SMICT education are discussed. This is followed by an elaboration of the two central domains in such a strategy, curriculum reform (section 5.3) and teacher education and development (section 5.4). In addition, both sections provide case studies of promising practices in these domains already in place in countries in sub-Saharan Africa.

### **5.1 National Strategies in Development of SMICT Education**

Under this heading the study has tried to gain insight into SMICT education at policy level. However, the country profiles provide relatively little information. The country profiles report on policies, plans, projects, issues, and activities, most of which are of a general nature, but some also apply to and affect SMICT education. They can be arranged in the following different categories:

- new training programs (e.g. on HIV/AIDS, gender, population studies),
- curriculum (various projects on further development of SMICT education),
- assessment (establishment of independent examination council),
- quality assurance (monitoring and data collection, baseline studies, independent inspectorate, monitoring quality of teaching),
- resources (programs to improve the resource base in schools for SMICT subjects, resource centers, dedicated SMICT schools),
- system wide strategies (medium-term planning and investment frameworks, centralized budgets, BTVET strategy),
- use of ICT (various national and multi-country ICT initiatives).

However, very little has been found in the country profiles that points to a systemic approach of SMICT education at the national level. In addition, many of the strategies are presented as plans (on paper). Only in a minority of the cases is reference made to plans actually being implemented. This issue is more common than desirable and an illustration of the fact that much time appears to be spent on policy formulation, but little attention is spent on implementation efforts. Also, national strategies appear to show little coherence.

### **5.2 Towards a Strategy for SMICT Education Development**

#### *Sensitivity to the implementation context*

Contexts in which policies are implemented can vary enormously. Urban and rural settings, differences in school size, private and government schools, and opportunities to raise funds privately are areas where differences occur (e.g. in the chance to attract good teachers and good

students). Therefore policies need to be sensitive to the context of implementation. *One size does not fit all* is the slogan most appropriate in this respect.

In many cases, the capacity to innovate is quite limited, but varies from one setting to another. Based on the stages of development model (de Feiter et al, 1995) and Vygotsky's concept of the zone of proximal development, Rogan and Grayson (2003) have formulated the *zone of feasible innovation*. Teachers and schools are at different levels of development, but are, in sub-Saharan countries, often at lower levels. It is therefore important to be sensitive to the possibilities and limitations of educational development to avoid disappointments in the impact of educational reform efforts. *Start where the learner is* is a sensible credo, which also applies to the school and the education system as a whole as learning organizations.

#### *Curriculum reform and teacher education as core activities in educational reform strategies*

The SMICT study takes the view that curriculum reform is at the heart of a coherent strategy for improvement of education, including SMICT education. Chapter 2 has outlined the issues that are currently important in sub-Saharan Africa and has formulated pointers for the way forward. Figure 2 illustrates the various components of a successful implementation strategy.

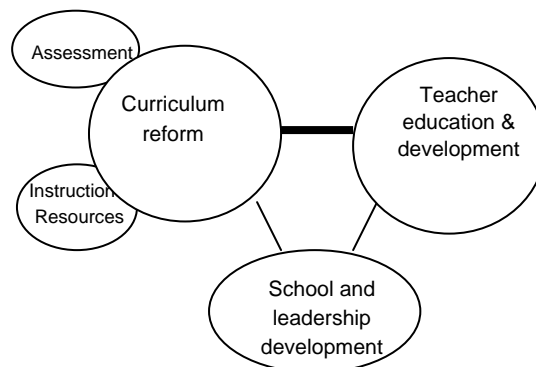


Figure 2. Strategy for development of (SMICT) education

In addition, much has been said about the interconnection between curriculum development and teacher development (cf. Loucks-Horsley et al., 1998), both initial teacher education as well as in-service teacher education and support. The importance of assessment as a curriculum component that can guide implementation in the right direction, once properly aligned with aims and objectives of the curriculum, has been discussed extensively in chapter 2. Similarly, the lack of resources is discussed in chapter 3 as a hindrance to a smooth implementation of reforms of SMICT education. However, the availability of resources is not at all a guarantee that the implementation will be successful. The SMICT study sees the teacher as the key to a successful implementation of education reforms. Thus, teacher education and teacher professional development must play a prominent role in any educational reform strategy. School development and school leadership development are important components in interaction with teacher development and with curriculum reform. These have, however, not been highlighted in the country profiles, and indeed schools are not seen as giving serious attention and priority to teacher development, except for private institutions like the Agha Khan schools in Tanzania.

The next two sections focus on the two main components in the strategy for development of SMICT education. Section 5.3 takes a closer look at curriculum reform, puts the pointers for the way forward in a coherent framework of curriculum components, and argues for alignment of the components to maintain coherence. The section closes with another brief look at some of the

promising practices in the curriculum domain, in line with the recommendations. Section 5.3 revisits the recommendations in the area of teacher education and teacher professional development and provides reflections of a number of promising practices in line with the recommendations.

### 5.3 Curriculum Reform: The Need for Coherence

The previous chapters on curriculum, instructional practices and assessment (chapter 2), school context and instructional resources (chapter 3) have produced many pointers for the way forward in the domain of the SMICT curriculum. These pointers are summarized in table 8 under the heading of SMICT curriculum. This section reflects on the issues brought forward and brings them together in a structured way. For this purpose, a framework is used which puts together curriculum components that address specific questions about the planning of student learning.

Table 8. *Specific recommendations for SMICT curriculum*

---

<p>1. <i>On curriculum (aims, content)</i></p> <ul style="list-style-type: none"> <li>• A critical review of the aims of the SMICT distinguishing between science courses for all students (in junior secondary) and more specialist science courses (in senior secondary) and addressing the present curriculum overload.</li> </ul> <p>2. <i>On teacher support for curriculum implementation</i></p> <ul style="list-style-type: none"> <li>• Support for curriculum implementation through pre-service and in-service teacher education programs and development of curriculum materials with specific guidelines for dealing with new teaching methodologies in the classroom.</li> </ul> <p>3. <i>On assessment</i></p> <ul style="list-style-type: none"> <li>• A reinforcing relationship should be established between the curriculum and the assessment system. The development of relevant assessment methods that help teachers improve the teaching and learning process should receive more attention.</li> </ul> <p>4. <i>On class size and instructional time</i></p> <ul style="list-style-type: none"> <li>• There is a need to examine the efficiency of teachers (class size in relation to teaching loads), as well as time on task. It will increase efficiency if teachers are qualified to teach at least two subjects.</li> </ul> <p>5. <i>On textbooks</i></p> <ul style="list-style-type: none"> <li>• Stimulate the production of quality local textbooks and teacher support materials, and provide opportunities and support for teachers and other educators developing these (as is achieved by the Science Teacher Association of Nigeria, STAN). Pay attention in in-service and pre-service programs to effective use of textbooks in the classroom.</li> </ul> <p>6. <i>On SMICT resources</i></p> <ul style="list-style-type: none"> <li>• Re-assess the physical provision needed to promote 'good' science. The use of simple equipment in kits and micro-science kits are examples used in many countries. Optimizing equipment for practical work and ICT through resource centres (Ghana), special science schools (Senegal, South Africa, Nigeria), and longer opening hours of schools combined with community-school cooperation providing access to ICT for the community.</li> </ul> <p>7. <i>On funding of SMICT resources</i></p> <ul style="list-style-type: none"> <li>• Funding possibilities other than government funding need to be explored. School funds, industry funds, tripartite arrangements between a private sponsor, commercial education service provider, and an education institution (schools, or ministry), cost sharing (e.g. religious foundations managing state aided schools and company schools built and partly run by large industries) are all examples of promising public private partnerships. A specific promising example is SchoolNet Namibia.</li> </ul>
--

---

The issues addressed in the recommendations above cover to a large extent the different curriculum components that make up the so-called curriculum spider web (van den Akker, 2003)

illustrated in figure 3. These components include Rational, Aims & Objectives, Content, Learning activities, Teacher Role, Materials & Resources, Grouping, Location, Time, and Assessment. The rationale, referring to the central mission of the plan, is the pivotal point to which the other nine components are linked (as well as linked to each other). These ten components can be arranged in a spider web configuration illustrating their interconnections, but also their vulnerability. Although the emphases on specific components may vary over time, at some point, alignment has to occur to create and maintain coherence.

However, the misalignment of curriculum aims and objectives and the assessment as well as the observation that the supply of textbooks to schools has not necessarily done away with note dictation and copying in the classrooms, as indicated in many country profiles, are striking examples of the lack of coherence between curriculum components. Implementation studies have clearly exposed the need for a more encompassing approach and systematic attention to other components before one can expect robust changes.

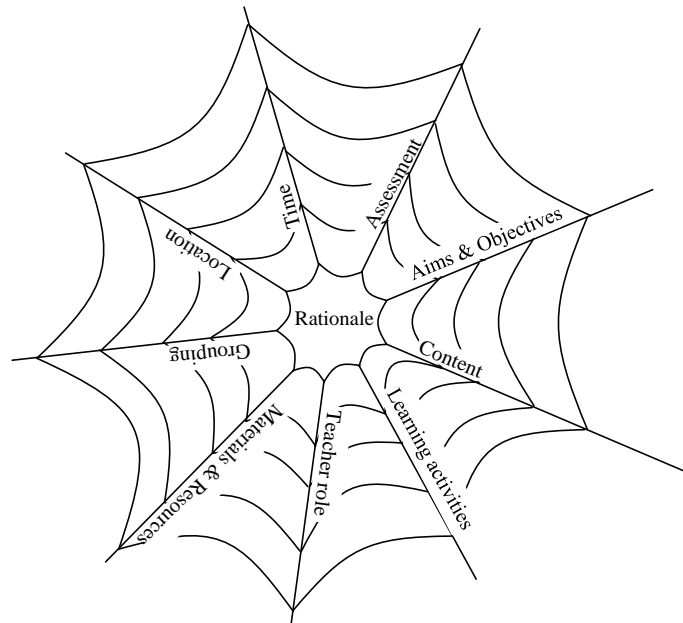


Figure 3. Curriculum spider web

The spider web also illustrates a familiar observation: pulling at one or more of the strings of the web will cause the rest of the web to shift. However, if the other strings do not move along adequately, the tension in the web may cause it to break. That seems a very appropriate metaphor for a curriculum, pointing to the complexity of efforts to improve the curriculum in a balanced, consistent, and coherent manner.

### *Promising practices in Curriculum*

Some of the recommendations in table 8 are already being implemented, though on a limited scale. The Life Science curriculum in junior secondary education in Namibia illustrates the success of curriculum reform if due attention is given to the various curriculum components outlined above (as outlined in chapter 2). It provides a good balance between academic knowledge and relevant skills, makes use of relatively simple equipment for practical work, and pays serious attention to the development and provision of instructional materials as well as to the assessment component. In addition, it has paid proper attention to teacher education and teacher professional development in support of the new curriculum. The Life Science project was donor funded, and indications are that the system may not be able to sustain the high level of support to teachers, especially those new to the subject.

Curriculum development by STAN, the Science Teacher Association in Nigeria, is another promising practice in this domain (see chapter 2). It shows how teachers can be involved in curriculum development, in this case through the activities of the science teacher association, in

the process generating royalties which are used for the professional development activities of science and mathematics teachers. Similar activities take place in Ghana by the local Science Teacher Association, GAST.

Two main efforts to counter problems with resources are observed in the countries in the study. There is a move towards much more simple equipment that does not require the use of a science laboratory. A second way to deal with this problem is to try to concentrate resources in special Science Resource Centers or in special science schools. Both are observed in the SMICT study. The establishment of just over 100 Science Resource Centers in Ghana (see chapter 2) is an example of how the latter is organized in practice. It also outlines the problems associated with the model, especially the logistical arrangements and problems with maintenance.

All three promising practices are operating successfully at the national level. Except for the activities of STAN, the problem is often the financial sustainability of the activities, either in the short term (the running of the SRCs in Ghana) or in the longer term, in the case of the Life Science project in Namibia.

#### 5.4 Teacher Education and Teacher Support

The specific recommendations made in chapter 4—teacher education and teacher support—are summarized in table 9. These recommendations (1-4) focus on issues of supply and demand, entry requirements of teacher education programs, and specific recommendations on teacher education programs. The recommendations further address the role schools can play in teacher education (rec. 5) and how this role can be strengthened (rec. 6). Recommendations 7 and 8 focus on upgrading the routes of teachers and on on-going in-service support for teachers. Finally, the use of ICT in teacher education is the focus of recommendation 9.

Table 9. *Summary of recommendations in teacher education*

- 
1. The need for data on supply and demand of SMICT teachers.
  2. Clear selection criteria for admission to SMICT teacher education programs; remedial measures (pre-entry/bridging programs) to safeguard against a fall in standards or decline in numbers for some subjects.
  3. Pedagogy in teacher education should be subject-based; teaching methods promoted should be realistic; qualification for at least two teaching subjects to teach integrated science and for maximal time-tabling efficiency at schools.
  4. School science curriculum should form the organizing principle in a practice-oriented teacher education curriculum. Additional subjects may be taught to optimise employability and efficiency of input.
  5. Experimental models for cooperation between schools and teacher education institutions should be designed and piloted (as is the case at Cape Coast University in Ghana and the University of Pretoria in South Africa). Teaching practice should be a natural part of such cooperation between schools and teacher education institutions. It is recommended that
    - *teacher leadership* programs for experienced teachers are developed to strengthen schools in this respect.
    - teacher education institutions may need to redirect part of their current capacity from pre-service teacher preparation towards in-service support of teachers and the training of *educational leaders*.
  6. A special program or strategy to raise the number of teacher education students at degree level may be more cost-effective than *upgrading routes* for teacher qualifications from Diploma to Degree level. Current upgrading programs often serve as a route out of the teaching profession. Other types of programs for career development more closely tied to professional skills are therefore preferable (see also previous recommendation).
  7. As part of initiatives for curriculum reform and long-term development, a system and related infrastructure (both human and material) should be designed for on-going support to schools and teachers, including a link to leadership development programs and teacher career development (see 5,6 above).
  8. To support the introduction of ICT in schools ICT should be introduced with priority in all teacher education programs.

- The International ICT Driving License could be used for this purpose (as in Botswana).
- Depending on the country's ICT infrastructure, ICT should be used as a promising vehicle for distance support to teachers, a platform for teacher communication, and a tool for school support.

An important aspect that runs through a number of the recommendations relates to the need for a program for the leadership roles of experienced teachers who could function in school-based teacher education programs. Teachers in leadership roles can contribute significantly to cooperation between schools and universities and teacher colleges, can play an important role in school-based teacher education programs and in on-going teacher support programs. The following paragraphs provide insight in some of the promising activities already taking place on the continent.

#### *Promising practices in SMICT teacher education*

The *SESS project* in the Ministry of Education and Culture in Tanzania uses a multi-pronged approach to development of O-level teacher and schools. It provides in-service education and support to teachers in 28 schools in three regions (see chapter 3). The project uses a cascade system for its INSET provision with specific attention to the selection and training of facilitators. The success of the project much depends on the effectiveness of the facilitator training. A recent study has put together a competency profile for facilitators and a possible curriculum for a diploma program for facilitators and other teachers in similar leadership roles. Reflecting on the effectiveness of the SESS project it is suggested that the organizational capacity in the Ministry should be linked to capacity in the design of programs and materials that exist at the University of Dar es Salaam (UDSM). Furthermore, through the link with UDSM the SESS project could also make use of tailor-made advance diploma in education, focusing on facilitator and mentor training. The SESS project in the Ministry of Education is donor-funded. Now that the project has come to the end of its funding period it is unlikely that activities can be sustained.

In line with international efforts to move teacher education in the direction of the schools, there are several initiatives in sub-Saharan African countries to make teacher education programs more school-based. Two case studies of promising practices focus on early initiatives in this area.

In the so called *In-In-Out System* at teacher education colleges in Ghana, student-teachers spend most of their third year in schools supervised by mentors and supervisors from the teacher education institution. The new *PGCE programme* at the University of Pretoria in South Africa is a second example of efforts to make teacher education more school-based. Both these promising practices have been outlined in Chapter 3.

The analysis of the In-In-Out system of training teachers has the potential to improve the quality of teachers in Ghanaian schools, especially at JS and SS levels. But to do so more effectively will require some changes in how it is practiced and a strengthening of the relevant professional support structures for trainees in the field. In particular, finding good schools where good practices are in evidence, finding and training good mentors, and the provision of good support materials for trainees and mentors are all issues that need to be addressed. The new PGCE program at the University of Pretoria is school-based. However, no evaluation of the program has taken place yet.

Upgrading programs for teachers exist in most countries in the study in one form or another. The *MASTEP programme* at the University of Namibia is considered a promising model for such upgrading programs, employing a mix of distance education and residential sessions in school

holidays. An analysis of the program suggests that the model is easily transportable to other contexts, other teacher education programs, and other countries.

There are several promising examples of how ICT is introduced in schools and how teachers are supported in guiding these activities (see chapter 3 for details). The Educators' Network in South Africa and the *World Links for Development* program in several countries in Africa support teachers in ICT lessons in their schools. Similar to the MASTEP program (see above) the *Educators' Network* uses a combination of distance learning and face to face sessions. It provides materials for use in the classroom with students on a CD or via a website. It uses ICT to create a platform for teacher collaboration. This also occurs in a number of other practices, which focus on teacher professional development. The *SEITT project* at the University of Zimbabwe was one of the first activities in Southern Africa to use ICT as a platform for information exchange and discussion for SMICT teachers. The *GEEP/RESAFAD initiative* in Senegal and Burkina Faso combines teacher professional development and ICT applications to create a platform for teacher communication, thus breaking the isolation of teachers in school, especially in the rural areas.

### **5.5 Upscaling and sustainability of promising practices**

Many of the case studies of promising practices described in this report exhibit problems with upscaling and sustainability. As already noted, when discussing promising practices in the curriculum domain, *financial* sustainability is at stake in many of these practices, especially when they are donor-funded. A second problem, as noted in the school-based 'in-in-out' teacher education strategy in Ghana, is the lack of capacity (in this case *lack of trained mentors*) to sustain the activities.

These two problems point to two crucial aspects of a strategy for development of SMICT education: the need for major investments in the system, and the building of capacity at all levels. It should be realized, however, that even when large amounts of money are invested in very short notice, no quick fixes can be expected of the multitude of interrelated problems. In particular, the huge capacity building challenges at all levels of the educational system need sustained and well orchestrated efforts along an evolutionary approach.



## 6 References

- van den Akker, J. (1998). The science curriculum: Between ideals and outcomes. In B. Fraser & K. Tobin (Eds.), *International handbook of science education* (pp. 421-447). Dordrecht: Kluwer Academic Publishers.
- van den Akker, J. (2003). Curriculum perspectives: An introduction. In J. van den Akker, W. Kuiper, & U. (Hameyer Eds.), *Curriculum landscapes and trends*. Dordrecht: Kluwer Academic Publishers.
- Black, P. & Atkin, J. (1996). *Changing the subject: Innovations in science, mathematics and technology education*. London: Routledge for OECD.
- Black, P. & William, D. (1998). Assessment and classroom learning. *Assessment in Education*, 5, 1, 7-74.
- Bregman, Jacob (2004). Trends in secondary education in OECD countries. Paper presented at Second Conference on secondary education in Africa. Dakar 2004.
- Bregman, Jacob and Karen Bryner, (2003). Quality of Secondary Education in Africa. Paper presented at the biennial meeting Association for the Development of Education in Africa (ADEA). Mauritius December 3-6, 2003. available at [http://www.adeanet.org/biennial2003/papers/7A\\_Bregman\\_ENG.pdf](http://www.adeanet.org/biennial2003/papers/7A_Bregman_ENG.pdf)
- Bregman, Jacob and Simonnet, Geraldine (2004). "Back to the Blackboard: "Looking beyond Primary Education In Africa." South African Institute of International Affairs, NEPAD Policy Focus series, NEPAD, August 2004. Also available at: [http://www0.un.org/depts/dhl/children\\_day/toc/toc3.pdf](http://www0.un.org/depts/dhl/children_day/toc/toc3.pdf)
- Briseid, O. & Caillods, F. (2003). *Trends on secondary education in industrialized countries*. Paris: International Institute for Educational Planning (IIEP).
- Caillods, F., Gottelmann-Duret, G. & Lewin, K. (1997). *Science education and development. Planning and policy issues at secondary level*. Paris: UNESCO.
- Cantrell, M., Kouwenhoven, W., Mokoena, T. and Thijs, G. (1992). *Bridging school and university*. Amsterdam: VU University Press.
- Cawthera, A. (2000). *Computers in secondary school in developing countries. An analysis of cost*. London: DFID/WorLD
- Crouch, L., & Lewin, K. (2000). *Turbulence or orderly change? Teacher supply and demand in South Africa – Current status, future needs and the impact of HIV/Aids*. Discussion Paper 26. Sussex: University of Sussex.
- Eraut, M (2000). Teacher education designed or framed. *International Journal of Educational Research* 33, 557-574.
- de Feiter, L., Vonk, H., van den Akker, J. (1995). *Towards more effective science teacher development in Southern Africa*. Amsterdam: VU Universiteit Press.
- Fraser, B. & Tobin, K. (Eds). (1998). *International handbook of science education*. Dordrecht: Kluwer Academic Publishers.

- 
- Guskey (2000). *Evaluating professional development*. Thousand Oaks, CA: Corwin Press.
- Hargreaves, A. (1992). Foreword. In A. Hargreaves & M. Fullan (Eds.), *Understanding teacher development*. New York: Teachers College Press.
- Howie, S. (2002). *English language proficiency and contextual factors influencing mathematics achievement of secondary school pupils in South Africa*. Doctoral dissertation. Enschede: University of Twente.
- INSTANT, 1996. *Baseline study*. Windhoek: INSTANT Project.
- Knamiller, G. (1999). *The effectiveness of teacher resource centre strategy*. London: DFID
- Laugksch, R. (2003). South African science education research. An indexed bibliography, 1993-2000. Cape Town: HRSC Publishers.
- Lewin, K & Stuart, J. (2002). Editorial Postscript. *International Journal of Educational Development*, 22, 3-4, 411-424.
- Loucks-Horsley, S. Hewson, P., Love, N. & Stiles, K. (1998). *Designing professional development for teachers of science and mathematics*. Thousand Oaks, CA: Corwin Press.
- Lewin, K. (2000). *Mapping science education policy in developing countries*. Secondary Education Series. Washington: World Bank.
- Montagnes, I. (2000). *Textbooks and learning materials 1990-99*. Paris: UNESCO.
- Montagnes, I. (2002). *World Bank support for provision of textbooks in Sub-Saharan Africa 1985-2000*. African Region Human development Working Paper Series. Washington: World Bank.
- Motswiri, M. (2004). *Supporting chemistry teachers implementing formative assessment of investigative practical work in Botswana*. Doctoral dissertation. Enschede: University of Twente.
- Ottevanger, W. (2001). *Teacher support materials as a catalyst for science curriculum implementation in Namibia*. Doctoral dissertation. Enschede: University of Twente.
- Prophet, R. (2002). *Handbook 2002/2003, Department of Mathematics and Science Education*. Gaborone: University of Botswana.
- Rogan, J. & Grayson, D. (2003). Towards a theory of curriculum implementation with particular reference to science education in developing countries. *International Journal of Science Education*, 25, 10, 1171-1204.
- Scheerens, J. (1999). *School effectiveness in developed and developing countries: A review of the research evidence*. Washington: World Bank.
- Shulman, L. (1987) Knowledge and teaching: Foundations of the new reform. *Harvard Educational Review*, 57, 1, 1-22.
- Tabulawa, R. (1996). Pedagogical classroom practice and the social context: The case of Botswana. *International Journal of Educational Development*, 17, 2, 189-204.
- Thijs, A. (1999). *Supporting science curriculum reform in Botswana: The potential of peer coaching*. Doctoral dissertation. Enschede: University of Twente.

---

Thijs, G.D., & Berg, E. van den (1995). Cultural factors in the origin and remediation of alternative conceptions in physics. *Science and Education*, 4, 317-347.