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Implementing Education Quality in Low Income Countries

IMPLEMENTING CURRICULUM CHANGE: LITERATURE REVIEWS – SOUTH AFRICA, RWANDA AND PAKISTAN

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SECTION 1: EXECUTIVE SUMMARY

The literature in all the three countries was reviewed on curriculum change, gender equity and poverty alleviation. The information points to the fact that in all the three countries, little research has been done that links school curriculum changes in mathematics and science to poverty alleviation. Research especially in Pakistan and South Africa has been carried out that addresses the issues of gender in mathematics and science. In general the literature review covers the research questions with specific reference to:

- curriculum change that focuses on education quality
- improving teaching and learning in mathematics and science in contexts of difficult delivery
- teacher education in mathematics and science
- improving gender equity in schools and classrooms
- issues of language of instruction in mathematics and science
- empowering learners, educators and communities in the context of poverty, including a focus on HIV\AIDS education in schools and classrooms

Most of the information was sourced from the three ministries of education, from websites, policy documents, media briefings and reports. Other sources of data such as the academic literature was sought from journals, books, newspapers, reports on national surveys such as the TIMMS by the Human Sciences Research Council in South Africa and the Student Achievement in Mathematics and Science by the Social Policy Development Centre (SPDC) in Pakistan and the Kigali Institute of Education in Rwanda. The other identified sources of information especially from Pakistan and South Africa are the doctoral and masters dissertations and research reports relevant to the research questions.

In all the three countries, matters of the national curriculum and curriculum change are the concern of the ministries of education and their affiliated bodies, such as the National Curriculum Development Centre in Rwanda. The changing of curricula is a government ministry of education initiative with inputs from general stakeholders.

All the three countries identify the shortage of qualified mathematics and science teachers. They also report that the quality of teaching mathematics and science can only be upheld if the number of qualified teachers improves and if their instructional approaches are addressed through professional development programmes, through the provision of support material such as textbooks, and through improved conditions of service.

Several research and funded projects have been undertaken in all the three countries that concentrated on mathematics and science instruction, quality education, school improvement and professional development for mathematics and science teachers. The problems still persist; strategies that enhance critical thinking and problems solving skills among learners of mathematics and science are lacking.

There is a general observation in all the reviews that the performance of learners, especially girls, in mathematics and science is of concern and drastic measures ought to be taken. Some of the initiatives undertaken to tackle and support good participation of learners in mathematics and science, especially the girl child include opening of girls' schools for science such as the FAWE Girls' School in Rwanda, the Sindh Primary Education Development Programme (Girl Primary Education Development Project) in Pakistan and the Dinaledi schools in South Africa.

The implementation of the new curricula would mean a change in the instructional approaches to those which appeal to problem solving and development of high cognitive skills among learners.

The teachers' levels of understanding and preparing mathematics and science lessons will have to change from the more traditional approaches to more innovative approaches that appeal to contractive learning as compared to rote learning.

The teachers' curricula at institutions of higher learning and research must address issues of gender and gender equity, approaches that identify with the new curricula and pedagogical approaches that reflect the content and skills outlined in the new curricula.

SECTION 2: MATHEMATICS AND SCIENCE EDUCATION IN PAKISTAN - A REVIEW

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Introduction

This meta evaluation of knowledge was undertaken as part of the large scale project *"Implementing curriculum change to reduce poverty and improve gender equity"* which aims to understand and analyse the process of curriculum change in mathematics and science classrooms in disadvantaged settings, so that barriers to learning and achievement could be identified, and strategies developed to address them.

The review covers two main areas: change and development projects in education, and a traditional research literature review, both with reference to Pakistan.

The following framework was employed to identify projects and research literature.

Relevance to research questions and purpose was an important consideration in including them in the review. Hence, national or provincial projects and research literature including information on some or most of the following elements

- curriculum change that focuses on education quality and greater relevance to mathematics and science
- improving teaching and learning in mathematics and science in contexts of difficult delivery
- teacher education in mathematics and science
- improving gender equity in schools and classrooms
- introducing change in language of instruction in mathematics and science
- empowering learners, educators and communities in contexts of poverty, including a focus on HIV aids education in schools and classrooms

Significance of the projects in terms of their impact on education policies and practice with specific reference to the above areas of focus.

Time frame projects which have been introduced over the last 15 to 20 years. The change and development projects included do not necessarily have a research component and mostly information about them is available in the form of evaluation reports and other documentation. These reports and other project documentation were reviewed to seek information on;
a) goals and objectives of the project
b) process & scope of implementation
c) the extent to which the goals and objectives were met
d) major success and challenges.

The data and information on the projects comes mainly though not exclusively from: sources of the ministry of education (e.g. websites, media briefs, reports); national data bases such as the National Education and Management Information System (NEMIS) and the Academy for Educational Planning and Management of the ministry of education; project reports by large donors and NGOs; the Research and Policy Studies Unit at AKU-IED also procured through its network and linkages hard copies of project evaluation reports and related materials. However, it should be noted that there were certain difficulties in gaining access to projects that dealt with the specified framework.

No research project on HIV\AIDS education in Pakistan was found. Furthermore, several projects did not directly fit into the proposed research purpose of curriculum change for poverty reduction and improving gender equity but dealt with these areas in a transient manner. For example, even though one of the aims of the Sindh Primary Education Development Programme (reviewed later) was to improve the quality of primary school teaching and learning, the latter was more generic in focus rather than explicitly focusing on mathematics and science. As such, quality of teaching and learning in specific subjects (e.g. Mathematics and science) was an embedded focus of the projects. We have been inclusive in our review and considered projects if they dealt with educational change and ensured that with careful reading and analysis insights into issues regarding mathematics and science teaching and learning and curriculum change were brought to the surface.

The academic literature includes journal articles and book chapters, reports on national surveys such as those by the Social Policy Development Centre(established in 1995, is a private sector research organisation that serves as a focal point for policy relevant research on social sector development in Pakistan) and the studies undertaken by the Academy of Planning and Management (AEPAM) of the ministry of education government of Pakistan.

Also included in the research literature review are masters and doctoral dissertations and research reports relevant to the scope of review. Mainly, these are by the students of the Aga Khan University in Karachi and the Notredam Institute of Education also in Karachi. Doctoral dissertations undertaken by faculty at AKU-IED and available in the library were also included.

With the above purposes and framework the paper is structured in three sections.

2.1 provides context and background
2.2 is a review of change and development projects in education and
2.3 is a more traditional literature review in the area of mathematics and science.

2.1 Context and Background

Pakistan came into being in August 1947, on gaining independence from British rule. It is a federation with four provinces i.e. Punjab, Sindh, Baluchistan and North West Frontier Province (NWFP); federally administered areas, Azad Jammu and Kashmir, and the federal capital Islamabad. The current population is about 160 million. Punjab is the largest and the most prosperous of the four provinces. Sindh and Baluchistan include some of the most poverty stricken regions in the country. Certain key facts about education in Pakistan are as below:

Table 1: Literacy Rate in Pakistan

Regional Literacy Rate	Year 2002	Year 2005
Pakistan	**45**	53
Rural	36	44
Urban	64	71
Baluchistan	**36**	37
Rural	32	32
Urban	54	60
NWFP	38	45
Rural	35	41
Urban	56	61
Punjab	47	55
Rural	38	47
Urban	66	72
Sindh	46	56
Rural	33	38
Urban	64	72

Source:
Primary: State Bank of Pakistan, Annual Report FY 2006.
Secondary: PSLM 2004-05

- In 2005, the overall literacy rate increased to 53% (Male: 65% & Female: 40%) compared to the 48.7% in 2003 and 45% in 2002. The improvement in literacy rate is visible across all the four provinces; however, wide disparity between rural and urban areas is clear.
- In the Education Census Summary Report for the year 2005, primary level gross enrolment in Pakistan was 12.4 million (males: 43% & female:57%); middle level gross enrolment was 6.6 million (male: 47% & female: 53%); and secondary level gross enrolments were 9.4 million (male: 42.5% & female: 57.5%)
- In the year 2006, 39% of students dropped out before completing their primary whereas another 20% left their education before completing their secondary level. Dropout rates are generally higher for girls. *(State Bank of Pakistan, Annual Report 2006)*
- The dropout rate at the primary level is calculated by various sources to be around 50%, whereas, 25% of the enrolled children dropout before completing grade 8 and another 15% leave by grade 10.

2.1.1 Policy Context

Federal government of Pakistan is responsible for policy making and setting the strategic direction. Education policy is also centralised and formulated at the federal level. Implementation is mostly carried out by the provincial governments and more recently from provincial to districts level. The current education policy 1998- 2010 was introduced in March 1998. The present government on coming into power put forward a number of action plans and position papers to support the Education Policy 1998-2010.

Of relevance to this paper is the Action Plan for Education Sector Reform 2001-2004 (extended to 2006), and the Action Plan on Education for All 2001-2015, the Poverty Reduction Strategy Papers I & II, and the National Policy for Development and the Empowerment of Women 2002.

A review of these action plans and papers shows they include the goals of achieving education for all, addressing poverty and focusing on increased provision for marginalised populations particularly girls and women. Implementation of these plans is seen in the context of decentralization and devolution of governance with the involvement and collaboration of civil society i.e. community, non government organizations and the private sector.

2.1.2 Curriculum Development

Curriculum development is the purview of the ministry of education in the federal government and is undertaken through a consultative process with the provincial governments through their respective education departments. Curriculum development is an ideologically driven process often leading to heated political debates in the country (Nayyar & Salim, 2003). For example, in the recent past the process of curriculum development and curriculum reform has received much attention in the print and electronic media.

There was no announcement of any change in the curriculum, until a leading newspaper "broke" the news on April 6, 2004, that the curriculum, initially in Punjab, was being changed into an anti-Pakistan, anti-Islam, pro-West syllabus. The belief was rapidly spread that the changes were being made at the behest of the USA, and in the light of a report by the Sustainable Development Policy Institute (SDPI). Objections were raised about conceptual changes made in the idea of jihad, the Quranic verses on jihad, the life of the Holy Prophet (pbuh), the Two-Nation Theory, the freedom movement in Kashmir, the Lahore Resolution, lessons on the recipients of Nishan-e-Haider and an attempt to pave the way for confederation with India.(Ayla Alvi, Daily News, May 2005)

Under the combined pressure of international and local criticism, the Ministry of Education has formed a curriculum council at the federal level. The specific tasks of the council are to review and modernize the curriculum. According to a press briefing by the federal minister of Education Javed Ashraf Qazi, the new national curriculum will be implemented in the junior (primary) classes in the academic year 2007 and will be introduced in all classes up to XII by 2009 (Irfan Ghauri, Daily Times, 25th July, 2006).

The new national curriculum has not been formally introduced for implementation. However, a preview of the document (MoE, 2006) shows the following key elements which are summarised below:

- The main objectives of the curriculum are to make the curriculum more vibrant and more responsive to the modern, socio-economic, technical, professional, and labour market needs of the country
- The most important feature of this curriculum is the goal of accelerating student progress through a standards based programme. These standards necessitate the provision of more continued, more substantive, more rigorous and systematic instruction to students. Benchmarks are provided to further elaborate the standards and provide indicators of expectations.
- The mathematics curriculum is organised in five standards which have been kept broad for flexible interpretations. These standards are: I) Numbers and Operations, II) Algebra, III) Measurements and geometry, IV, Information handling, V) Reasoning and logical thinking
- In the national curriculum for mathematics the teachers' role has been rerouted from dispensing information to planning investigative tasks, managing cooperative learning environment, and supporting students' creativity in developing rational understanding of the concepts of mathematics (MoE 2006, National Curriculum for Mathematics grades I – XII, p. 2-3)

To date (Feb. 2007) the national curriculum 2006 for science across grades I – XII was not available. However, separately the curriculum document for Physics was available (MoE, 2006, National Curriculum for Physics for grades IX-X and XI-XII). The organisation of curriculum in Physics is also according to standards and benchmarks. There is emphasis on promotion of process skills such as problem solving, application of knowledge to real life situations for making physics learning more relevant and meaningful (p. 5)

In terms of organisation and expectations, the standards and benchmark approach in the curriculum of 2006 is a shift away from the objectives based approach in the curriculum 2000. Moreover, the new national curriculum takes an explicit account of the mathematical thinking skills in Standard V and emphasises investigation and cooperative learning strategies for learning. This is a shift from the earlier versions where emphasis was greater on knowledge acquisition, drill and practice.

2.1.3 Mathematics and Science Textbooks and Examinations

The national curriculum so developed is implemented by the local governments. There are federal and provincial Textbook Boards in the country, which develop textbooks which follow the national curriculum. All government schools in the country are expected to prescribe textbooks which follow the national curriculum and which have been developed by the Textbook Boards. Currently the Textbook Boards select authors for the textbooks, who submit the manuscript for approval by a relevant Board. Approval by the board is followed by the submission to the Curriculum Wing of the Federal Ministry of Education which ensures that the textbooks are consistent with the national curriculum. However, in the new education policy there are going to be minor changes to this process which are noted in the information provided by the ministry of education (http://www.moe.gov.pk/mediacell.htm).

Textbooks are of paramount importance in any consideration of educational reform in Pakistan because more often then not textbooks are the sole reading material that the students will have access to and which the teachers will use as an instructional resource.
Hence the impact of textbook could be immense. In the recent past there have been several reports on the inadequacies, biases, and other weaknesses in prescribed textbooks (Nayyar & Salim, 2003, SPDC, 2003). The SPDC survey undertook a thorough analysis of the textbooks being used in mathematics and science classrooms in the government school. For example,

By comparison, prescribed textbooks are largely to-the point narrations and encourage retaining factual material as it is presented. They do not contain the required level of detail to apply ideas to real world phenomena. There is excessive emphasis on formal definitions; e.g. on mathematical derivations and on laws that govern physical behaviour as in the case of physics[----]-In the prescribed textbooks it is not uncommon to find statements that are misleading or plainly wrong (SPDC survey, p.143)

Like textbooks, the conduct of secondary and higher secondary examinations in Pakistan is centralised under various boards of examinations. Students in the government and private schools registered with the examination boards sit for the secondary school examination (matric) at the end of class IX and class X respectively and sit for the higher secondary examination at the end of classes XI and XII of the higher secondary school.

The examination is almost 100 percent based on the content of the textbook. It promotes knowledge recall and reproduction. They *'do not test understanding, reasoning, originality or creativity (SPDC, 2003,p129).* Recognising the impact of the poor quality of examination in driving the classroom processes of teaching and learning there was immense public support for the setting up of private examination boards that would provide schools, parents and students with the option for a better quality examination system. The Aga Khan Education Board is a new initiative; the results of the first examination under this board have yet to come out.

2.1.4 Mathematics and Science Education in Pakistan

Pakistan's Education system can be broadly divided into 'Basic Education' (primary, elementary and secondary levels) and Higher Education (post secondary and graduate levels). Both are governed by separate ministries with distinct management and financial systems. Mainstream or government schools offer primary education from class I – V (5 to 9) and then middle or elementary schooling, class VI-VIII (10-13) and finally secondary schooling, class IX – X (14 – 15). In classes IX and X students take the secondary school matriculation examination which is conducted by the Boards of Secondary Education. The medium of instruction in primary schools is Urdu, but English is introduced as a second language in class VI. The medium of instruction in the public schools is mainly Urdu, however, most of the teachers use their regional language as the language of instruction. Schools in the Provinces also teach their regional languages as a subject. However, Sindh is an exception where government schools can opt for Sindhi as a medium of instruction. As noted in the white paper and subsequently elaborated in media briefs in line with the curriculum reform to be introduced in 2007, the Ministry of Education has taken a policy decision to change the language of instruction to English in Science and Mathematics classrooms from grade VI and above (Hasan Ali 2006).

Science is taught as a compulsory subject at primary and elementary level (I-VIII) in an integration of biology, chemistry, physics and earth science. In primary classes (I-V), students study science 12 % of the total school time. At middle school level (VI-VIII) students spend 13-15% of their school time in studying science. At the secondary school level (IX-X) science is optional and those who opt for it study 12-14 % on each science subject – physics, chemistry and biology. The content of the teaching in the middle classes revolves around three broad areas: living things, matter and energy, and the earth and the universe.

Mathematics is also taught as a compulsory subject for classes I – VIII. The curriculum content is organized mainly into five major strands; number and number operations, measurement, geometry, data handling and algebra. At the secondary level (classes IX & X) students can opt to take science group or general group. The former includes among other subjects physics, chemistry, biology and advanced mathematics (with a greater focus on algebra, functions, and trigonometry). The latter includes humanities and a course in general mathematics (with greater emphasis on arithmetic and less emphasis on algebra, functions and trigonometry). However, in 1995-96 the policy has changed according to which both groups take the same course in mathematics at the secondary level. A consequence of this policy is that school examination at class VIII serves the role as gate keepers in terms of who gets the science group and who doesn't. Those who perform well in mathematics and science at class VIII level get the opportunity of taking the science group. This bifurcation at an early stage in the academic life has implications for subsequent employment opportunities and poverty reduction.

In a historical account of science education in Pakistan, Iqbal & Mahmood (2000) maintain that until 1950 science was not taught at primary and middle level. It was the Science Education Commission established in 1959 which recommended that science education be made compulsory for classes VI-VIII. In the early sixties science education was made compulsory for I – VIII but its quality was very poor. Iqbal & Mahmood (ibid) have shown that various education policies (1972, 1979, 1998-2010) have increasingly shifted the emphasis from a general education to science and technology education with a concomitant emphasis on school curriculum reforms both at primary and secondary level, to trigger students' curiosity in scientific inquiry and understanding of scientific concepts and processes. For example, a recommendation of 1979 policy was to set Science Education Project (SEP) a six years project initiated in 1984 for promotion of science education in Pakistan at elementary and secondary and higher secondary level (6- 12) in collaboration of Asian Development Bank (Hill & Tanveer 1990).

2.1.5 Profile of Mathematics and Science Teachers in Pakistan

It cannot be denied that teachers are central to the quality of teaching (in this case mathematics and science) and would need to be taken into account in any study on implementing curriculum change in science and mathematics. Hence, this review tries to build a profile of mathematics and science teachers in Pakistan so that issues of teacher preparation and teacher professional development could be identified.

The National Education Management Information System (NEMIS) data bases and other relevant sources such as policy documents were looked at. However, data is organized around gender and general qualification but it is not organized around qualification of teachers with respect to their subject specialization. Even though NEMIS data bases do not provide information on teachers with respect to their subject expertise, there is circumstantial evidence from which it can be inferred that there is a scarcity of mathematics and science teachers in the country. For example, the National Education Policy 1998-2010 (p. 47, section 6.1.5 p.37) highlights this issue as "It could be usual to find a school, where there are no vacant posts, but science and mathematics teachers are in short supply." The situation is even worse in female schools as it is further stated in the policy documents "Even in township and cities, the female secondary schools do not have teachers in science and mathematics."

To understand the reasons for this shortage of mathematics and science teachers it is helpful to look at the policies pertaining to recruitment and deployment of teachers. According to the recruitment policies, separate designated posts for mathematics and science teachers are not budgeted and advertised. Hasan Aly (2006), states that there are 203 teacher training /development institutions in the country. In addition there are about 300 Teachers Resource Centres set up under the Education Sector Reform Programme.

The basic qualification for a primary school teacher is to matriculate with a Primary Teaching Certificate (PTC) in the country except in Punjab. For middle (elementary) schools it is intermediate with a Certificate in Teaching (CTC) and for secondary education and higher secondary it is Bachelor of Education (B. Ed.) and Masters degrees respectively.

However, it is important to note that the Allama Iqbal Open University also awards a very large proportion of B.Ed. degrees through its open and distance learning programme. Teachers from the rural and remote areas (particularly females) are recipients of these degrees. Moreover, there are no clear policies and provisions for inservice teacher development. More recently private institutions have started to offer inservice teacher education (e.g. programmes offered by the Institute for Educational Development Aga Khan University, Karachi and its affiliated Professional Development Centres in the remote northern areas of Pakistan).

The National Education Policy 1998-2010, p.38, section 6.1.5) states that, "In all the provinces teachers are recruited and deployed on the post of Trained Graduate teachers which is further categorised as Junior School Teacher (JST), and Senior School Teacher (SST). A consequence of this policy as identified in the National Education Policy, 1998-2010 (section 6.1.14, p. 49) is that students studying mathematics and science subjects (chemistry, biology and physics) are often taught by the teachers with no special training in these subjects. Consequently, the National Education Policy 1998-2010 concedes that there were very few opportunities teachers have to identify themselves with their subject specialties and to interact with their peers of same subject areas.

Data on teachers' general qualification was used to infer the number of mathematics and science teachers from among the total number of teachers. The annual School Education
Statistics of NEMIS published the numbers of schoolteachers at each level of qualification but it does not indicate the number of science graduates. For example, it tells the numbers of school teachers with qualification up to higher secondary, bachelor and master level but does not tell how

many of them have science degrees. Only School Education Statistics of 2000- 2001 showed this bifurcation for the province.

Table 2: Number of teachers by Gender and Academic Qualification Pakistan School Education - Statistics 2000-2001

Academic Qualification	Male	Female	Total
F.A.	6141	3562	9703
F.Sc.	566	164	730
B.A.	7339	3443	10782
B.Sc	788	346	1134
M.A.	4182	1092	5274
M.Sc	326	106	432
Other	2174	578	2752

From this table it is interesting to note, for instance, the disproportionate low numbers of teachers specialising in Science and those that are not. For example, overall a mere 2,296 teachers have studied science up to higher secondary level or above (i.e. F.Sc., B.Sc. and M.Sc.) as compared to an overwhelming majority (25,759 teachers) who have not majored in Science after first-year college and onwards (F.A., B.A. and M.A.). Hence, the ratio of teachers who have studied science up to higher secondary (FSc) against those who have not, is about 1:11. One could infer from this discussion that in a girls' school (particularly at primary and middle levels) where female teachers are deployed, mathematics and science would be taught by teachers who have themselves studied science only up to year eight and general mathematics up to class X because after class VIII students bifurcate in science group and general group.

On the basis of a comprehensive review of the state of education in Pakistan, the SPDC survey 2003 confirms that there is an acute shortage of science and mathematics teachers in Pakistan. However, they have classified a science teacher as with a BSc or higher qualification. Their finding shows that number of science (including mathematics) teachers as a percentage of total number of teachers stands at 21%. However, they have also acknowledged that official data on science teachers is not available in the national data sources except for the province of Punjab (p.137).

To conclude, the profile of mathematics and science teachers is not easy to construct because the educational data bases in the country do not organize information according to subject specialization of teachers. However, through inference and analysis it could be said that in the elementary schools particularly for girls, there is a great likelihood that the teachers are not adequate in their academic preparation in the subject of mathematics and science.

The quality of teacher preparation and in-service education for mathematics and science teachers is an issue which is highlighted in a number of studies. For example, in an extensive survey of mathematics and science teachers' subject and pedagogical content knowledge it was found that in a randomly collected sample of 511 teachers from elementary schools in four districts there were 31 teachers who had studied science up to higher secondary level, 33 up to undergraduate level and 24 had studied science up to post graduate level. The teachers who studied science at graduate and post graduate level were mostly male and dwellers of urban localities (Pardhan, Mahmood, Babur & Rizvi, 2006).

2.2 A review of change and development projects in Pakistan

As noted in the introduction, this section reviews a number of development and change projects in education, in accordance with the review framework and were undertaken during the last two decades in Pakistan.

(I) Sindh Primary Education Development Programme

Sindh Primary Education Development Programme (SPEDP), a nine year project, was launched in 1990 by the Government of Sindh and international donors including the World Bank, Department for International Development (DfID) UK, Norwegian Agency for Development (NoRAD), and the United Nations International Children's Education Fund (UNICEF). The project aimed to:

(i) increase participation in schools in both rural and urban slum regions (emphasizing education for girls);
(ii) improve the 'delivery' of primary education
(iii) increase students' learning and achievement.

The evaluation report of the programme (Choudhry et al., 1999) highlighted a 9% increase in the gross enrolment in primary schools with a significant gross increase (23%) in rural girls' enrolment. Boys' enrolment, however, increased marginally by 2% since 1992. Gross participation rate (public, private community and NGO schools) has increased from 52% in 1990 to 54% in 1998. Girls' gross participation in rural areas increased from 14% (1990) to a significant 34% (1998), while boys' participation also increased from 69% to 75%. Nevertheless, program sustainability is uncertain due to a 'lack of political will, financial constraints, inadequate capacity and vision and the absence of donor funding (Choudhry et al., 1999, p. 28).

To improve the quality of teachers SPEDP agreed to provide incentives to teachers for innovations in their teaching because the negative effect of poor quality teaching and learning materials on students' achievement was noted in Sindh at the time the project was being designed. For example, textbooks that were being used in government schools at the time had many shortcomings that included "… poor language grading from one level to another, lack of exercise material, inappropriate pedagogical level, factual and grammatical text errors and gaps between pedagogical requirements and teachers' abilities to teach" (Choudhry et al., 1999, p. 24). To enhance student achievement, therefore, SPED provided training to improve the quality of teaching-learning materials, textbooks and supplementary reading materials in all public schools in Sindh. Training materials/teachers' guides were produced for primary subjects by the Sindh Textbook Board in June 1997 and a review of these indicated that they were of a high quality but there is little elaboration on the criteria for quality (Choudry et at ibid.).

(II) Girls Primary Education Development Project (GPEDP 2005 – Phase II) – Sindh Component

The objectives of the Girls Primary Education Development Project (GPEDP, 1998-2005) were access, equity and quality (MoE, 2005, p.4), to increase opportunities for girls to receive quality education leading to mastering basic literacy skills for life-long learning as well as acquisition of productive skills. The project focused on: (i) increasing girls' access to primary education, (ii) improving the quality of primary education, and (iii) providing institutional support to Community Model Schools (CMSs). It was funded mainly by Asian Development Bank (ADB) and also by the Organization of the Petroleum Exporting Countries (OPEC). The project was undertaken in two phases and in three provinces excluding Punjab. Reports and documentation were available for the Sindh component.

For the purpose of quality improvement in primary education, three interventions were made by this project. Firstly, English language and Mathematics Interactive Radio Instructions (IRI) programmes were developed for grades 3 to 5 and were introduced in all CMSs. The Provincial staff received training at National workshops while Learning Coordinators (LCOs) and CMS teachers were trained by each province in the use of IRI English and Mathematics. Focus on mathematics included improving mathematics knowledge of the primary school teachers through teaching key concepts required for primary mathematics teaching and construction of test items for assessing learning. In addition, radio cassette players, cassette teacher guides and student workbooks were provided to teachers (grades 3 and 5) in each CMS. Secondly, 'quality improvement' entailed using the Instructional Materials that were already produced in Pakistan. For example, packets of reading material were provided to CMSs to help reinforce basic literacy skills in the early grades as well as consolidate reading and comprehension skills in grades 3 to 5. Finally, the assessment of students' achievement was another intervention that fitted under the realm of quality improvement.

Evaluation of the project indicated that project targets had been met in terms of the establishment of 220 Girls Community Model Schools (GCMSs); (ii) decrease in dropout rate; (iii) provision of (a) furniture, (b) material, (c) equipment etc. Thus, basic facilities were successfully provided to all GCMSs (n=220) established throughout Sindh. The platform for quality primary education in rural areas has been laid (e.g. with the provision of teaching kits/materials, establishment of Girls' Community Model Schools – GCMSs, furnishing these schools with basis facilities) and ultimately achieved through accessibility of girls to primary education in rural areas and an overall increase in the literacy rate in Pakistan. The report states that the IRI Mathematics consultant fulfilled the objectives of the project. That is to say the local consultant attached to this assignment prepared the lessons for classes I and II. She also arranged several workshops to train teachers and field staff. However, the "performance of (the) consultant of IRI English was very poor and sub-standard due to which no progress in this respect could be made" (MoE, 2005, p. 18). Although the development of minimum competency literacy tests for annual administration to grades 2 and 4 students of CMSs was an integral component of the project, there is no mention in the report (either in the text or appendices) of these tests being developed and used. The report merely highlights that 6 days' training workshop that was conducted in various districts to train participants in the use of an objective method of assessing students. At the same time the report also points out that the position of 'Consultancy' for Test Development was not filled.

An issue that surfaced was recognizing the need to maintain the sustainability of the project by having an active monitoring and evaluation system in place. A further issue involved the delay in staff development due to a ban on the recruitment of teachers. Yet another issue related to the idea of Learning Coordinators who were intended to be the main avenue for promoting quality education in the CMSs. However, the idea did not materialize because in the context of the project, the Learning Coordinators were merely matriculates while the Headmistresses were mostly postgraduate. Hence, this "mismatch of mental calibre could not work" (MoE, 2005, GPEDP Project Completion Report p.21).

(III) Teacher Training and Material Development Cell (TIMDC) and Primary Education Programme-Improvement of Learning Environment (PEP-ILE)

A comprehensive programme – TIMDC/PEP-ILE – was introduced in 1996 by the Government of NWFP in order to improve the situation in the education sector. This programme is donor-funded from Germany (GTZ); Netherlands (NEDA); and the UK (DFID) and because of its scale and impact considered to be a very significant project in NWFP which is among the smaller provinces of Pakistan. The programme offered the following components:

- Development of new pupils' books, workbooks and teacher guides
- Grade-wise introduction of the new material through large scale teacher training
- Providing training for teachers in both conceptual and pedagogical skills

- Management support to the Districts to establish and run a regular system of teacher training
- Rehabilitation and construction of new classrooms

The Government took on the responsibility of training for the programme. It was recognised that the quality of teaching and learning was the main factor for improvement and the Directorate of Primary Education and Literacy and Provincial Institute for Teacher Education were assigned the management of this training.

A large scale impact study was conducted in Nowshera and Chitral districts in North West Frontier Province (NWFP) Government primary schools. The purpose of this study was to evaluate the large scale inputs of the TIMDC/PEP-ILE programme (i.e. large scale training and new material) for primary schools in NWFP from 1997 to 2001. The study aimed to find out:

i) the learning achievement of children (Kachi, Pakki and Grade 2) - Pre-primary classes in the state schools are referred to as 'kachi' classes. In the context of a state school, 'pakki' means class 1.

ii) if given districts had improved significantly after introducing new books such as pupils' books, workbooks and teacher guides and after the teachers had received training;

iii) if the learning achievement of Pakki and Grade 2 children is significantly higher after being exposed to the new teaching material and to the active methodology of teaching (eg. group work, use of interesting questions; involving pupils actively in the class; story telling techniques) for two years;

iv) if there had been a significant improvement in the quality of teaching in classrooms after the teachers had received training in (a) using new material, (b) on basic concepts and (c) on active teaching methodology;

v) if the phonic approach had been taken up in schools in the district of Nowshera, and if those children showed a better performance in their reading abilities in Urdu or in Pushto (their mother tongue).

A base line was conducted on students' achievement in mathematics and Urdu in districts Nowshera and Chitral of the NWFP and followed up with post tests. For researching the pedagogical quality and classroom environment an observation sheet (15 items and 5 points rating scale) was used to determine pedagogical quality. '1' denoted the lowest rating on the items while '5' represented the highest. The items comprised of different aspects such as a teacher's professional behaviour, pedagogical behaviour and classroom activities. Results indicate a complete improvement in classroom atmosphere and teachers' behaviour in Chitral after the training that is statistically significant for each item. Despite these encouraging findings it needs to be noted that the results were mainly due to the improvement of the male teachers and that, in accordance with the criteria, the standards have merely reached an average level of pedagogical quality.

The following key findings emerged from the above study. (Although there were other key findings as well, these are not with references to teaching and learning of mathematics and have therefore not been included):

- A significant increase in children's achievement (Kachi, Pakki and Grade 2) after the introduction of new books, textbooks and teacher guides by large scale teacher training;
- There was no gender neutrality of the inputs: that is, girls benefited more from the inputs than boys in relative terms; nevertheless, in absolute terms the girls' achievement was more or less the same as the boys after the implementation of the programme;
- An increase in achievement was found even during the second year after the programme had been implemented;
- There is a clear cumulative effect, overall, of the programme inputs and exposure. Even though the new approach contributes towards the improvement of Pakki and

Grade 2 children, the effects, although statistically significant, are comparatively low.

- There is a more child-centred and more activity based teaching after teachers have received training. In Chitral, the improvement is on the male rather than on the female style (PITE 2002, Improving Students' Achievement in NWFP Government Primary Schools)

(IV) Middle Schools Project 1994-2004

The Middle Schools Project, initiated in 1994, is a well known and large scale project aimed at *equity and access improvement*, *quality improvement* and *institutional strengthening*. It comprised of sub-projects at provincial level and a national programmes at the federal level. In line with the project aims the targets included upgrading 460 primary schools (I-V) to elementary/middle schools (I –VIII). However, the project had a delayed start of a year and was suspended again for another year, from September 1996 onwards, due to a shortage of funds. Hence, the initial target of upgrading 460 primary schools (classes 1-5) to middle schools (classes 1-8) – to increase access – had to be revised to 179.

As a means of improving the quality of schooling at the middle level, the MSP aimed to enrich curriculum and textbooks. Support through consultancy, overseas training and research assistance was provided to the federal curriculum bureau in the ministry of education to review and restructure the curriculum for middle schools. The project's report recommends an increase in instructional time for the core academic subjects i.e. Mathematics, Science and Social Studies, but the proposed increase in the amount of instructional time is not mentioned. It recommends the development of more relevant and attractive text materials (i.e. higher quality text subject content and improved book layout), and the development of teachers' and headteachers' handbooks that are in line with the curriculum.

Of the various provincial projects, the Punjab Middle Schools Project is the most well known and well documented for the work accomplished in the area of mathematics and science teaching. For example, accounts of the teachers' guides are available in the Middle Schooling Project that was implemented in the Punjab. Teacher guides in Mathematics at the primary level deal with topics such as Number concepts, Equity in Mathematics, Fractions etc. Pictorial illustrations, step-by-step procedures, providing examples of application of mathematics in daily life situations etc. are some of the key elements that characterize the manner in which these topics are dealt with in the teacher's guide. Similarly, teacher guides in Science cover topics across the Science curriculum such as Living Organisms, Classification of Organisms by Structure, Static and Current Electricity, Our Earth, Reflection and Refraction of Light etc. These guides, once again, are comprehensively and creatively depicted with illustrative diagrams that help to teach concepts in a more practical and learner-friendly manner.

(V) Science Education Project (SEP)1986-1994

The Science Education Project (also known as the Secondary School Science Education Project), was undertaken to review the provision of and quality of science education in the secondary schools in Pakistan, and to develop a proposal for strengthening the science education for classes VI- XII. The main objective of SEP was to improve the quality and relevance of science education in secondary schools. The major components of the project were to establish science laboratories (in middle and high schools); provide science kits; bring about improvement in science education through research-based curricula; promote staff and institutional development; and offer consultancy. The scope of the project was national in that the criteria for selection of middle schools – for the provision of science rooms/facilities – included all the provinces of Pakistan. These handbooks are intended to broaden and update knowledge of both headteachers and teachers. Funding for this project was from the Asian Development Bank (ADB) and by the Organization of the Petroleum Exporting Countries (OPEC).

In the context of SEP progressive science curricular was taken to mean aligning science curricula with the needs of the country. Also the emphases of such curricula would be on demonstration and practical work to facilitate pupils' understanding of concepts in science: hence, the need for science rooms and equipment to be in place. Additional problematic areas that needed to be addressed were the institutionalizing of in-service training and setting up a monitoring/evaluating component to realize specific project objectives.

Mid-term review of the project revealed that the main objective of the project (i.e. improving the quality and relevance of science education in secondary schools) had been attained. For example, the project report highlights the development and implementation of research-based science curricular, textbooks, teacher guides and students' manuals for elementary classes (VI-VIII). Not all of the specific objectives (e.g. development of progressive science curricular for Pakistan, upgrading facilities in middle/high schools and training institutes, provision of infrastructure to initiate and coordinate the development of science education) had been achieved to the same degree (MoE 2002, SEP Project completion report p. 24).

A formal impact evaluation of the Secondary School Science Education Project was undertaken (Ministry of Education, 2002, AEPAM research study no. 166). The impact of Science Education Project on science education at the secondary school level was gauged by examining five aspects: (a) curriculum and textbooks, (b) instructional methods, (c) internal efficiency, (d) external efficiency, and (e) external examination (Secondary school examination). Key lessons learned were:

- Though the project was 'somewhat successful' in enhancing the institutional capacity, strengthening the physical and professional inputs, these could not be achieved fully due to a lack of coordination, bureaucratic set-up and red-tape.
- Training programmes for teachers can only be effective if the required materials for teaching are made available before the activity begins, for which funds are needed and therefore the required funds must be made available to purchase training materials.
- This study did not find any evidence that could suggest that there was a significant impact of the science project on students' achievement in secondary school examination. Change in student achievement is not possible unless reforms in teaching practices and examination system are reviewed and initiated accordingly.
- After teachers have received training in teaching Science it is necessary to monitor their performance in classrooms specifically in terms of providing them feedback on their teaching styles and techniques used to involve pupils in the learning process.(MoE 2002, AEPAM Impact evaluation report # 166, p. 51-52 and Tahir, 2002)

Based on the impact evaluation of the SEP the following measures are suggested to improve the efficiency and effectiveness of secondary school science education:

- Provincial SECs should establish a monitoring and evaluation mechanism for implementing of science education projects.
- A Project Information System (PIS) needs to be in place in order to support the planning and monitoring of the project activities.
- Supplementing governmental funds for secondary education is necessary in orderto reduce and share the cost of financing secondary education. Schools should been couraged to generate funds through fund-raising programmes.
- Involving more female teachers in teaching Science and getting highly committed and motivated individuals in the teaching profession. Special incentives would need to be given particularly to teachers in the rural areas.

- The need to introduce a differential curriculum in Science and Mathematics at the secondary level to help promote advanced knowledge and skills among students.
- Counselling and guidance services need to be arranged in secondary schools for the promotion of science education to all students particularly in rural areas and female role models to motivate them to opt for sciences (MoE, 1992, SEP Project completion report).

(VI) Teachers' Training Project (TTP 2001)

This project was funded by the Asian Development Bank (ADB) and launched in all the four provinces of the country. The objectives of the project were to (i) increase capacity building in teacher education so that the present and potential future paucity of quality teachers could be met; (ii) provide increased access to training (particularly for females) in rural and disadvantaged regions; (iii) improve the quality of teacher education programmes, and (iv) improve – and run – teacher training institutes efficiently. The initial date for project completion, December 1998 was revised to December 2000 due to a late start and the non-completion of activities.

Overall, the immediate goals of the project were achieved and this is highlighted in section III-C: 'attainment of benefits' of the project report (Memon, Khokhar and Siddiqui, 2001, p. 10). Thus, the project report indicated the increased training provided to master trainers, teachers and officers (table 3). Despite this overall achievement, however, the report also points out that the project '… could not be implemented fully as it was conceived' (p. 10). Project activities that were implemented at provincial level were successful, centralizing the implementation of the main components of the project at the Federal Co-ordination Unit (FCU) level meant that delays in one province slowed down the progress in the other provinces as well.

Table 3: Training acquired During the Project

Master Trainers (n=440)	Primary Teachers (n=17448)	Secondary Teachers (n=2017)	Officers (n=256)	Overseas Training (n=21)

Male	*Female*	*Male*	*Female*	*Male*	*Female*
240	200	8729	8719	1507	510

Even though one of the objectives of the project was to meet the shortage of 'quality teachers', the latter term is not unpacked in the context of the report. Thus, there is no explicit description (or even any mention) of what characterizes a 'quality teacher'. Nevertheless, from the activities outlined in the project (e.g. training of Master Trainers; overseas training for teachers; in-service teacher training) it is possible that the term 'quality' might be attributed to enhanced pedagogical awareness of teachers through exposure to both overseas as well as local training programmes.

(VII) Aga Khan Educational Services, Pakistan

The field based teacher development programme in Northern Areas of Pakistan was launched by the Aga Khan Educational Services, Pakistan (AKESP) in partnership with the government of Pakistan in the mid 1980s. The AKESP is a large NGO with 123 primary and secondary schools in Ghizer and Gilgit districts of the northern Areas, which were initially only for girls but later became co-education schools.

The field based teacher education programme provided professional development opportunities for untrained practising teachers at their local primary school over the period of a full academic year under the supervision of master trainers. Evaluation of this programme showed that the impact was greater on women because for cultural reasons women were denied the opportunity of going to large urban centres to access teacher education. The Field based Teacher Education Programme marked a shift in the traditional perceptions, from universities and colleges of education being the centres of teacher education to the recognition of the school as a centre for teacher learning (Pardhan & Thiessen, 2006).

(VIII) Aga Khan University Institute for Educational Development: Programmes in Teacher Education

The Aga Khan University Institute for Educational Development which was established in 1993, initiated a number of research and development projects mainly in teacher education, school improvement and school leadership. Key features of programme offered by AKU-IED are:

- Courses are underpinned by a philosophy of reflective practice with an explicit focus on action research, maintaining reflective journals and encouraging a critically questioning stance towards own practice and to all knowledge.
- Programmes are field based i.e. as part of the course participants have opportunities to work in real world of classrooms.
- Pedagogic and other knowledge promote constructivist approaches to learning with concomitant roles of teacher and learner

Programmes offered by AKU-IED are innovative and ground breaking in the context of education in Pakistan. These programmes invariably include a focus on improving mathematics and science teaching. A body of knowledge is emerging as a result of the research in mathematics and science teaching undertaken by the faculty and students at AKU-IED[1].

A significant project because of its scale of operation and focus on change in curriculum at the classroom level is the Baluchistan Mentoring Programme. It was a donor funded programme carried out in 20 out of 23 districts in Baluchistan within a partnership between the government of Baluchistan, and AKU-IED (Memon, Lalwani & Meher 2006).

This programme was initiated to provide classroom support to teachers as they implemented new curricula and methodology in primary classrooms. The mentors' support to the primary school teachers was in core curriculum areas which included science, mathematics and social studies. Mentors spent considerable time clarifying teachers' concepts in science, mathematics and social studies. In mathematics this included mentors and teachers working through the mathematics problems given in the text books (Memon etal 2006; p. 112)

(IX) Education Sector Reforms Assistance (ESRA)

The Education Sector Reform Assistance (ESRA) program is a $71.5 million project that is funded by the United States Agency for International Development (MoE, 2004). Its aim is to support the Education Sector Reform (ESR) initiatives of the Government of Pakistan. ESRA comprises a group of national and international partners and operates

[1] For example the works of Halai, A. Halai, N., Pardhan, H. Pardhan S. and the masters thesis reviewed in this paper

across six technical areas which are; policy and planning, literacy, public-community partnerships, information communications technology, public-private partnerships and professional development in nine districts; Thatta, Hyderabad, Khairpur, Sukkur, Killa Saifullah, Chagnia, Noshki, Keh (Turbat), and Gawadar.

The work of ESRA is geared towards school improvement and empowering stakeholders within the system to identify and solve their own problems related to school improvement. It has a Professional Development Infrastructure (PDI) team which offers in-service professional development to teachers, head teachers and administrators in ESRA districts, tehsils, SMCs and schools (ESRA Project Team, 2005).

The teacher development component of ESRA recognises the significance of taking a field based development approach to teacher professional development. Hence, it includes the "Cluster Based Mentoring Programme" as a key programme of its professional development component. With other institutions the Aga Khan University –Institute for Educational Development offers the Cluster Based Mentoring Programme.

Key features of this programme include

(i) developing reflective skills and strategies for improving teaching/learning;
(ii) understanding different ways of teaching/learning (focus on mathematics, science and social studies);
(iii) developing the knowledge, skills and attitudes to become an effective teacher educator;
(iv) discussing current issues in teacher education from a contextual perspective;
(v) developing an understanding of different strategies for ongoing professional development.

Conclusion

An overview of the development and change projects in education in Pakistan, within the last two decades, indicates the following trends:

- Projects are mainly donor funded and have looked at improving access especially for girls and for rural children. They recognize the issues of regional and gender inequities and target those areas for development.
- Quality (in terms of teaching and learning) is mostly not reported explicitly even when it is the focus of the project. There is a tendency in the reports for quality to be seen in terms of the hardware of education so that the importance of quality teaching and learning is 'side-tracked' when these are portrayed as subsets of the bigger and more tangible project aims such as building the physical infrastructure of a school, etc.
- Where quality of teaching and learning is the embedded focus of change and development, the significance of mathematics and science is recognised as areas of curriculum that would lead to improving the prospects of the learners and the community.
- Nationally the desperate need to improve the quality of science and mathematics curriculum, teaching and learning is recognised and has led to several large scale reform projects in these two curriculum areas.
- Improvement in mathematics and science is seen through improving curriculum materials specially the text books and teacher guides and improving teachers' knowledge and competency. There is recognition that textbooks are poorly produced, and there is a shortage of appropriately qualified and competent teachers of mathematics and science
- There is perceptible shift towards large scale programmes which provide school and/or classroom support recognising the value of classroom support for improving teaching and learning and curriculum implementation.

- In cases where formal impact evaluations have taken place the studies have looked at student achievement in mathematics and language. These report that the interventions have favourably impacted student achievement in girls as compared to boys. However, this finding is contradicted by the SPDC survey 2003. (See the section on student achievement later in the paper)

2.3 A more traditional literature review in the area of mathematics and science

This section reviews research studies in the area of mathematics and science education.
As in the case of development projects, the review has made an effort to identify and include studies which are relevant to the focus and purpose of the project.

Research into education, particularly mathematics and science education, is not a well developed field in Pakistan. However, a knowledge base is emerging slowly mainly as the result of research into mathematics and science classrooms conducted by faculty and students at the Institute for Educational Development at the Aga Khan University (AKUIED).

The review showed that mostly issues are the same in science and mathematics curriculum reform for poverty reduction and improving gender equity. These pertain to the centrality of the teacher in improving teaching and learning; issues of gender bias in curriculum and inequities in societal perceptions of gender roles; cultural issues in perceptions of knowledge; role of language and language in education policy in facilitating or inhibiting quality of learning in mathematics & science.

2.3.1 Curriculum development and implementation

Using a phenomenological approach Watson and Aubusson (1999) studied curriculum implementation in Pakistan, from the perspectives of three members of National Science Curriculum Review and Implementation Team. The participants were asked to give their perceptions about curriculum implementation in Pakistan. Through participants' accounts the researchers examined the changing patterns of science curriculum implementation in Pakistan and the factors which influenced the change. The researchers also assessed different views of curriculum implementation with reference to the culture of Pakistan.

"The [participants'] views suggest that an authoritarian system operated [in curriculum development and implementation] in the past: a system in which teachers and administrators had prescribed and limited functions. Authority was derived from rank and position, and knowledge and expertise were associated with that rank rather than the knowledge and expertise giving rise to authority."
(p. 611).

However, the participants acknowledged the country's attempts in shifting the orientation from the authoritarian approach (top-down) of curriculum development and implementation towards an approach which was based on cooperation from all the stakeholders. For example, they considered that through the Science Education Project (reviewed in the preceding section) the Education Ministry had demonstrated its readiness to bring about change as it provided a forum for teachers from the college cadre and school cadre to think together about what and how science should be taught. The participants also viewed that those efforts could not bring significant results because of two reasons. First, it was difficult to adopt a sustainable cooperative approach in curriculum development and implementation in an authoritarian society. There are many forces acting in these societies which play a discouraging role in bringing about any improvement in the curriculum. Second, many individuals who were engaged in curriculum development did not seem to have enough experience, knowledge and attitude about their role as science educators and curriculum developers.

The study also reveals that there are conflicting principles in an attempt to reform the curriculum. For example, there is emphasis from different groups of the society that the science curriculum should have cultural consideration. On the other hand, culture is not stagnant; rather it is continuously shaped through schooling and curriculum so there is an expectation from a group within the country that the school and the curriculum should act as change agents for political empowerment and social change through science education.

Pakistan's social structure and economy is based on gender and class differences. Children of different socioeconomic and gender groups receive different kinds of educational experiences. That is why Khan (1993) and Hoodbhoy (1998) argue that education does not support people in the lower strata of the society to move up the socioeconomic ladder. For a number of reasons, most of the children from rural and poor urban families do not go beyond classes. One of the reasons for that is that the children in many poor families have to provide financial support to their parents (Ismail et al. 1994).

In this connection, Zahur, Barton & Upadhyay (2002) conducted research to explore the role of science education in poor urban communities in Pakistan in bringing about political empowerment and social change. Zahur et al (2002) presented a detailed case study of one female science teacher educator, Haleema (pseudonym) who had been committed to empowering communities through science education. Haleema's narrative helped the researcher investigate how teachers (working with Haleema) crafted their roles when engaged in science education for political empowerment and social change.

The researcher has identified three key issues for science teaching and curriculum development. First, a dissatisfaction and alienation of learners from school science because it has failed to meet the need of poor urban communities in Pakistan as the schools neither have enough physical resources nor have qualified teachers. The study illustrates that the school science curriculum does not help children to develop their understanding of environmental and health issues in their communities. Second is the need to shift the primary goal of teaching science from acquisition of the state curriculum to individual and community empowerment. Based on her findings, Zahur et al (ibid.) recommend that viewing students as agents of change could bring about change in their families and community if they are educated for that. She argues it is ironic that children who do not have adequate running water and proper sewerage facility, who have to breathe in bad quality air because of industrial waste, who suffer from water borne diseases such as typhoid, hepatitis and dysentery, who live in poorly-ventilated houses where they cook food on wood and coal, are still expected to learn a curriculum that has no relevance to their life situation. They should be encouraged to take stock of their situation and come up with some solutions. For example, if the children look into the reasons why their houses are filled with smoke it might be possible that they, with their families, could develop inexpensive ways to deal with it. Third, the study highlights the role of science teacher education in achieving the shift. Teacher education programmes should help teachers to think that science emerges from everyday experiences such as cooking in the kitchen, tending a garden, disposing the waste, reading a list of ingredients on packets of household items etc. Thus, through Haleema's case study Zahur (2002) provides some proofs of incompatibility of the curriculum with the children's need in underdeveloped areas of the country.

The study has an implication for curriculum development and associated professional development as top down approaches are usually not very significant in helping teachers bring about change in the curriculum and teaching practices; rather, they need support to implement new approaches in the classroom and to refine those approaches to suit their particular needs and the needs of their students.

Nature of science as part of the curriculum

Halai, N. (2002) and Halai & McNicholl (2004) highlighted another aspect of curriculum change. They argued that science education is not only about the learning of science but it should also include learning about the nature of science. In an in-depth case study of science teachers in Karachi, Pakistan Halai, N. (2002) found that teachers perceived science as a fixed body of knowledge which can be acquired through the scientific method. Ahmed (2000) & Halai, N. (2006) found that professional development courses have limited influence on teachers' conception about the nature of knowledge and they suggest explicit curriculum orientation in this direction. They maintain that it is important for teachers to learn about the nature of science because it would break the cycle of teachers with a traditional dogmatic view of science going to teach their students.

In a comparison of perceptions of the nature of science in teachers from Oxford and Karachi, Halai & McNicholl (2004) found a sharp contrast. For example, in Oxford, teachers perceive science as being knowledge-based, and religion as faith-based but the teachers from Karachi perceive that all knowledge arose from the Quran and religion and science knowledge should not be seen as different. The researchers reported that those teachers faced problems in conceptualizing the evolutionary theory and classification of humans as animals as they thought that Humans are *ashrful mukhlooqat*. This phenomenon has implications for curriculum development in terms of how to include a scientific stance of a particular phenomenon without conflicting with people's faith-based knowledge.

While there have been no similar studies about teachers' perception of the nature of mathematics, similar work done elsewhere (e.g. Ernest, 1999) suggests that curriculum change in mathematics should also include an emphasis on changing perceptions about the nature of mathematics knowledge.

2.3.2 Improving Teaching and Learning in Mathematics and Science

Typically a mathematics classroom in Pakistan is characterised by a focus on the product only in the form of a right answer and is characterised by a lack of focus on understanding, reasoning, critical thinking and creativity (Warwick & Reimers, 1995; Halai, 1998, 2001, 2004; SPDC Survey 2003).

Various factors have been identified for this. Mainly these pertain to the quality of teachers & teaching; curriculum and curriculum materials used; and examination. The mathematics and science curriculum place heavy emphasis on rote memorizing which does not promote deep or conceptual learning. To a great extent this is a consequence of the rigid structure and guidelines of the national curriculum and the fact that teaching is geared towards examination and achievement. The problem arises with the interpretation of the curriculum which is in the hands of practitioners. As Nelofer Halai (2004) argued,
"In Pakistan the greatest challenge lies not in developing curricula and new ideas but in supporting teachers in implementing them and refining them to suit their practical needs and needs of their students."

Teaching approaches and reform in teaching are important elements of curriculum change because it is through teaching that the curriculum is negotiated by the learner. Several studies reviewed in this section have looked at the process and outcomes of introducing change in the classrooms through improving teaching of mathematics and science. Improving teaching has been seen through teaching strategies which promote, for example, greater student social interactions; encourage higher order thinking through more challenging and richer tasks, and develop mathematical skills through problem solving and investigations.

Halai, AmirAli, Kirmani & Muhammed, (2004) studied the impact on students' learning of different teaching strategies introduced in an in-service programme for mathematics teachers. These new methods of teaching included: different research-based teaching strategies – do-talk-record (Brissenden, 1988); cooperative learning (Johnson et al, 1993); and problem-solving (Polya, 1957). Findings revealed that teaching strategies introduced in classrooms brought about positive changes in the classroom discourse which became less teacher directed and more student centred. For example, it was found that "…students' shared their real life experiences in relation to mathematics, offered alternative solutions to the mathematics problems and solved questions with less dependency on the teachers, when the teachers tried out new methods of teaching" (Halai, AmirAli, Kirmani & Mohammed, 2004, p. 139). Student outcomes – in terms of academic achievement, their classroom participation and development of interpersonal skills – were also impacted upon positively, as evidenced in the 'broader and richer classroom discourse'.

Elsewhere Halai (2004) claims that the teaching practice of a teacher was far richer with the introduction of different teaching strategies in the Mathematics classroom: the tasks that [the teacher] designed so that they were amenable to the use of concrete materials, were invariably richer and broader than the tasks taken directly from the textbook because they were usually more open-ended, and allowed for the use of students' own creative approaches to problem solving. (Halai, 2004, p. 528)

Not only was teaching positively impacted upon but it was found that students too benefited academically (the average class percentage had increased from 34% to 67%) and non-academically (improved confidence and social skills). Evidence of the latter was in the types of questions asked by the students and their increased level of participation in the mathematics classroom.

Baig & Halai (2006) is an in-depth study of students' learning mathematics rules with reasoning. The study showed that certain teaching strategies empowered the learners so that they could make sense of the mathematics rules leading to a more meaningful understanding of these rules. These strategies included a more interactive setting where students engaged with concrete materials and pictorial representations of mathematical ideas, as opposed to only symbolic forms of mathematical representations. Furthermore, a conducive environment (e.g. where students could argue, raise questions and describe their thinking without hesitation) was found to be an integral aspect in learning rules with understanding. However, field evidence reported in the study showed that concrete materials and socially interactive learning situations did not always lead to students learning mathematic rules meaningfully. The teacher had to use her critical professional judgment for an effective use of the innovative teaching methods so that mathematics rules were learnt with reasons.

In her doctoral research Halai (2001) studied the role of social interactions in students' learning of mathematics. The study was based in two classrooms in Karachi, Pakistan where a small group of students was observed respectively while doing mathematics in a setting which was set to promote mathematical discussion and argumentation as strategy that empowered students. However, these changes could not be imposed by the teacher, rather the classroom norms and practices had to change and be more inclusive of practices such as discussion and argumentation. The teachers needed to work *with the students* in a variety of ways so that taken-as-shared understandings might be developed of the purpose of the changed classroom practices. (Halai, 2001, p. 260)

Several other studies in classroom change looked at teaching strategies that promote discussion in the classroom. For example, Khatta (1995) explored the use of mathematical talk in the teaching of Mathematics. He reports that the use of mathematical talk in the classroom promotes deeper understanding on part of the students, However, he went on to identify several issues that arose in the course of promoting student talk. He found that a teacher's lack of interest in the use of innovative methods led to sole reliance on traditional expository methods of teaching Mathematics.

The teacher's lack of skill and understanding of effectively facilitating such discussion in a meaningful manner also arose as an issue. Overall, therefore, communicating ideas about an innovative strategy to teachers and facilitating them to translate those ideas into their own practice would need to take into account how teachers are enabled to do so.

A more recent action research study by Yusuf (2002) on the role of discussion in pupils' mathematical learning has revealed some promising findings. It was found that small group discussions provided pupils with mutual opportunities to communicate and listen to the ideas of classmates. During such communication it was found that pupils got an opportunity to formulate and clarify their thinking. Additionally, pupils developed mathematical language skills through participation in small groups and the whole class discussions. The teacher's role in promoting (through questions and probing) such mathematical discussion in the classroom was a crucial one. Finally, discussion helped the teacher assess students' learning through interactive discussions and appropriate on-the-spot responses.

In his small-scale qualitative study Samuel (2002) explored the experiences of two lower secondary school teachers who implemented a problem solving strategy in their mathematics classroom. Problem solving appeared to be an effective way to teach and learn mathematics as it enhanced students' participation in the classroom and enriched the curriculum content through tasks which provided a higher level of cognitive challenge to the students. However, it was found, for example, that teaching conventional content through problem solving was challenging for the two teachers because the use of the strategy entailed spending a great deal of time on mathematical problems. It was also found that designing problem solving activities proved difficult for teachers who seemed to lack the requisite knowledge and understanding of mathematics that was required to plan such activities. This finding was further compounded by the fact that the content of existing mathematics textbooks lent themselves heavily to traditional methods of teaching mathematics.

"Each of the questions in most pupils' textbooks has one right answer, is unambiguous, and the questions lend themselves to solution through known algorithms … These are the textbooks that the majority of the pupils and teachers use in their classrooms. The designing of the so called "low order questions", found in these books, calls for specialized skills. The designing of good mathematical problems requires even more specialized skills, and a deeper understanding of the mathematics content. To ask teachers to design such mathematical problems or activities is asking for too much …" (Samuel, 2002, p. 73)

Hence, Samuel contends that it is a bit 'over optimistic' to assume that all teachers will become expert in the ability to design curriculum materials consistent with the problem solving approach. The implication is that 'good curriculum materials' need to be made available to teachers if the latter are to bring about change in their teaching (Samuel, 2002).

In science classrooms also studies have looked at improving students participation and social interactions, through strategies such as cooperative learning (Jawed, 1995); investigative approach (Ahmed, 1995 and Trindade, 1998); activity-based teaching (Augustine, 1999; Kiani, 1998); promoting science learning through science language (Tejani, 1998; Jan 2003); inquiry-based approaches in science classrooms (Ali, 1998; Siraj, 2002).

Pardhan and Bhutta, (2001) conducted action research on students' questions in the context of science education in Pakistan. The study focused on the question "how can a primary science teacher promote students' questioning skills?" The researchers observed students' questioning before intervention and found that that there were a very few questions asked by the students and the teachers asked most of the questions. 70% of these questions were closed and factual questions such as: 'Are plants living or nonliving?' and 'Where do these animals live?' The second largest proportion of the questions were procedural questions such as 'Where is your journal? Have you finished your work?' The researcher found very few (2%) open and thought-provoking questions. In the intervention stage the researcher used innovative approaches according to the level of development of the students. For example, questioning about a picture, peer questioning, guessing game, story-telling and ask an expert to motivate students to ask questions. The researcher found significant differences in the classroom dynamics, students' and teachers' participation in construction of knowledge and students' questioning skills.

The study suggests that primary science teachers in Pakistan need to review their role in the teaching/learning processes in the science classroom, otherwise any attempt to bring change will not be effective.

Discrepant Events and Alternate Conceptions in Science

The role of discrepant events in learning science, and its implications for teaching and curriculum were studied by a number of researchers (e.g. Mustafa, 1998; Muhammad,1998; and Halai, 2006). Discrepant events create a conflicting situation which challenges learners' existing beliefs about a physical phenomenon. The situation is often psychologically uncomfortable for the learners who are compelled to produce alternative explanations for the phenomenon by putting in their intellectual resource. As a result the learners usually are able to develop better scientific understanding of the phenomenon.

However, these studies also found that at the same time teachers faced problems in designing discrepant events for their teaching and required a lot of time in planning and implementing the curriculum materials designed for learning through discrepant events in the classroom. Halai, N. (2006) has elaborated the process that the teacher goes through a three-stage process when teaching through discrepant events.

The first stage Halai referred to is the "wow and vow" stage where the teacher admired the successful presentation of discrepant events set by the facilitator. The teacher enjoyed the way the events produced a cognitive conflict and the way she, with the help of tutor and peers, resolved the conflict. However, Halai noticed that sometimes the discrepant event worked well and sometimes it did not work. She also noticed that the fellow teachers were at different levels of understanding at this stage. Some of them could not easily grasp underlying scientific concepts as their focus of attention was the activity rather than the teaching content.

In the second stage, which the researcher called "muddling through" stage, the teacher had to develop lessons based on discrepant events, first, to micro teach in a small group of teachers and then teach in the real classroom. The researcher noticed that the participant teacher successfully went through this stage by making two important decisions. First, the teacher selected the topic, then she chose the activity. If one activity did not work, she chose another activity but did not change the topic whereas fellow teachers had changed topics when the activity did not work. It shows that the important thing for the participant teacher was to make a plan for teaching the specific content and not to plan discrepant events per se. The second decision the teacher made was to enhance her content knowledge in the chosen topics. She made good use of the human and library resource available to her during the course. She considered that during this stage the pressure and support provided by the course tutor was extremely valuable. Halai mentioned that without going through 2-3 cycles of "muddling through" it was highly unlikely that teachers continued using innovative approaches in their teaching practices.

The third stage which the researcher referred to as "second thought" was the moment when the teacher began reflecting on how she could use newly learnt approaches in her own classroom without the support of course tutors and resources available to her during the course. Halai's study put an emphasis on professional development courses to help teachers in the process of "muddling through" to help them prepare for the "second thought" stage. The researcher suggested that a field based teacher education initiative is one of the ways to help teachers in trying out new strategies in their classrooms during the period when they are in contact with the professional development team.

Pardhan and Bano (2001) conducted a study to explore middle school (class 6-8) teacher's alternative concepts of 'direct current'. These were the concepts which did not match with "expert's concepts". The researchers compared their findings with the findings of similar studies conducted in other countries. In the study there were six teachers involved who had studied physics up to year 12 (intermediate level in Pakistan). The researchers reported that all six had 'improper' and insufficient understanding of the central concepts of electricity. However, some of these misconceptions were not different from the concepts which teachers in many other countries hold. Following are some examples of the alternative conceptions that the study highlighted:

- a battery or cell is the source of energy whereas a bulb is consumer of energy;
- a dry cell is a store of electrons and conducting wires are like hollow pipes. When a circuit is completed, stored electrons start flowing;
- when more bulbs are added in an electric circuit more electric current passes through it because more bulb means more electric current; etc.

The researchers also identified the source of the alternative conception held by the teachers in this area. Some of them were teachers because of their own schooling, reliance on the textbooks as a main source of information, intuitive ideas of teachers, use of scientific terminology (e.g. current, voltage) in everyday language. The study suggests that it is important that teachers are involved in the discussion about scientific phenomenon. In this way they can assess their own concepts in relation to what other people hold.

Strategies for Cognitive Acceleration and Conceptual Change

Iqbal and Shayer (2000) reported the results of a two-year Cognitive Acceleration through Science Education (CASE) intervention research in the context of Pakistan secondary education. The main aim of CASE intervention was to improve 12 -14 year students' formal operational thinking by providing them with conflicting situations. The theoretical foundation of CASE is partly Piagetian which emphasized that the conflicting situations encouraged young students to construct reasoning pattern of formal operations.

Another aspect of CASE was Vygotskyan which emphasized social construction of reasoning through metacognitive reflection and carefully managed use of language of thinking. There were four pillars of CASE: concrete preparation, cognitive conflict, construction and metacognition, and bridging. The finding of the research was that CASE methodology where teachers were to develop new professional skills, produced cognitive gains of the order of over 1 standard deviation and brought students up some 30 percentile points on representative population norms. However, the researchers found that the general environment in Pakistani schools was rigid and structured. Students were not encouraged to be involved in discussions and the act of asking questions by students was considered a lack of respect for the teachers.

CASE methodology was based on construction of knowledge and concepts in small groups through discussion, posing questions to teachers, answering teachers' questions and reporting to students rather than the teachers. These strategies were new for the students as well as for the teachers. In some cases teachers and students partially internalized the underlying philosophy of CASE and switched over to the old tradition of direct teaching and telling. The researchers suggested more research in this area to understand how pre-service teacher education and in-service professional development programmes could be structured to help teachers bring changes in their teaching and at the same time meet the expectation of school administration and students.

Pardhan and Wheeler (2000) described their efforts to facilitate the development of science students' conceptual understanding of content, pedagogy and pedagogical content knowledge. They devised a framework for their student teachers to adopt and implement contextually relevant material such as Primary School Teachers and Science (PSTS) project. It was a four-step conceptual change process. In the first step they conducted a 20 items pre test which they adopted from PSTS and called Science Test of Content Knowledge (STOCK) on one of the topics of school science curriculum, kinetic molecular theory. In the next step they involved student teachers in interactions with the structured material in an active manner with fellow students and tutors. Then they engaged students in reflection and discussion on how to adopt new learning to different grade levels and the interrelationship with science with other topics or science disciplines. In the final step they conducted a post test of STOCK which was also adopted from PSTS.

They found that all nine students achieved a significant gain (5-41% with average gain of 18.7%) in pre- to post-STOCK performance. In addition to quantitative achievement the researcher showed qualitative evidence of the achievement as well. They quoted statements of one of the participants from her reflective journal as, "…this programme seems to be both content- and skill-based. I am not only enhancing my scientific knowledge but I am also learning how to teach science in a real classroom situation. 'Why'? The question 'why 'is helping me to revisit my existing notions in which I gave more importance to teaching than students' learning."

The summary of Pardhan and Wheeler's research on their own teaching is that an enhancement of pedagogical content knowledge was possible if necessary conditions are provided and a support mechanism established.

To conclude, the studies in this section have identified several elements in both mathematics and science (e.g. critically reflecting on the curriculum, enhancing content knowledge, using a variety of innovative teaching and learning strategies, etc.) that have a positive influence on students' learning. At the cornerstone of this is the teacher who has a key role to play in facilitating and enhancing the quality of teaching and learning.

2.3.3 Student Achievement in mathematics and science

Students' achievement levels are low in science and mathematics. The SPDC survey 2003, conducted achievement tests in mathematics, physics, chemistry and biology from twenty colleges across the country. They ensured that all students in the sample had completed the secondary school certificate. The test results show that with pass percentage fixed at 40%, the percentage of all students who passed (40% or above) in mathematics is 19.1%, in physics 4.3%, in chemistry 7.7% and in biology 37%. Gender wise analysis shows that boys achieved a higher passing percentage than girls in mathematics, physics and chemistry, while girls performed better in biology.

The National Education Assessment System (NEAS) conducted a national level student achievement test in language (Urdu) and mathematics for grade IV students (Tests will also undertaken in social studies and science). The NEAS national achievement scores are reported on a scale of 1-1000, with a mean set at 500 and a standard deviation of 100.

This scale is the same as used in TIMSS, SAT, TOEFL etc. The 2005 national mathematics results show that grade IV students achieved a national scaled mean score of 421 in mathematics (MoE, 2005a, National Assessment Report p.10). These results show that the NEAS achievement test scores are well below the international average mathematics score 495 in TIMSS 2003. But there are four countries (Iran, Philippines, Morocco, Tunisia) whose mathematics scores are lower than the NEAS mathematics score. This comparison is only indicative and not entirely valid because of the differences in NEAS and TIMMS curriculum framework, sampling outcome and other details (MoE, 2005a National Assessment Report p. x).

In 1999 the Academy of Educational Planning and Management (AEPAM)[9] conducted a national study to measure learning achievement at primary level in Pakistan. The sample comprised 2,794 students from class V from 145 government schools (75 boys' school & 70 girls' schools) across the country. It looked at the learning achievements of the AEPAM Research Study No. 167 (Learning achievement), No.177 (Study on Access & Equity) and No.178 (Assessing and Comparing Schools for Quality) for students at the primary level in Science, Mathematics and Language (Urdu)10, to identify major factors associated with the students' performance at this level.

Main conclusions drawn from the study were:

- The mean national score in mathematics is 48% while for science it is 65% and in Urdu it is 60%. Children's performance in science is satisfactory (65%) while their performance in mathematics (48%) is quite low.
- Urban students have performed significantly better than the rural students in both mathematics and science.
- Girls performed significantly better than boys in both subjects.
- Teacher's academic qualification has a positive impact on students' achievements and it has had more influence on the performance of the urban than the rural students.
- Similarly, professionally qualified teachers (C.T. and B.Ed.) have a positive impact on students' achievement.
- Students taught by teachers having 6-10 years experience and 16 years or more experience had a strong impact on their achievement.
- The availability of physical facilities/resources in the school (boundary wall, drinking water, chalk, blackboard, students' books) has a great influence on a student's achievement. (MoE, 2002, AEPAM Study No. 167).

More recently, AEPAM conducted a study to compare school performance to understand which schools are doing better by assessing and comparing quality. This study also looked at student achievement of class V students in the country's government and private schools. Achievement tests were administered in mathematics, science and Urdu to randomly selected students. The results of this study were;

- The mean percentage score in Mathematics at national level was 48 (48% of questions answered correctly). On average, one in five students performed very well. Half of the students did not qualify the test and they got grade D which indicates that the majority of the students lack the basic competency in mathematics. This was characteristic of both the private and the government schools.

(As the focus of this meta analysis is on Mathematics and Science, results pertinent to Urdu will not be reported.)

Table 4: Grade-wise Distribution of Mathematics Scores by School Type

Grade	Public			Private			Total		
	Mean	SD	%	Mean	SD	%	Mean	SD	%
A 1: Excellent	85	5	7	86	6	12	85	6	9
A: Very good	74	2	9	74	2	11	74	2	9
B: Good	65	3	16	64	3	16	64	3	16
C: Satisfactory	52	3	19	52	3	19	52	3	19
D: Poor	40	3	19	40	3	19	40	3	19
F: Fail	22	9	30	22	9	23	22	9	28
National	**46**	**21**	**100**	**51**	**22**	**100**	**48**	**22**	**100**

Source: (MoE, 2004, AEPAM Study # 178)

- By comparison, students performed well in Science at the national level obtaining a mean score of 60. A significant difference in performance was observed between the private and government school students. The performance of girl students from public schools was better than that of boys in both rural and urban areas and the difference of the mean score was significant. Similarly, the performance of rural boys in the private schools was better than that of the rural girls and the difference of the mean score was also significant.

Table 5: Grade-wise Distribution of Science Scores by School Type Percentage

Grade	Public			Private			Total		
	Mean	%	SD	Mean	%	SD	Mean	%	SD
A 1: Excellent	86	18	5	87	24	5	86	20	5
A: Very good	74	14	2	74	12	2	74	13	2
B: Good	64	25	3	64	23	3	64	24	3
C: Satisfactory	52	18	3	52	20	3	52	19	3
D: Poor	40	14	3	41	14	3	40	14	3
F: Fail	22	11	10	23	7	9	22	10	10
National	**59**	**100**	**20**	**62**	**100**	**19**	**60**	**100**	**20**

Source: (MoE 2004, AEPAM Study # 178)

- The mean percentage scores of students studying in private schools was significantly higher than those of students studying in public schools.
- The girls performed significantly better than the boys in both science and mathematics.
- It was found that teachers' academic and professional qualifications had a positive impact on students' achievement which was more influential in the case of girl students. Furthermore, teachers' qualification had more influence on the performance of urban rather than rural students.
- A teacher's experience also had a positive influence on the achievement of pupils. Students taught by teachers having 1-5 years of experience got the highest score that was followed by students taught by teachers having more than 16 years of teaching experience.
- The availability of physical facilities/resources in the school and the level of parental education – particularly the mother's education – had a significant impact on the performance of children. (MoE, 2004)

To conclude from the above studies, a number of factors were associated with students' performance such as gender, whether they came from rural/urban contexts, the teachers' experiences and qualifications, introduction of different pedagogical approaches, the availability of resources in the school (physical infrastructure, teaching resources), the system of school, etc. Some of the major findings in these studies were:

- National level achievements in mathematics are low as compared to international standards. Results in science (e.g. SPDC survey 2003) show that students achievement are low.
- urban students performed significantly better than the rural students in both Mathematics and Science;
- girls performed significantly better than boys in both subjects; However, this finding is in contradiction with the SPDC survey (2003) and earlier reports of gender gap in student achievement (Warick & Reimers, 1995). A possible reason could be that the NEAS and AEPAM reports are based on achievement in primary school while SPDC reports are based on achievements in secondary school where reportedly the gap in teacher quality in boys and girls school is wider
- teachers' academic and professional qualifications had a positive impact on students' achievement which was more influential in the case of girl students;
- the availability of physical facilities/resources in the school and the level of parental education – particularly mother's education – had a significant impact on the performance of children;
- a significant increase in children's achievement at lower primary level after introduction of new books, textbooks and teacher guides by large scale teacher training.

2.3.4 Gendered perceptions of mathematics and science

Pakistan takes explicit account of gender in setting up and administering its government primary schools. It divides schools into those with male students with male teachers, female students with female teachers and coeducational schools with male and female students and teachers. Typically, secondary schools in Pakistan are single sex schools. Parents prefer to send their girls to a single sex school. In case where secondary schools for girls are not available, parents opt not to send their girls to a co-education secondary school. In case some private schools offer co-education at secondary levels, boys and girls usually sit in separate sections of the same class. This reflects the cultural values prevalent in the society which is segregated along gender. A consequence of this setting is that secondary school teachers have experience of teaching boys or girls. It is very rare for them to have experience of teaching boys and girls together.

A highly quoted, and ground-breaking national survey of schools (grades 4 and 5) in Pakistan researched to see if this use of gender made any difference to the achievement of male and female students in mathematics and science (Warick & Reimers, 1995; Warick & Jatoi, 1994).

The researchers selected 500 government schools, 1000 teachers, 11,000 grade 4 and 5 students and 300 supervisors all over the country through standard methods of probability sampling. The sample included 47% male, 28% female and 25% coeducational schools. The researchers gave a curriculum based achievement test in mathematics and science and a brief questionnaire to the students of class 4 and 5 of the selected schools. They conducted interviews of teachers, head teachers and supervisors of those schools.

It was found that students of male teachers had significantly higher achievement scores in mathematics than students of female teachers in the same grades. However, the study goes on to examine and provide explanations for this finding. In contrast to student gender it was found that teacher gender explained ten times more regarding student differences in their mathematical achievement. However, it was not possible to look at the independent effect of school gender on students' achievement in mathematics as the former overlapped with both student and teacher gender. As such, school gender is likely to be a proxy indicator for student and teacher gender rather than an independent influence on mathematics achievement.

The study concluded that rural elementary schools are the main source of gender gap in mathematics achievement. Their most critical deficiency is in the inability of rural schools for female students to retain women teachers with adequate training in mathematics. About 75% of the women teachers come from cities. The study goes on to elaborate the reasons and issues that women teachers from cities face when they are posted in rural areas. Also, the study reports that the gender gap in achievement in mathematics could be caused by higher average levels of education for male teachers than for female teachers (p.70-72).

The study also provides evidence that the gender gap favouring male teachers is highly significant in rural schools, particularly teachers responsible of more than one grade. It disappears or is reversed in urban setting. For teachers who have university degrees, the gender gap favours women. Female teachers, who cover more curriculum areas, have students with significantly higher achievement scores. It implies that students' achievement depends not only on the education of the teachers and the location of the schools but also on how the teachers actually teach mathematics.

The study highlights the deficiency of rural elementary schools as the main source of gender gap. The female schools in rural areas generally failed to retain women teachers who are adequately trained. Well qualified women from urban areas do not prefer to teach in rural areas because of the challenging living conditions and also they do not receive any incentive for being transferred in to rural areas.

While this study is somewhat dated, the findings are still relevant because the discussion in the section on Context and Background shows that gender disparities in access, provision and quality of education still persist. A recent World Bank country gender assessment report (2005) highlights two most important constraint factors that impede female access to education. Only 46% of the sample villages in Sind and Punjab had had an elementary girls' school inside the village. In contrast 87% had a boys' elementary school within the village.

Bikak (2003) studied the extent to which girl students in Pakistan had freedom to select science subjects (which includes a study of advanced mathematics) for their further study. This study shows that there are several inhibiting factors which influence girls' selection of science as the course of study. These include: perception of science as a difficult discipline, meant for boys to study; curricula which are not contextually rooted; cultural tradition of early marriages for girls and therefore not opting for science which is closely correlated with career advancement; lack of awareness among girls (possibly also boys) of the career options available to science graduates (Bikak, 2003, p.59).

These factors, which have an impact on the girls' selection of the sciences as an area of further study, are rooted in the culture and traditions of the society and have implications for girls' better employment and contribution to poverty reduction.

Halai, N (2004) used the life history of a young female science teacher in urban Pakistan to understand various aspects of teachers' professional and personal lives. She identified five significant elements in the teacher's personal history which are as follows:

- observation is independent of theory
- science is a received knowledge
- science is a superior, value free and stable way of knowing
- science education is a matter of enculturation into the language of science
- science is a masculine subject

Through Munazza's (pseudonym of a female research participant) life history Halai N.(2004) described a female teacher's perception about male students' participation in the science classroom which, to a great extent, reflects the perception of a patriarchal society. For example, Munazza considers that teaching boys is more challenging and rewarding because they have a better understanding of science and ask lots of questions. These questions, in a coeducational setting, help female students to learn from the students of the opposite gender and also push teachers to prepare better for the teaching. Munazza is also proud of the fact that she teaches boys because she thinks that it is more likely that her male students will join valuable professions such as medicine and engineering. So she thinks that she could contribute to the welfare of the nation by producing good human resources through teaching science. Though Munazza has an understanding that 'boys know better than girls do', she did not think that this is their innate quality; rather she thinks that boys are better because they 'go out'. As Munazza thinks that the girls do not have many opportunities to learn science from their everyday experiences she gives especial attention to girls in the class and advocates that this 'preferring treatment is more gender appropriate in Pakistani cultural context.'

Munazza's story reflects the transition which the patriarchal society of Pakistan is going through. In the country, boys have better opportunities of learning science, so it is likely that they will perform better in schools which provide them with opportunities for higher education and further advancement in their career. However, Munazza represents the group of female teachers who recognize this gender disparity in the society and work to overcome the gap by encouraging females through their empathetic behaviour to get female children more involved in learning science. Further research is needed to explore whether it is true that boys outperform the girls in the science classroom and if so, what are the reasons for that.

Halai, A. (2006) has similar findings related to gendered perceptions of mathematics. She conducted a survey of a cohort of mathematics teachers' beliefs about boys and girls as learners of mathematics. Findings showed that 86% of them agreed with the proposition that boys were better mathematicians. The reasons given were twofold. Boys were better and hence, they came to be better mathematicians by default (nature). Additionally, teachers also saw boys as better mathematicians because of the different manner in which they were nurtured and their different experiences as a consequence of socialization into culture (nurture). That is, the different role expectations of boys and girls provided each with a unique set of experiences that seemed to prepare boys differently for mathematics as compared to girls. Hence, boys 'want to apply' their learning to 'different contexts' because of their participation in activities like shopping for groceries, etc. while girls want to 'rote learn' and 'follow rules' because they are expected to stay at home and be obedient. In the mathematics classroom, therefore, male superiority is translated into boys being better mathematicians.

Gender Bias and Textbooks

Halai (2006 reported earlier) included a review of the mathematics textbooks prescribed by the Sindh textbook board. She maintains that she analyzed these textbooks in particular because these not only follow the national curriculum guidelines but are also prescribed for government schools, which is likely to have a substantial impact on the teaching and learning of Mathematics in Pakistan. Her findings show that boys are favoured in Mathematics classrooms in Pakistan, in terms of content and layout of the officially prescribed textbooks. She goes on to show that examples that are offered to teach, say 'word problems', are favourably biased towards boys (e.g. formulating questions on 'cricket', 'batting averages', etc.). Table 6 depicts gender bias in elementary Mathematics textbooks in Pakistan.

Table 6: Gender Bias in Mathematics Textbooks

Topic/class Word Problems	Percentage Class VIII	Percentage Class VII	Ratios & Proportions Class VI
Number of word problems in the chapter	41	51	33
Real World Setting	Taxes, Commission, Business (profit/loss), Zakat	Taxes, Commission, Business (profit/loss), Zakat	Partnership, Inheritance, Proportions in other everyday settings
Reference to males through nouns or pronouns	31	49	29
Reference to women (nouns and pronouns)	4	2	4
Problems that were gender inclusive or neutral	6	-	-

Source: Halai (*2006*)

Ashraf and Shah (2006) have also conducted an extensive and systematic textbook analysis from classes I to V of the Sindh Textbook Board from a gender perspective. Their findings also confirm and further extend those of Halai (2006) shared above. Their analysis reveals the following representations for boys/men and girls/women which reflect the gendered dimensions of the roles and responsibilities of women, and the implicit gender bias in the mathematics textbooks:

- frequency of fe/male characters in illustrations - they found that the number of female illustrations depicted was greater (i.e. 89 females compared to 61 males). In contrast, there were more frequently cited male characters in texts (123 males in comparison to only 49 females). Additionally, men have been portrayed as more powerful in terms of:

- variety of professions that they are able to take (females have been depicted in 4 professions as compared to males who represent as many as 12 different professions);
- variety of attire (Males are seen to wear a variety of attires that suit the jobs that they perform. On the other hand, females are shown to be wearing shalwar kameez on each and every occasion irrespective of the nature of their jobs)
- Males were shown to be using 'technology' (e.g. operating a computer; riding a motorbike) on six occasions whilst females were depicted in a similar role merely once. Thus, access and variety of technologies are represented to be more characteristic of males.
- Females are shown to participate in games less often (n=2) while males are portrayed more frequently (n=12) in similar activities.
- males are depicted slightly more frequently (i.e. 26 times) in different locations as compared to females who are shown 19 times. This 'locus of activities' has some important gender implications. It suggests that males have more access and mobility to different places as compared to females who are generally homebound and have limited access. Hence, males are seen to have more opportunities than females to socialise.
- Male names have been used more frequently (n=111; 73%) as compared to female names (n=41; 27%). Similarly, the names of males have been capitalised on more occasions (n=128; 69%) in comparison to the names of females (n=55; 31%).

Such bias is likely to suggest a greater involvement of males in mathematics.

- Furthermore, the different types of male and female possessions are also brought out. Boys have been depicted alongside tractors, cars, robots, etc. that imply training for their future role as men. In contrast, girls have not been projected in such a futuristic role preparation as women. (Ashraf & Shah, 2006)

An implication of these findings is that continued gender disparity in mathematics classrooms has meant that girls are denied the opportunity to engage in a positive manner with mathematics and to accrue the benefits from opportunities that advanced study of mathematics could yield.

2.3.5 Language of instruction in mathematics and science

Pakistan is a linguistically diverse country with over 300 dialects and approximately 57 languages spoken throughout the country's four major provinces (Khan, 2002). While Urdu is the country's national language, it is the primary language of less than 10 percent of the population (Laporte, 1991). English is the preferred language of education and is most often recognized as the language of the elite and the ruling class. Pakistani schools that use English as the medium of instruction are called English medium schools. They are found in both urban and rural areas. Students in Pakistan's English medium schools learn their subject matter content and the English language simultaneously and are expected to become proficient in both. According to Khan (2002) and Haque (2002), almost all Pakistanis prefer to study in English medium schools because it is seen as a language that opens the doors to professional and academic opportunities.

Halai A. (2007) showed that students in reform oriented mathematics classrooms where group work and social interactions were promoted, translated back and forth between the language of instruction and the learners' national language (Urdu). This translation was particularly evident when students worked with each other in small groups. In situations where students were reporting their group work to the whole class or where they interacted with the teacher, they reverted to English or resorted to Urdu after seeking permission from the teacher. She goes on to suggest that students' code switching could be seen as a resource which enables students in a multilingual classroom to learn meaningfully.

Jan (2003) confirmed the earlier study by Halai but in the context of science teaching, the school policy of teaching science in English as a medium of instruction was followed. However, the teacher and the students resorted to translation into Urdu of certain key ideas and concepts. His findings show that there is a *"language of science consisting of symbols, pictures, diagrams, and other materials and mathematical representation which is not easy for students to learn themselves*" (p.60).

Panah (2000) focused on primary school science teachers' perception and practice regarding teaching science through English, which was a foreign language for most of the students. He observed that teaching science through a foreign language was very challenging when the students were not able to communicate because of lack of language proficiency. In that situation children could not participate in classroom activities and became passive listeners and teachers would just give lectures and translate the textbook material into the children's language. As students could not express themselves in English, during classroom teaching and in the examination they relied on rote memorization. Despite the difficulties, teachers and students perceived that it was important to learn science in English medium as it contained science terminology which would help the students in higher education. Panah mentioned that the "students felt superior because of being taught in English while Urdu is considered as low status language". In this situation mixed language strategies evolve which are beneficial for both learning science content and the development of proficiency in foreign language.

2.3.6 Concluding Remarks and the Way Forward

The review of the state of knowledge in mathematics and science education in Pakistan highlights certain factors that contribute to marginalisation and poverty in teaching and learning of mathematics and science. These include,

- cultural factors such as gendered dimensions of roles in the society, leading to gender disparities in provision and quality of science and mathematics education for boys and girls;
- ideological factors in curriculum reform, so that issues of legitimacy of knowledge are closely aligned with people's religious beliefs, leading to a potential alienation of learners from the classroom science and mathematics;
- issues of language of instruction and language of learning which play their role in including or excluding learners from accessing mathematics and science ideas and concepts;
- issues of incompatibility between content and processes of teaching and contextual realities and needs of learners which make education ineffective to bring about change in the life of the learners or the communities they live in.

The findings and discussion of the studies reviewed above highlight several issues in mathematics and science education in the context of classrooms in Pakistan and provide insights that could be of value for a study on implementation of a new curriculum in the area of mathematics and science. Key issues that need to be taken into account when implementing a curriculum that is aimed at reducing poverty would be to enable the teachers to interpret the curriculum so that its essence in terms of gender inclusiveness and providing intellectual challenge to students is realized. Such a change in the curriculum is meaningful if the teaching is appropriately modified. For example, it was found that the existing curriculum content due to its 'prescriptive' nature lent itself heavily to more traditional approaches to teaching. Implementing the new curriculum would entail innovative teaching strategies so that teaching reflects the content and skills outlined in the curriculum.

Teachers' own levels of preparation and understanding of mathematics and science were identified as a significant issue that needs to be taken into account if mathematics is to be taught for problem solving and development of higher cognitive skills. Similarly, it is pointed out that gender bias is prevalent not only in the prescribed curriculum materials but in teachers' own perception of these disciplines as male. However, studies (e.g. Bikak 2003 & Halai 2002) caution that gender issues are rooted in the culture and tradition of the society so that concepts like "gender sensitive curriculum" need to be unpacked and seen as being co-opted from the Western notions.

In addition to that, teaching for conceptual understanding of mathematical concepts would also entail a careful re-examination of the aims of the existing mathematics curriculum and the way in which it is designed. Finally, teachers would need to reconsider the ways in which they assess their students so that the latter are given credit for offering a variety of responses as opposed to conventional 'one method' solutions.

Several issues discussed with reference to change in science and mathematics curriculum and teaching and learning show clearly that curriculum development takes in life in the reality of the classroom. And the teacher is a key player in the classroom.

Finally, as noted earlier in the paper, in Pakistan the recent review & revision of the national curriculum in mathematics has led to five standards one of which is "Reasoning and Logical Thinking" (Ministry of Education, 2006, Mathematics National Curriculum grades I-XII). To put this curriculum reform into the policy context; beyond 2011, English would be the language of instruction in mathematics and science in all classrooms at the class VI and above. A direct implication for mathematics teachers and teacher educators is to enable students to become proficient in communicating mathematics ideas and relationships through various oral and written approaches in the English language. But, findings suggest that factors, processes and developments that apply to mathematics learners in multilingual classrooms should be different from those where learners use their first language to learn mathematics.

The way forward for a research programme in science and mathematics curriculum would certainly need to take into account these issues and complexities:

- Recognise the centrality of the teacher in the implementation of a new curriculum and empower the teacher through critical reflection on issues which inhibit students' learning of mathematics and science.
- Enable teachers to interpret the national curriculum for a conceptual learning and not banking and memorisation of facts. Promote problem solving, critical thinking and reasoning in mathematics and science as means to reduce poverty.
- Develop and promote gender sensitive curriculum materials, enable teachers to practice a gender inclusive pedagogy and become aware of implicit gender bias in the curriculum, curriculum materials and generally in the society.

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SECTION 3: IMPLEMENTING CURRICULUM CHANGE TO FIGHT POVERTY AND PROMOTE GENDER EQUITY: MATHEMATICS AND SCIENCE EDUCATION IN SOUTH AFRICA

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3.1 Introduction

This review seeks to identify key themes and priorities relating to implementing curriculum change to fight poverty and promote gender equity, with a special emphasis on the key subjects of mathematics and science. The project thus has three Quality themes considered within the fields of mathematics and science education:

- fight poverty
- promote gender equity
- implement curriculum change

The review falls within the general objectives of the RPC programme, whose overall aim is to determine global priorities for raising education quality and indicators that may be used to measure quality, particularly for low-income countries. However, a specific focus of this part of the review is on key issues from an African perspective. Thus, the following key question arises from the general focus of meeting the millennium development goals from an African perspective:

- How can curriculum change in science and mathematics education be implemented in a way that is most relevant for Africa, particularly focusing on situations of poverty and on promoting gender equity?

The specific objectives of the literature review, focusing on their relevance for Africa, are to:

1. identify key themes and priorities relating to educational quality;
2. contribute to the development of key indicators of educational quality;
3. develop shared understanding of issues relating to implementation;
4. indicate the methodological approach the project should take.

To address these objectives in relation to the three elements of the project, and to work with the different areas of expertise of the contributors, this review is organised as follows:

3.2 Education reform and social development in Africa
3.3 Implementing curriculum change in science education in low-income countries
3.4 Some issues concerning mathematics education and poverty in low-income countries
3.5 Gender issues in mathematics and science education in low-income countries
3.6 Towards a way forward

This review will includes critical perspectives on mathematics and science education curriculum change in Africa. It draws on research concerning mathematics education and science education although to different degrees in each section. Thus each section should be seen as illustrative, with the aim of identifying issues, rather than as comprehensive. Issues discussed in the context of science education, for example, are likely to be equally relevant for mathematics education.

Literature has been reviewed with a particular focus on low-income countries, although research from middle- or high-income countries has also been referred to where there may be relevance to the project.

3.2 Education reform and social development in Africa: the centrality of teachers

3.2.1 Global context

The past half-century has seen some of the most significant attempts to change the education systems in many countries, especially in Africa. After many countries in Africa gained independence in the 1950s and 1960s, there was a period of much optimism around economic development in the former colonies. This optimism was associated with a belief that education would result in economic growth and the development of human resources in these parts of the world. African leaders made a conscious effort to reverse the discriminatory education policies they had inherited from their former colonizers and to transform school curricula towards greater social and economic relevance (Sékou Touré 1961; Nyerere 1968). Countries that gained independence more recently, such as Zimbabwe and South Africa, have been even more explicit in their formulation of education policies aimed at promoting access to educational opportunities for previously disadvantaged groups.

Global initiatives, particularly the Education for All (EFA) movements and the Millennium Development Goals (MDGs), have led to a push towards even greater expansion and a growing focus on equitable provision in Africa. Investment in education has grown substantially, largely as a result of external support and a universal focus on previously disadvantaged groups within society. As a result, many countries in Africa have come close to achieving Universal Primary Education. By 2001, many countries in Sub-Saharan Africa, including some very poor countries such as Lesotho and Malawi, were reported to have achieved Net Enrolment Rates (NER) of over 80% in primary education (UNESCO, 2005). However, Lesotho, Malawi and Togo were also reported to have Gross Enrolment Rates (GER) of well over 120%. This suggested that vast numbers of learners stayed on in the education system well beyond their official ages for their levels, possibly because of huge inefficiencies in the education systems. One indication that focus on access has put pressure on quality is the low proportion of new teachers who were reported to have met national standards in countries such as Lesotho (11%) and Togo (2%), possibly due to the trend to recruit unqualified teachers in order to meet expanding levels of enrolments.

The UNESCO report cited above further argues that education quality, particularly in the areas of mathematics and science, is a good indicator of future productivity. It supports this position by citing evidence from countries that have made huge progress in achieving quality education such as Cuba and Finland as having invested substantially in their education systems, particularly in the training of teachers. This is in spite of global debates about the returns of investing in education (see Harbison and Hanushek, 1992).

In South Africa, economists such as Van den Berg (2004) have argued that the quality of outputs in the form of good pass rates and satisfactory completion rates has remained *unaffected* by the substantial redistribution of resources (the increase in inputs) that has taken place in the poorest quintiles of South African schools since 2002. This apparently depressing finding should however be weighed against the fact that the increases in inputs are very recent and may not yet have had time to take effect, and that the *measurement* of outputs (principally Senior Certificate examination results) may be inadequate. Furthermore, case study research in poorly resourced rural schools in South Africa indicates that 'poorly-performing schools tend to have extremely unsupportive social contexts' (Musker and Narsee, 2002, p. 20). Such findings confirm international findings from Carnoy and Marshall's (2004) recent study 'Comparing Cuban Primary Students' Academic

Performance with the Rest of Latin America' which strongly suggests that societies demonstrating a high degree of social equality and cohesion are more likely to achieve high education output levels in public education.

Debates about social and economic returns from investing in education have raised questions about which input to focus on in education. Despite conventional wisdom that school inputs make little difference in student learning, a growing body of research suggests that schools can make a difference, and a substantial portion of that difference is attributable to teachers (Fuller, 1999; Darling-Hammond, 2000). Students who are assigned to several ineffective teachers in a row have significantly lower achievement and gains in achievement than those who are assigned to several highly effective teachers in sequence (Sanders and Rivers, 1996). Teacher effects appear to be additive and cumulative, and not generally compensatory.

3.2.2 Teachers at the centre

In Africa, studies about which characteristics of schools have the greatest effect have revealed interestingly similar findings about the centrality of educators, together with good school management, particularly in poorly resourced schools (Musker and Narsee, 2002). Concerns about the state of teachers in South Africa, for example, have, however, been raised consistently in the past by, for example, the NEPI Report (1992) and the National Teacher Audit (Hofmeyr & Hall, 1996). These reports all document the need for greater coherence in the in-service training of teachers and better support structures. It is clear that providing the *right kind* of teachers is of crucial importance to achieving quality and equity within the South African education system. It is not just a question of numbers, but of quality educators. The research by Musker and Narsee (2002) supports the 'teacher quality' argument, since key factors in school performance relate to the importance of school managers and teachers in making a difference particularly in poorly resourced schools. In their study of well-performing and poorly performing South African schools (all of which were in the poorest quintile), they present the following 'strongly triangulated' findings:

- *Characteristics of school management*: In well-performing schools, the principals are generally perceived by staff to be good managers, and are specifically seen as good managers of human relationships who manage crises competently. There are high levels of punctuality among learners and teachers, which seems to be attributable to firm management policies and practices. Good relationships prevail among stakeholders.
- *School management practices*: In well-performing schools, principals have good administration systems and ensure that key documents are readily available. However, they are not only 'administrators' but also 'curriculum managers', giving active support to the learning and teaching process. They also encourage teachers to attend DDSP training programmes.
- *Characteristics of teachers***:** In well-performing schools, teachers' morale is high; they are satisfied with their jobs, and they maintain good levels of discipline.
- *Practices of teachers*: In well-performing schools, educators are punctual and consistent in their attendance at work. They give learners homework regularly and check this homework. They are good motivators, giving encouragement to the class as a whole and to individual learners. (Musker and Narsee, 2002, p. 49).

In South Africa, there has been a proliferation of research questioning the quality of teachers, with a tendency to generate negative conclusions. This is perhaps to be expected given not only the apartheid legacy but also the subsequent history of teacher experiences in the years immediately after the achievement of democracy. South Africa in 1994 was far behind other developing countries in educational achievement and literacy and numeracy levels, and the post-apartheid experience has often had unintended consequences which disempower teachers, despite (and also because of) the educational merits widely recognized in the Revised National Curriculum Statement

(RNCS). The Presidential Education Initiative (PEI) Report (Taylor and Vinjevold, 1999) is particularly critical of teachers. It suggests that South African teachers' conception of their activity is superficial and that their subject knowledge is weak: "teachers' knowledge of key mathematics and science topics at the Grade 5 to 7 levels is little better than that of their pupils …" (p. 141). The report cites incidents in which teachers missed discrepancies noted in learners' understanding and even gave learners misleading information such as "when a teacher told learners that expanded notation is when the number gets bigger" (p.139). This bleak picture regarding teachers' knowledge was confirmed by the Review Committee for Curriculum 2005 which reported that many teachers have a shallow understanding of the curriculum and that there is a wide gap between "what teachers say they know and what they actually do in their classrooms" (DoE, 2000, p. 78). Again, this is to be expected given the lack of emphasis put upon subject knowledge during the apartheid era, and the subsequent inadequate training provided for the very demanding and entirely new approach represented by the RNCS (DoE, 2000).

Criticism of teachers obscures important issues, however, such as the difficult, resource-poor conditions in which most teachers operate. It ignores the role played by overcrowded classrooms, neglected buildings, poor management and support structures in demotivating educators (Chisholm, 1999). The attack on the quality of teachers also often downplays the complex and often difficult conditions in which teachers operate and their calls for support in the form of effective and cohesive professional development programmes on specific activities such as assessment (SADTU, 1999).

Much of the weakness in the quality of teachers in South Africa can be blamed on the apartheid teacher education system. But it is also worth noting that the voluntary severance package (discussed below) further decreased the availability of subject specialists, as well as leading to a great deal of uncertainty and the lowering of morale amongst teachers. The over-supply of teachers can be put down partly to the independence of teacher training institutions from central control over student intake (Steele, in Lewin, Samuel and Sayed, 2003), together with the lack of perceived availability of other professional career paths particularly for young women dating from the apartheid era, leading to a situation where, by 2000, there was a large pool (approximately 50,000) of unemployed teachers (mostly trained as primary school teachers) and a shortage of approximately 10,000 subject specialist teachers (especially in mathematics, science and languages) in the secondary grades. (Parker, 2002, p. 4)

The grave situation around the quality of and retention of mathematics and science teachers is not peculiar to South Africa. Most countries studied under the DfID funded MUSTER programme, reported high attrition rates accompanied by increased demand due to expansions of enrolment rates (Lewin & Stuart; 2003). For example, Lesotho was reported to be producing very few teachers at a very high cost. As a result, a high proportion (estimated at a quarter) of the teaching force is untrained, with the situation expected to deteriorate as enrolments increase due to the new policy on Free Primary Education (FPE). Malawi's situation has already reached critical proportions with a pupil-teacher ratio of 65:1, a high proportion of untrained teachers (about half) and an attrition rate of more than 10%.

3.2.3 Implementing curriculum change: Curriculum 2005 in South Africa

It is worth dwelling a little on Curriculum 2005 because it brings into sharp relief the challenges of curriculum reform. The implementation of Curriculum 2005 came as almost a necessity. Seen as 'the pedagogic route out of apartheid education', Curriculum 2005 emphasised achievement and outcomes by all at different paces, a break away from the content-laden, prescriptive apartheid education system (Chisholm, 2003, p. 3). Enormous challenges were observed around enabling teachers to recontextualise their adoption or 'take-up' of curriculum in their different contexts and related practices (Adler, 2002). It became evident during an evaluation of a teacher development programme at the University of the Witwatersrand that teachers' appropriation of conceptions of ‘good’ practice advanced by Curriculum 2005 was uneven across contexts (Adler and Reed, 2002). Their study provides evidence to show how, for example, in taking up dominant messages to increase exploratory talk in class, teachers struggled to complete the journey from informal exploratory talk to formal discourse-specific writing in English. This observation has been supported by findings from other studies where teachers were notably unable to assist their learners in translating their informal activities into formal scientific concepts (JET, 2001).

The complexity of language in science and mathematics instruction is dealt with in Section 4. However, it is worth briefly discussing a significant contradiction around the use of language here, in order to illuminate the challenge of curriculum reform. It has become accepted that the use of home language can be a powerful tool for enabling learners’ construction of meaning across subjects, including mathematics and science (e.g. Adler, 2001; Setati, 2005). Adler (2002) describes how, in spite of having espoused the potentials of using home language, they came to observe a continuing emphasis on the use of English language even where this appeared to disadvantage learners whose first language was not English. A deeper analysis of this contradiction revealed how in non-urban areas, English in and around the school was like a foreign language, used only inside the classroom and rarely heard or spoken anywhere else. Because there is very limited English infrastructure in the surrounding community on which teachers can build, exposure to English is via the teacher. This puts pressure on teachers to use English as much as possible (Adler et al., 1999). One notable lesson from this study is that, in popularizing ideas such as exploratory talk and learner-centred teaching, we need to use research to pause and consider whether the good ideas being promoted are working for the benefit of the learners they are intended for or whether it serves to disadvantage them.

As well as making connections, Curriculum 2005 advocated a less instructive role for the teacher and greater involvement of the learners. Evidence from South Africa has revealed how some of the most effective lessons may be described as teacher-centred. For example, in a rural, under-resourced, South African classroom, one teacher who appeared to make the most notable impact on her learners took a very instructive role in her teaching (JET, 2002). An interview with the teacher revealed her level of awareness of the necessity to explicitly provide opportunities for learners to engage with formal scientific concepts in a context where the learners’ own limited backgrounds and the school’s scarce resources would allow for learner exploration. Generalizing ‘good’ practice as either ‘learner-centred’ or ‘relevant’ ignores the nuances of the variety of contexts in which teaching and learning take place.

3.2.4 Concluding remarks

The work discussed above highlights three important factors in the quality of education which must be addressed in any implementation of curriculum change:

1. Teachers are a central to educational quality and development.
2. There are many challenges facing teachers, including issues of poor subject knowledge, poor prior training and experience and difficult working conditions.
3. Curriculum development needs to be context sensitive and avoid simplistic generalisation that can often have inadvertently detrimental effects on the most marginalized students.

Any curriculum change proposed by this project must take account of this context.

3.3 Implementing curriculum change in science education in low-income countries

3.3.1 Introduction

It is not unreasonable for developing countries to consider the role that science and technology can play when seeking to improve their economic performance. It is then a short step to look at the school system and its potential to supply scientifically skilled and literate students able to contribute to that improvement. As a result of such reasoning the history of educational development in developing countries is littered with curriculum improvement programmes that broadly speaking are importations of Western Modern Science (WMS). Success in implementation is highly variable. A World Bank report published in the late 1980s (Verspoor, 1989) documents well this variable success in a period between 1965 and 1987. More recent literature (see for example Rogan and Gray, 1999 and Rogan and Grayson, 2003 in respect of C2005 in SA), suggests that many of the factors identified by Verspoor (ibid) appear to remain unheeded.

This short review of some of the literature published since the World Bank report in 1989 reports briefly on some of the central issues that continue to concern researchers in respect of how school science might best be oriented and configured in order to fulfil the aims set for it by governments of developing countries wishing to improve their economic position.

3.3.2 Issues for a research programme in science education in developing countries

Over the last 15 years or so, key commentators on science education in developing countries (e.g. Jegede, Ogawa, Okebukola, Ogunniyi) have explored in depth the various problems encountered with the implementation of Western science curricula. In 1999 the Journal of Research in Science Teaching dedicated a special issue to 'Science education in the developing world' (see Gray, 1999 for an overview). The purpose of the issue was to bring together the expertise of a range of researchers and commentators who could bring to the fore the stumbling blocks that seemed to be constraining successful transfer of WMS curricula to developing countries. What follows below is a summary of some of those issues that ought to be included in any research programme in developing countries that looks to make recommendations about the place and the nature of science education into the future.

3.3.3 The universalism (or Eurocentrism) of Western Modern Science

There is widespread concern about the way Western Modern Science asserts for itself as a knowledge-based system of thought. Often referred to as the hegemony of WMS, the debate centres on the way that WMS positions itself in relation to other knowledge-based systems of thought. In effect WMS, chooses to appropriate or absorb those aspects of other systems that it perceives useful but remains at best uninfluenced or unperturbed by the means by which that knowledge has been obtained or at worst simply rejects those means. (See Cobern and Loving, 2001)

3.3.4 The tension between WMS and indigenous knowledge (IK)

Much has been written on the tension between WMS and the cultural traditions of many developing countries. (See Okebukola, 1988, for one of the earlier commentaries). In this and other studies it is reported that WMS is seen as irrelevant to the traditional life (often village life) where the 'old ways' developed through generations of trial and error have produced more effective mechanisms in managing rural life. It therefore seems that some individuals are comfortable holding apparently contradictory beliefs about science, i.e. almost in parallel, such that for example the notion of causation in WMS is accepted whilst at the same time holding beliefs about the spiritual world that assign phenomena to more mystical roots. (See Shumba, 1999, who found that many educated Zimbabweans will at times of uncertainty fall back on their beliefs derived from their indigenous African culture.)

3.3.5 Epistemological pluralism and the role of indigenous knowledge

There is no tradition in the education systems of non-Western societies to offer any critical interrogation of Western science. In respect of this, Snively and Corsiglia (2001) argue strongly for proper recognition to be given to culture-based knowledge systems in non-Western countries and that WMS should position itself to be informed by such knowledge on equal terms. They offer examples of IK which they term traditional ecological knowledge (TEK) and argue for the legitimacy of the knowledge base. In contrast, Cobern and Loving (2001) warn of the hegemony of WMS and argue that IK (or TEK) can best be attributed appropriate status by accepting IK on the basis of epistemological pluralism. In this way, TEK can be used to inform WMS.

3.3.6 IK and school science

It is clear from the literature that many curriculum reforms in developing countries involving science education have paid little attention to the potential contribution of IK to enhance the success of curriculum implementation. Waldrip and Taylor (1999), for example, maintain that enculturation tendency of WMS to the scientific worldview results in the separation of the majority of students from their traditional beliefs and practices. Cobern and Loving (2001), would argue that IK should be seen as a tool for learning about culture-laden nature-knowledge systems and that students should be helped to understand that all knowledge systems are culture laden, including WMS.

Acknowledgement of this would have considerable implications for teacher training and the development of a new pedagogy for science education. More radically, Carter (2004) suggests there is a severe mismatch between science taught in African schools and African culture and that re-reading science educational discourse through postcolonial theory would re-establish the importance of cultural diversity.

3.3.7 Cultural practice and schooling; differing worldviews

Traditional practice causes students to behave in ways that highlight differences between indigenous thought and the practice and Western science (Shumba, 1999). Many studies confirm the difficulty that young people have when required to assert themselves within the classroom (see Peacock, 1995). One example is the questioning nature of science which students and their teachers alike find problematic. Another is the causal reasoning processes that form the basis of WMS which conflicts with traditional attributions of effects to ancestral or spiritual causes. Indeed, the situation is not helped when science teachers do not clearly distinguish between scientific and traditional worldviews (Shumba, 1999). Arguably, science teachers should be aware of their own inclination and commitment to their indigenous culture and how this may consciously or unconsciously be interacting with their pedagogical approach to science education. Aikenhead and Jegede (1999) in their article explored the transition between a student's life-world and school science as a *cultural border crossing.* They identified four categories of increasing difficulty with respect to transition; *smooth, managed, hazardous* and *impossible*. In addition, they examined the cognitive conflicts the students experienced and proposed a number of recommendations that educational policy makers might bear in mind when attempting curriculum reform.

3.3.8 Language and learning

Lemke (1990) puts this point very succinctly – learning science in a foreign language: it is as if it were twice removed from the subject matter. Most often English is the medium of instruction and strict adherence is paid to ensuring the mother tongue is not utilised. Parents too have expectations that their offspring will learn English (it is seen as a high status language) and are disappointed if this not the case. Dlodlo (1999), among others, has explored students' learning in science and come to the conclusion that eschewing the mother tongue hinders comprehension rather than enhances it. To this effect he has constructed a nomenclature for physics terms in the Ngani language. For Zimbabwe where there are only two indigenous languages, this may be feasible. Across the African continent where some countries may have in excess of 200 languages this may be less practicable. Nevertheless, the students themselves are clear that Lemke has a point, and that without mother tongue support, understanding of science concepts will never breach the rote learning level.

3.3.9 Access to work

The point made at the outset of this review that economic prosperity, curriculum reform and science education are inter-related is often raised as the justification for curriculum reform. The question some researchers have asked, however, is which comes first. Does the ready supply of a skilled and knowledgeable workforce force the engine behind technological change, or is technological change itself the motivation for students to engage in science education? To answer this, Dzama and Osborne (1999) investigated whether the improvement in the performance of students in science in Malawi succeeded rather than preceded industrial and technological development. They concluded that the job market needs to be in place first. In other words students need to see that the time and effort required to succeed in mastering science was only worthwhile in effect if they could enhance the income of their families by succeeding in the job market. Families were disappointed if this was not the case and thus saw an education as an irrelevant pursuit if no material benefit accrued. This finding, too, has important consequences for science curriculum reform if it is clear that success in the job market is likely to be confined to a tiny minority of students.

3.3.10 Implementation of curriculum reform

Rogan and Gray (1999) and Rogan and Grayson (2003) have studied the implementation of the outcomes based education reform instituted in South Africa under the title of C2005. Despite all best intentions to bring South African science education into the 21st Century, the reforms have not achieved the success planned for them. Rogan et al offer a range of insights into why this might be the case, identifying in particular the lack of attention paid to the implementation phase. This seems all too surprising given the very clear analysis given by Verspoor some 10 years earlier. Rogan et al then propose a model of science curriculum implementation which uses Vygotsky's concept of the zone of proximal development as a means of thinking about how steps should be provided by those responsible for curriculum innovation that would make implementation at least feasible.

Other studies of various programmes of curriculum change and teacher development provide further evidence that where these processes do not involve teachers from the outset, they are much less likely to succeed and conversely, where approaches can be found to involve teachers, programmes are likely to be more successful (e.g. in Botswana, Koosimile, 2005; in Indonesia, Thair and Treagust, 2003; in mathematics in Malawi, Mwakapenda, 2002; in Sri Lanka and South Africa, Peacock and Rawson, 2001; in South Africa, Motala, 2001). Thair and Treagust (2003) argue that such programmes need to avoid positioning teachers as 'dependent and reactive', seeking instead to empower them.

3.3.11 Concluding comments

In the sections above, I have tried to draw out some of the debates that are germane to the establishment of a research programme for science education in developing countries. The oft repeated phrase that change is a process rather than an event is apt with respect to curriculum change in developing countries. It is clear from the literature that the point is well understood by most players in the process – the problem is that to do it properly is expensive. In principle, curriculum change in non-Western cultures is no different from curriculum change being required of Western educational systems, only the constraints are different and possibly considerably more complex.

The issues discussed in this section in the context of the science curriculum give a sense of some of the broad issues involved in curriculum development. Any curriculum, however, is more than a set of guidelines or prescriptions; any curriculum comes into existence through classroom processes. In the next section, some of these processes are discussed in the context of mathematics education.

3.4 Some issues concerning mathematics education and poverty in low-income countries

3.4.1 Introduction

In this review, a broad definition of poverty is adopted, incorporating material or economic disadvantage, but also including social marginalisation and disempowerment. 'Tackling poverty' therefore includes finding ways to empower people to address important issues and needs in their lives as well as to improve their material circumstances. Education, both in terms of students' learning and teachers' professional development, is an important means through which the process of 'tackling poverty' can be developed.

In the field of mathematics education, there have been various attempts to understand links between poverty or social marginalisation and mathematical achievement. In southern Africa, Howie and Plomp's (2002) analyses of South African data from the Third International Mathematics and Science Study (TIMSS) indicates correlations between mathematics attainment and socio-economic status and language background.

Both of these factors are closely related to race (Reddy, 2005). Thamane et al. (2003) also found links between levels of nutrition and students' performance in mathematics, also in South Africa. This work suggests that there are complex factors both internal and external to schooling which influence mathematics attainment. As Reddy (2005) argues, however, more needs to be done to make these macro-level analyses relevant to classroom practice.

In the rest of this section, I will discuss some of the issues highlighted above with a particular focus on classroom-related research.

3.4.2 Multilingualism and classroom interaction

Southern Africa arguably leads the world in research into the role of multilingualism in mathematics classrooms. This is due to widespread multilingualism combined with politically contentious educational language policies. In much of the region (as well as increasingly in Asia), English is the officially mandated classroom language.

Much of the research in this area overturns previous assumptions that multilingualism is a problem or barrier. Thus research by Setati (2005) shows that the use of two or more languages in mathematics classrooms is common, despite a commonly expressed ideal that only English be used. Setati's work shows that English tends to be used for procedural discussion (e.g. the steps in a calculation) whilst learners' other languages tend to be used for conceptual discussion (e.g. why a particular calculation is required) (see also Setati and Adler, 2000). In classrooms where learners' main languages are suppressed, conceptual discussion is likely to be lost, so that students only develop a more limited procedural mathematical understanding. Setati (2005) argues that multilingualism should therefore be seen as a resource for learning, rather than a barrier.

Within the context of English as the official classroom language, the use of learners' other languages provides a crucial means of mediating between learning mathematics and learning English.

Managing the use of several languages in a mathematics classroom presents challenges for teachers. These challenges include how to use the different language resources in a classroom and how to support students to learn mathematical English –the particular form of English used in mathematics. Adler (2001) has explored the nature of these challenges, characterising them in terms of three dilemmas. The first dilemma concerns the issue of when to switch between languages, since using English is necessary to develop mathematical English, but using students' main languages facilitates mathematical learning. The second dilemma concerns when to focus specifically on language, rather than mathematics, since a focus on language moves attention away from mathematics and often interrupts the flow of mathematical thinking. The third dilemma concerns when to intervene and formulate or correct students' efforts to express themselves. When, for example, a student struggles to give a mathematical explanation in English, a teacher may complete their explanation. In the process, however, they may impose a different meaning on the student from the one they intended and miss an opportunity for the student to work on their mathematical English.

More broadly, there is a general concern with the nature of mathematics classroom interaction. Many mathematics classrooms in Africa (and elsewhere in the world), often with large student numbers, tend to have relatively teacher-centred patterns of interaction, with little opportunity for students to discuss their ideas, either with the teacher or with each other (e.g. in Kenya, Bunyi, 1997; in Zimbabwe, Cleghorn et al., 1998; in Ghana, Mereku, 2004).

Research suggests, however, that learning is enhanced by different forms of discussion. In one small-scale study, for example, Nkhoma (2002) interviewed 14 mathematically successful black South African high school students about the factors in their success. One factor that emerged was that the students attended extra after-school classes. These classes were more informal, with more discussion and peer-tutoring than the time-tabled school classes (see also Adedayo, 1999).

3.4.3 Social class

Research suggests that students' responses to school mathematics is related in some way to social class. In studies in the UK, Cooper and Dunne (2000) showed that, in their responses to mathematical word problems, some students would treat the problem in its own terms, whilst others would treat it as a schooled activity with its own accompanying set of requirements. For example, in a problem about people using a lift, some students would consider the motivations of the people, whether they were in a hurry etc., whilst others would ignore such issues and focus on what calculation the word problem was designed to rehearse. Cooper and Dunne found that students from working class backgrounds tended to take the former approach (and therefore produce an 'incorrect' solution), whilst middle class students tended to take the latter. In effect, middle class students are better at working out 'the rules of the game' of school mathematics. It is likely that such effects arise in many societies. A study by Chacko (2004), for example, suggests that Zimbabwean students respond in similar ways to word problems as students in the UK. Although Chacko did not compare responses across class-based groups, the general similarity of students' responses suggests that such differences would arise.

3.4.4 Cultural factors

There is widespread concern that school mathematics does not connect well with students' wider experiences of the world, including their wider mathematical experiences. One response to this has been to investigate the mathematics inherent in students' cultures (an approach broadly known as ethnomathematics), and to seek to use this mathematics either to enhance school mathematics or as a basis for an entirely new mathematics curriculum (e.g. Gerdes, d'Ambrosio…Knijnik, 2002).

This approach has been criticised from various perspectives. Some have argued, for example, that ethnomathematics is based on neo-colonialist discourses of indigenous authenticity, leaving intact the idea of a global modern mathematics that is implicitly seen as superior (Vithal and Skovsmose, 1997).

3.4.5 Mathematical practices in and out of school

A substantial body of research has investigated the different mathematical practices used by students in out-of-school occupational activity and in similar in-school work. Research in this area has, for example, studied child street vendors in Brazil (Nunes et al., 1993) and Beirut (Jurdak and Shahin, 1999). This work highlights a mismatch between the mathematics taught in school, and the use of mathematics outside of school. Street vendors, for example, will use efficient, accurate methods of calculation as part of their trading activities. In school, however, they use different strategies, often incorrectly. Such research has led to arguments about the 'relevance' or otherwise of school mathematics.

As Nyabanyaba (1999) shows, however, the idea of relevance is complex and is related to tensions between the world of the curriculum and the world of the learner. The teacher's difficult task is to mediate between these two worlds.

3.4.6 Mathematics education and empowerment

Partially in response to many of the issues discussed above, a movement has emerged that sees mathematics education as a potential means of empowerment for disadvantaged teachers and students (e.g. Vithal and Skovsmose, 1997). This approach sees mathematics as a means to better understand and critique the world. By learning mathematics, students have greater power to participate and change society. Further, however, researchers subscribing to this approach argue that the teaching and learning of mathematics must reflect this position, so that learners and teachers have greater opportunity to shape their learning. Thus, Knijnik et al. (2005), for example, worked with trainee mathematics teachers within Brazil's Landless People's Movement. Her approach involved exploring cultural differences in the context of mathematics, leading to consideration of the role of oral mathematics and so to discussion of how the teachers gave meaning to different mathematical situations. Thus the teachers were empowered to shape their learning, to give voice to their mathematical experience and too engage critically with schooled mathematics.

3.4.7 Concluding comments

I have highlighted various factors linking poverty and marginalisation with the teaching and learning of mathematics. Language, social class, cultural background and experience and occupational uses of mathematics are all implicated in the production and maintenance of disadvantage. It should also be noted that in countries like South Africa, all these factors inter-relate closely with race. Underlying these factors, however, is a fundamental process of power. Students and teachers who learn English gain a form of power. Students who learn 'educated' (i.e. middle class) ways of reading classroom texts, interpreting their experience in school contexts and interpreting school experiences in other contexts are likely to have greater access to further education and employment.

These social processes are all implicated in the teaching and learning of mathematics. One response is to seek to empower students and teachers through mathematics classrooms. Rather than merely seeking better methods to teach subtraction or algebra, mathematics education can seek to give students and teachers a voice. This approach does not necessarily mean that the curriculum should be torn up. Giving students and teachers a voice can mean allowing them to use their different languages or to draw on their cultural experience, to make mathematics relevant for themselves, rather than having it made relevant for them.

3.5 Gender issues in mathematics and science education in low-income countries

3.5.1 Introduction

The main concerns in work on promoting gender equity in mathematics and science education are:

- to increase girls' participation in mathematics and science,
- to enhance girls' attainment in mathematics and science.

Relevant research has sought to understand how differences in participation and attainment arise. At a macro level, Colclough et al. (2000) propose that gender disparities in education are produced by cultural practices in the home, school, the labour market and wider society. They therefore argue that gender inequalities will not be reduced as income rises – policy interventions targeting cultural practices are also necessary.

Stephens (2000), however, makes a case for school-level intervention. In his study of access and gender in schooling, life history interviews were conducted with 89 women and girls from different parts of Ghana in 1995, including teachers and students. He explores family-related factors, economic factors and school factors and concludes:

> *For those charged with improving the educational system it would seem important to look not just at an array of inputs that need putting into the system or the outputs as measured by examinations scores, but to giving greater priority to the day to day processes of teaching; to examine ways in which the teacher can be better supported in what he or she tries to achieve*. (p. 45)

In this section, we briefly highlight some areas of cultural practice, both in and outside of school that have been shown to influence students' participation and performance in mathematics and science, with the aim of identifying areas in which teachers can make a difference.

3.5.2 Gender differences in society

A number of studies have explored issues of gender related to mathematics and science education in Africa. One large set of studies was carried out by FEMSA (Female education in Mathematics and Science in Africa in four African countries (Cameroon, Ghana, Tanzania and Uganda) in 1996 and 1997 (see [1]). These studies show that an important factor that influences girls' interest in mathematics and science is students', teachers' and parents' perceptions of the role of education in general and of science education in particular. In societies, where gender stereotyping is strong and the prime role of women is seen as being a wife and looking after the children and home, many question the value of education for girls, particularly of science education. Men are often seen as the bread-winners and education is therefore seen as more important for men.

Many science and mathematics oriented jobs are dominated by men and are therefore seen as unsuitable for women. Poverty exacerbates the situation. If a choice is to be made for economic reasons as to whether to send a boy or girl to school, the girl usually loses out.

Girls' and boys' different roles in society also have an impact (FEMSA publications [1], Lenga and Mwanycky, 2001). Girls are brought up to be obedient and subservient, particularly after the onset of puberty, leading to reluctance to ask questions in class. Boys are encouraged outside school to be involved in technical and construction activities. This can lead to boys tending to dominate the equipment to the exclusion of girls, when there are practical activities in science lesson.

Societal pressures can also have a detrimental effect on whether girls get to school at all. In addition to the problems of education being seen as of less worth to girls, there are concerns (FEMSA [1]) about the safety of girls, when there is a long journey to school, concerns about girls being removed from education for early marriage or because of pregnancy, and concerns about inadequate toilet facilities that prevent girls from attending school whilst menstruating. Certain traditional rituals and practices can also interfere with schooling. Girls and boys traditionally have different chores to do at home and the chores of the girls tend to be more time-consuming and can interfere with homework.

3.5.3 Textbooks

The conception that science and mathematics is not for girls can be reinforced by textbooks.
In a study by Obura (1991), for example, a sample of Kenyan school textbooks was analysed for gender stereotyping. Science textbooks mostly used male images and examples and reinforced the idea of women as mothers in domestic settings and perpetuated anxieties about girls' self-images and desire to please men in order to become wives. Joshi and Anderson (1994) report an analysis of Nepali textbooks. They found that mathematics textbooks were highly gendered. Choices of proper names (e.g. in word problems) and illustrations again strongly favoured male examples. Where human activity was portrayed, women were again not shown in paid employment, being shown instead doing household work. Such findings clearly raise issues for textbook and curriculum developers. They also, however, raise issues for the teachers who must work with such materials.

3.5.4 Students' self-concept

The factors we have already mentioned are likely to influence girls' self-concept, potentially leading to underachievement in science and mathematics and to perceptions that girls are unable to achieve well in these subjects. Githua and Mwangi (2003), for example, conducted a quantitative study of 649 students in 32 schools in Kenya. They collected data in order to infer students' mathematics self-concept (self-perceptions of mathematical ability, interest and enjoyment) and their motivation to learn mathematics (interest, relevance, confidence and satisfaction). They found a significant correlation between the two measures. They found a clear gender bias, with boys having a more positive view of their mathematical capabilities. Girls in co-educational schools were at the greatest disadvantage. Such gender differences are difficult to change. Research in Germany suggests that changes girls' self-image with respect to mathematics lags behind changes to greater equality in wider society (Kaiser-Messner, 1993).

3.5.5 Schools and classrooms

The culture of mathematics and science classrooms plays a role in maintaining or challenging gender disequity. In a classroom observation study in Kenya, Ndunda and Munby (1991) noted deeply rooted cultural notions of aggressive masculinity. For example, boys would rush out to take science equipment, and girls tended not to ask as many questions as boys. In their study of power and relations in a school in Uganda, Mirembe and Davies (2001) show how the school culture strengthened hegemonic masculinity and reinforced the girls' role as second-class citizens. Tiedemann (2002), in research conducted in Germany, observed differences in how elementary school mathematics teachers treated boys and girls only when the teachers were found to have strong gender stereotyped attitudes, suggesting that teacher attitudes are an important factor.

Girls and boys may respond differently to different teaching approaches. Adedayo (1999), for example, reports that, whilst interactive activities were beneficial for both girls and boys, girls gained more from individual interactive activities, whilst boys gained more from group activities. Whilst this finding is based on one small study, and may not be replicable in different societies, it highlights the way gender interacts with various aspects of teaching and learning in complex ways. Thus, Atweh and Cooper (1995), in their research in Australia, found that gender interacted with social class.

3.5.6 Sexuality and sexual behaviour

Lack of sensitivity to gender issues by teachers can reinforce girls' negative image of science. It is reported that this is particularly true in lessons concerning human sexual reproduction and that in some classrooms teachers even use specific girls as examples to talk about sex organs.

Mirembe and Davies (2001) report findings from an ethnographic study of a curriculum intervention concerning AIDS education in Uganda. Their article focuses on a coeducational boarding school that had earlier been a boys school. They report a highly gendered school culture which worked against the aims of AIDS education. Key features included: the positioning of girls and women teachers on the basis of sexuality and appearance rather than academic success; a gendered approach to discipline, which meant that girls were more controlled and less likely to be let off; the prevalence of sexual harassment; a culture of hetero-sexuality through which interaction between girls and boys was expected and reluctance to participate was stigmatised. Amongst other things, it seems likely from Mirembe and Davies' study that sexual harassment and male sexual dominance is an important factor in girls lower participation in mathematics and science education.

3.5.7 Concluding comments

It is clear that promoting gender equity in mathematics and science education is a complex task, not least because gender issues permeate the whole of society. Schools and teachers cannot directly and immediately change widespread gender stereotyping of occupations and societal roles, for example. They cannot change perceptions that mathematics and science are not girls subjects. And they cannot change some of the factors that make it harder for girls to attend school at all. Nevertheless, schools and teachers have a role to play. Schools and teachers can, for example:

- develop gender sensitive materials, including textbooks, that depict mathematics and science as suitable subjects for girls, both for study and for future employment
- develop teaching strategies that challenge gender stereotyping when it arises in classroom interaction, or in textbooks
- develop strategies that challenge students' own gendered expectations of themselves in mathematics and science
- explore how girls and boys may respond differently to different teaching methods and develop more inclusive approaches to teaching mathematics and science
- find ways to discuss, challenge and change cultures of sexual behaviour.

If progress is to be made on such an agenda, however, it needs to be through working with and empowering teachers and students. One possible approach has been developed by Solar (1995). She draws on feminist research in education to propose a model of 'inclusive pedagogy' with which to address gender differences and discrimination in mathematics classrooms. The framework is constructed around four dialectical aspects:

- silence/speech
- passivity/ active participation
- powerlessness/ empowerment
- omission/ inclusion

Solar uses this framework to challenge practices in four areas: teaching, learning, curriculum and educational environment. The aim is to promote girls' and women's participation, inclusion and empowerment through, for example, giving women a voice in defining the content of the mathematics curriculum, avoiding stereotypes, ensuring all students have time and space to respond to questions, and creating a supportive atmosphere.

Solar's approach could form the basis for an action research cycle amongst a group of teachers, for example, since it provides a framework for discussion from which new strategies could emerge and be tried out and then further discussed and developed.

3.6 Towards a way forward

3.6.1 Introduction

The preceding material provides a basis for discussion and a context for planning. In this short section, some key points are highlighted and some very broad suggestions offered for future directions for the project.

3.6.2 Key points from the review

The following key points emerge from the review set out in the preceding sections:

- Teachers are a key component of educational quality.
- Teaching and learning mathematics and science is highly contextualised; each school, class, teacher and students have different characteristics, attitudes and experiences.
- Many curriculum change initiatives have failed in the past due to top-down, homogenous approaches that assume specific 'silver bullets' can 'fix' education across countries and regions. Such an approach tends to position teachers as reactive.
- Change is a process, not an outcome.

- Mathematics and science education is (contrary to much popular opinion) closely bound up with issues of language, class, culture, race, gender and sexuality.
- Mathematics and science education can contribute to poverty reduction and gender equity, particularly through educating children to be critical thinkers so that they are better equipped to understand, to question and to take control of their lives.

3.6.3 Possible future directions and quality indicators

The following prompts suggest some starting points:

- Working with teachers in ways that empower them and support them to develop and share their practice is one possible principle that would place teachers at the centre of the process of curriculum change.
- Approaches to curriculum change need to be developed that are sensitive to context.

A teacher-centred research approach has the potential to provide such context sensitivity.

- Rather than giving teachers new certainties to replace old ones, frameworks need to be developed that allow for dialogue. Solar's framework (mentioned in section 5.7 is a possible example). Her framework does not include specific methods; rather, it provides a basis for structured discussion and reflection about teaching, learning, classroom interaction, teaching materials and curriculum content. Through such discussion and reflections, new teaching methods and ideas can emerge.
- As for quality indicators, an ideal method would be sensitive to context and to a dialogic process. It may be, therefore, that quality indicators should be negotiated with participating teachers. The research team could provide a broad framework to ensure that different aspects of education were addressed (e.g. classroom interaction, curriculum content etc.) but specific indicators could be developed by participating teachers.

Notes

1. http://www.fawe.org/femsa/Defaultold.htm

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SECTION 4: A REVIEW OF MATHEMATICS AND SCIENCE EDUCATION IN RWANDA

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4.1 Introduction: An overview of the education system in Rwanda

In Rwanda, formal education was introduced by the colonial system. The first school was constructed in 1900 in Nyanza by the Germans and the doors were only opened to a small number of boys. These pupils were taught reading, writing, and arithmetic. In 1929, after the Germany defeat in the First World War, the school was transferred by the Belgians to Astrida (Butare today) with the same conditions of accessibility. It is important to note that the "Kabgayi minor seminar" (preparing future priests) was the first secondary school in 1913 while the first secondary school for girls was opened by Roman Catholic religious nuns in 1937 at Save (not far from Ngoma town today). Other schools were later set up and mainly managed by missionaries as well, with the objective of evangelisation, and training administrators of the colonial power.

Formal education during the colonial times was mainly run and managed by missionaries and many times they have been criticised for providing too much – or too little schooling, and for not adapting education to the needs of the local society (UNICEF, 1992). Indeed many Rwandans believe that education at that time was characterised by mistrust of traditional values, knowledge, and literature and thus there was no effort to incorporate the Rwandan traditional experience in the colonial education system. It must be noted as well that girls who were already victims of the socio-cultural context in which Rwandans consider women as 'homemakers' were not given consideration by the colonialist education system at the beginning. As mentioned above formal education for girls started almost forty years after the first boys had been to school.

After the independence in 1962, a ministry responsible for education was established with the major role of elaborating laws securing the general regulation of education. The education system has since then been marked by adjustments.

The mathematics and sciences curricula have been ambitious and overloaded. There has always been a lack of practitioners (teachers) to implement the curricula. The pedagogy applied is that the teacher is considered as a knower, and students as passive receivers. Scientific schools prepare students for higher education. The language of instruction in classrooms has been at all time a paradox; all Rwandans speak the same language (Kinyarwanda) but from the 4th year of primary school (9-10 years old), foreign languages are used as medium of instruction. Before and after the independence the whole education system used French as the medium of instruction up to 1978. In this year, the education system underwent a reform which involved two major changes: one, the medium of instruction changed to Kinyarwanda and, two, the length of primary education which used to be six years, became eight years. The reforms were short-lived, and came to a halt in 1991 when the government decided to go back to the old system (i.e. using French as the medium of instruction and shortening the number of years of primary education from eight to six years).

Socially, the common denominator of the education system before 1994 was the discrimination on the part of Rwandans. The transition from the lower level to a higher one was based on ethnic/regional criteria rather than on individual performance. (Different quotas were provided for different ethnic groups and regions). Thus the curriculum has always ignored human values and the result was the horrible April-July 1994 genocide in which the highest qualified 'educated' were leaders and active participants.

After 1994, the urgency was to re-launch the education system destroyed during the genocide. A new curriculum was quickly put in place in 1998 in order to accommodate the learning needs of different Rwandans in the country at that time. Along similar lines English was introduced as an alternative medium of instruction in schools. Thus the education policy is actually trilinguilism: one national language and two foreign languages (French and English) recognised as official languages. Research on the impact of languages in teaching/learning sciences should be welcome.

At present, the education system, as other national sectors, must be geared towards achieving the Vision 2020. (This vision seeks to fundamentally transform Rwanda into a middle income country by the year 2020.) It is invited and expected to play a role in the socio-economic development of the country. "To promote science, mathematics and technology with special attention to ICT" is one of the objectives of the education sector policy (MINEDUC, 2002).

A number of institutions, both public and private, provide formal education ranging from pre-primary to university levels. MINEDUC (the Ministry of Education, Science, Technology and Scientific Research) leads policy formulation and has the responsibility for the formal system composed of:

- Pre-primary education or nursery schools: children aged 3-6
- Primary education is compulsory and fees free for all children. The official age is 7-13 and the duration is 6 years.
- Secondary education with two levels, the first level is made up of 3 years (children 14-17 years old) named "tronc commun" (ordinary level or lower secondary school). The second level is also 3 years (students between 18-21 years old) known as upper secondary school.
- Higher education (a minimum of 4 years): universities and specialised institutions.

Transition from primary to secondary levels and from lower to upper secondary levels, and entry into higher education are subject to passing national exams.

It is important to observe that

- The national exams at the end of the six years of primary education push the majority of children (12-13 years old) out of the education system because only a few places are available for secondary education. For example, the statistics for year 2001/2 show that only 26.07% of the candidates who sat for the examinations passed. Of this figure, 36% were girls, (MINEDUC, 2003a).
- There is a higher failure rate in maths and science national exams at all levels of education.

What about the actual physical environment? Most schools are lacking basic equipment and books. The lack of equipment, including technological equipment continues to be of great concern. School facilities are in a bad state with inadequate and missing equipment and often this is unevenly distributed throughout the national territory. There are severe regional disparities in terms of access and distribution of educational resources. Most schools in Rwanda have been rehabilitated but water and sanitation problems still exist.

4.2 Gender issues in mathematics and sciences

As has already been pointed out earlier, formal education for girls in Rwanda started much later than that of boys, almost 40 years after the first boys had been to school. Even when the first girls were admitted into schools, it is believed that it was mainly to serve the needs of the newly 'educated' Rwandan colonial administrative assistants who wanted to get spouses who were more educated and presentable in the higher circle of society in which they belonged. It is not surprising therefore that girls' education at that time was geared to make them better 'home managers' than anything else. Thus the gender disparities evident in the Rwandan education system today could be a result of these 'late starters'.

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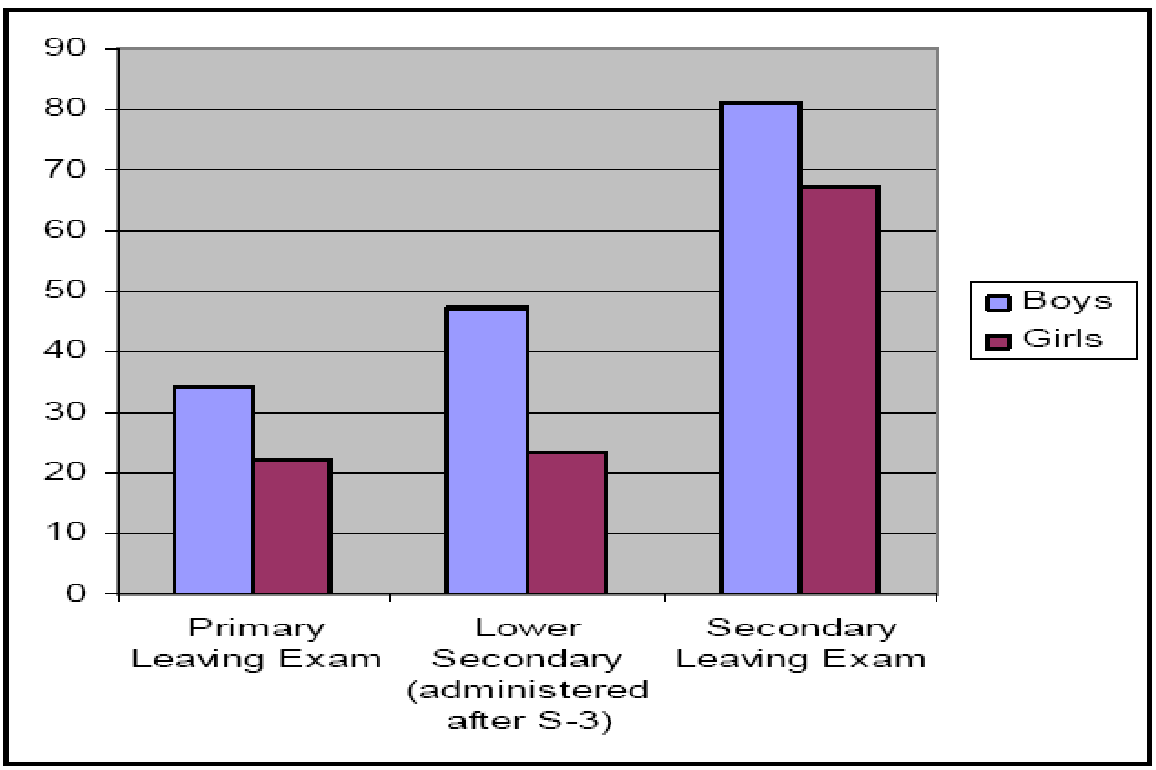
Improving girls' access to education, with a goal of attaining gender equality is a critical component of promoting development and meeting the Millennium Development Goals (MDGs) and other national plans such as Vision 2020, Education Sector Policy in Rwanda. These policies have been adopted among other things, to correct the historic marginalisation of girls from the education system and from the political and economic spheres more generally. With an enabling policy environment therefore, Rwanda has made strong progress in improving access to education at all levels, and improving gender parity at primary (50.2% are girls) and secondary (49.4% are girls) school levels (MINEDUC 2002).

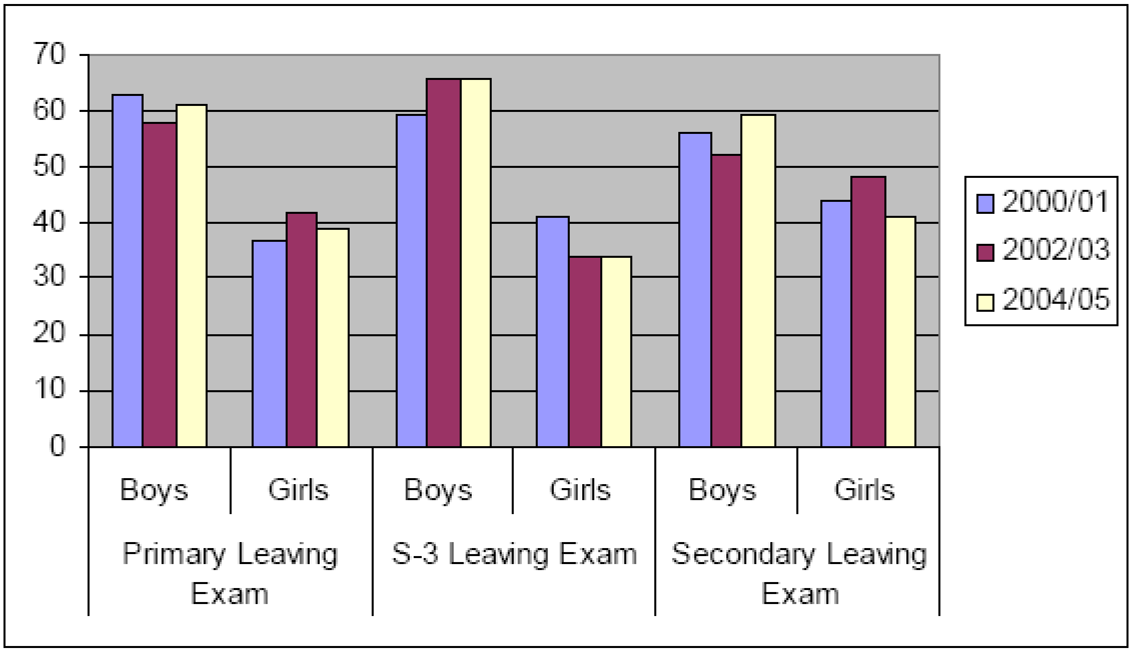
Despite significant progress in increasing primary and secondary school enrolment, completion rates for girls continue to be low. Although specific gender disaggregated data on completion rates is not readily available, completion rates for girls are known to be lower than those of boys at all educational levels. Also important to note is that boys comprise a higher percentage of students in government secondary schools, which tend to be of a higher quality and less expensive than private schools. A higher number of girls on the other hand are registered in the private secondary schools. The argument is that girls perform less well than boys in end of primary exams and hence are enrolled in a greater numbers in private schools where the entrance criteria are lower than the public secondary schools (MINEDUC, 2003a; p.36). It must be noted that admission to secondary school and higher education in Rwanda is largely based on students' performance and boys consistently outperform girls at all levels.

Examination Performance by Gender, Rwanda, 2003/04



Source: FAWE website, 2007 as cited in Huggins & Randell 2007

Gender Breakdown of Students who pass National Examinations, Rwanda 2000/01, 2002/03, 2004/05



Source: chart produced by authors from data of NEPAD Secretariat and UNIFEM Rwanda. Independent Review Report on the Progress and Prospects of Gender Mainstreaming in Rwanda, 2000-2005, May 2006, cited in Huggins & Randell 2007

One wonders why this low performance of girls? According to *Huggins et al (2007), "although policies have been revised to promote equal access to education at all levels, peoples' attitudes have evolved more slowly, and socialized roles and stereotype continue to prioritize boys' education and access to employment"* (ibid, p.15)

Prioritizing of Science and Technology Subjects

"Science and mathematics teaching and ICT shall be at the heart of the education system" (MINEDUC 2002 p.21).

It must be noted that mathematics, science and technology subjects are given priority in line with the country's vision of building a knowledge based economy. These subjects are also prioritized at university level entrance and in allocation of government scholarships.

However there is a high failure rate of students in general in maths and science at national exams at all levels. For example at the end of the academic year 2003/4, the percentage of pupils' enrolment in scientific subjects at upper secondary school represented 20.8% of which 35.5% was female (Umutoni, 2006).

This has been attributed mainly to the lack of qualified mathematics and science teachers and inadequate facilities such as laboratories in schools. Nevertheless, statistics show that boys out number girls in maths and science at secondary level and thus gain access to positions in government schools specialising in teaching these subjects. In addition many girls have been socialised to see arts subjects as more appropriate for them to study, and science and technology as subjects reserved for boys (Huggins & Randell,2007).

Taking into account the above scenario, some initiatives (public and private) have been and/or are engaged in ensuring quality education, basic education for all children, promote gender equity, eradicating misconceptions of math and sciences especially towards girls. These initiatives are working under different trajectories. Examples of such initiatives are:

FAWE (Forum for African Women Educationalists)

In order to eradicate girls' misconceptions towards sciences and mathematics, and to promote gender equity in education, FAWE Rwanda with the support of the Ministry of Education opened and is running a secondary school named 'FAWE Girl's School' in the Rwandan capital city. This boarding school is exclusively for girls. It has lower and upper secondary levels where students only specialise either in Math-Physics or Biology-Chemistry. The school is well equipped with science and computer laboratories and teachers are gender sensitized. Model schools of this kind are planned to start in four more regions in the country. However the FAWE initiative has been criticized sometimes for serving the interests of 'the well to do' since school fees are rather high compared to ordinary secondary schools and only the best qualified girls can be admitted there (many of them from primary schools in Kigali City).

To counter this there has been effort to support the education of bright girls from poor background through different bursary schemes such as Education for Democracy and Development Initiative (EDDI), PACFA and others. These schemes have especially supported orphan girls and girls from rural areas. In 2004 the school had 293 students admitted under such bursaries.

Engendering the curriculum

There have been efforts by the Ministry of Education through the National Curriculum Development Centre to gender the curriculum and approve text books on the basis of gender sensitivity especially at primary level. This is a continuous effort that requires skills and finances in order to engender all instructional materials throughout the education cycle. The revised curricula for primary and secondary schools also include units on gender sensitiveness.

Other efforts to promote gender equality in education include documentation and information dissemination, prizes for best performing girl students, gender sensitization to mention but a few. However more effort to challenge gender inequalities in education is still needed. We would suggest commencing by changing traditional behaviour in which a girl is seen as "house keeper" rather than politico-economic participant.

4.3 Existing initiatives in curriculum change

As pointed out earlier the current curriculum was established in 1998 and contains, at the lower level:

- 6 periods per week of Maths, French, and English. One period is 50 minutes.
- 6 periods per week of sciences (Biology, Chemistry, and Physics)
- Other subjects such as Geography, History, etc.

The Rwandan government plans to move from 6 to 9 years of the basic education system (primary education) by 2010. Plans are underway to extend free basic education to include lower secondary education. This has already begun in some rural schools where by three classrooms of lower secondary have been added to well established primary schools.

In light of the Dakar goals (April 2000), MINEDUC (Ministry of Education, Science, Technology and Scientific Research) published the "Education for All Plan of Action" presenting a basic education development projection for the period 2003-2015. This plan is a reference for all stakeholders and partners who would like to support the sector of basic education in Rwanda (MINEDUC, 2003a; p.6). Concerning teaching and learning mathematics and sciences:

- MINEDUC started the review of the curriculum (process is on going), and the provision of textbooks so as to improve the quality of education and give people relevant skills.
- Curriculum will include health education with emphasis on HIV/AIDS mobilisation at all levels of education system.

This implies

- Improving life skills and gender sensitivity
- Improving science and technology teaching with special attention to practical laboratory work and ICT
- Improving the quality of teaching through in-service training of unqualified teachers and pre-service training of new teachers.

Statistical data for 2001/2 shows that the percentage of qualified teachers was 81.2% in primary and 51.9% in secondary schools. The pre-service is strengthened by teacher training colleges (TTCs for primary school teachers) and KIE (for secondary school teachers). Furthermore KIE includes the distance training programme (DTP) for the upgrading of in-service teachers as recommended by MINEDUC (MINEDUC, 2003a; p.42).

Particular attention is paid to the teaching science and on the use of ICT in Education. The EFA Plan of Action states that:

- science and mathematics teaching and ICT shall be at the heart of all levels of education;
- links will be started between all higher learning institutions, secondary and primary schools (ibid., p.49)

The Action plan enumerates other strategies:

- train a critical mass of science and ICT teachers
- establish model centres of excellence in science, mathematics and ICT at secondary level
- develop the ICT curriculum for all levels of education
- ensure that science and mathematics programmes at primary and secondary levels are coherent
- establish partnerships between education institutions of different levels
- ensure practical skills and provide science equipment and computers to identified schools and progressively to all schools, as means allow.

Concerning ICT, the idea behind these strategies is to gain ICT skills as well as to use it in teaching/learning other subjects such mathematics and sciences. Some questions could be raised here: what is the impact associated with deploying computers to support teaching in traditional curriculum area? Can these technologies help pupils learn about mathematics, sciences, etc.? Cuban (1986) observes that the enterprise of marrying educational practice with contemporary technologies has a long story. But on the other hand actual research projects have shown that the use of new technologies in mathematics classrooms enable learners to improve their learning skills and their innovative provided the teachers' volunteer to adopt new pedagogical approaches (Sutherland, 2007).

Nevertheless it is worth noting that the effectiveness of the use of ICT in classroom depends also on pupils' motivation. Quoting Leask and Pachler (1999), "motivation theories have recognised the effects of the locus of control of the learner: the extent to which learners see events as being *under their personal control*. It has been suggested that learners' personal perceptions of how much control they have over events in which they are involved will also affect their attitude towards ICT" (Leask and Pachler, 1999; p.21). Other studies in education showed that new technologies can bring mathematical concepts to life. Through manipulating virtual worlds children are helped to understand the "artificial reality" of maths. Their talk with the teacher and with one another is crucial to development of understanding. ICT-based mathematical activities can become a source of general problem-solving strategies that can be applied across the curriculum (Wegerif and Dawes, 2004; p.5).

The question remains how to construct a national mathematics and sciences curricula that allow the integration of ICT in the teaching/learning. Before having a closer look at the curriculum it might be worthwhile to underline some engagements in implementing curriculum change.

In order to help MINEDUC in managing, regulating, monitoring and evaluating the education system, the following institutions were set up. We cite only their involvement in curriculum:

- General Inspectorate, to ensure pedagogical and management standards through the school system
- NEC (National Examinations Council), to ensure provision of appropriate
- examinations at all levels of the school system
- NCDC (National Curriculum Development Centre), to develop the content of what is taught in schools (curriculum) and to certain extent of the methodological teaching.

In addition these three institutions must work together to ensure that curriculum is implemented as intended and the outcomes of schooling are realised as planned (MINEDUC, 2002).

In response of MINEDUC call: "*the importance of the participation of all different partners is acknowledged -government, parents, communities, donors, the private sector, NGOs and civil society…*" (MINEDUC, 2002a, p. 41) some NGOs took and are taking part in implementation of quality education.

a) Institutions of higher education

Putting in action the partnerships between education institutions of different levels, the following higher education institutions play an important role:

- KIST (Kigali Institute of Science and Technology) provides basic computer literacy to in-service teachers, and development of e-library in conjunction with other institutions.
- KIE (Kigali Institute of Education) provides, content subject knowledge and educational skills to pre-service secondary school teachers. But it remains to be seen how many of these young graduates are motivated enough to stay in the teaching profession.

Furthermore, it also ensures the training of in-service secondary school teachers within a distance training programme. At this point we should note that 166 secondary school teachers completed the 2006 KIE-distance training programme in Math-Physics and Bio-Chemistry with Education. They have been awarded a diploma in education. But this could be seen as a 'drop in the ocean'.

KIE conducts research on the use of ICT in teaching mathematics and sciences at basic level. KIE works jointly with EdQual. This is a consortium of six African and British universities, sponsored by the UK's Department for International Development (DfID) to carry out research into the implementation of education quality in low income countries (http://www.edqual.org).

b) VSO (Voluntary Service Overseas)

VSO Rwanda has been supporting Rwanda through the project "Research into the cost of quality teaching in Rwanda" since 2005. This support involved participatory research looking at the factors affecting education quality and teacher motivation in Rwandan basic education sub-sector, and providing long-term financial projections of the cost of achieving quality universal basic education (UBE) by 2015 in Rwanda.

4.4 Mathematics and Sciences Curricula

Different research projects have established that school mathematics has adopted different pedagogical and curricula approaches and this varies between countries. "What is specified in a mathematics curriculum is only one aspect of the multifaceted influences on how a mathematics teacher approaches teaching in the classroom, the fact that so many differences emerge in the specification of national curricula does suggest that different mathematics cultures prevail around the world" (Sutherland, 2007; p.14).

Very few studies have examined the Rwandan education system, especially on the curriculum. The Rwandan science curriculum has been generally presented in terms of objectives, contents, methodology and references. According to Earnest and Treagust (2002) and drawing on our own experience as secondary school teachers, during the period 1994-1998 the Rwandan curriculum was a combination of one that had been established in 1991 and others borrowed from neighbour countries[2]. One could observe that it was mainly administered in Kinyarwanda.

The MINEDUC implemented a new curriculum for the primary and secondary schools in September 1998. The curriculum is content-laden, teacher centred, requiring rote learning, copying of a teacher's notes from the board and memorisation of factual knowledge in exams and tests. Citing Earnest and Treagust "*a highly qualified science teacher in an elitist urban school tries to make sense of the detail in the curriculum in Rwanda: the course content of the science subjects is too detailed and there are too many topics to be covered and time is usually not on our side, there is too much to cover within a short period of time. I cannot understand why it is necessary to include so many subjects and have so much content*" (pp.17-18).

The curriculum does not encourage development of knowledge, skills and attitudes. Often the content is outdated and does not reflect current pedagogical best practice. Referring to Porter, Archbald and Tyree's curriculum policy strategies, Fowler and Poetter developed a framework to analyse the successfulness of French mathematics curriculum for elementary schools. They point out three main questions that can guide an analysis:

- What type of pedagogy should the Rwandans use to teach elementary mathematics?
- What curriculum policy strategies and instruments should the Rwandan use to implement the elementary curriculum?
- How should the formal mathematics curriculum be structured? (Fowler and Potter, 1999;p. 291)

They go on to present five questions about pedagogy:

- What kind of mathematics is taught in a lesson?
- How are the mathematical concepts or procedures presented to students?
- What are the students expected to do during the lesson?
- Does the teacher lecture directly, summarise, and/or select problems that require student thinking to move in one direction or another?
- How is the lesson organised?

Our purpose is not to answer these questions but simply to present the criteria which practitioners should use when implementing the new curriculum. Concerning the curriculum, Porter, Archbald, and Tyree argue that there are two basic curriculum policy strategies: a top-down curriculum control strategy and a bottom-up empowerment strategy. The former usually includes several elements, such as curriculum materials, frameworks, and tests. The implication of this type of curriculum is that the teachers are less responsible of the planning of their activities. The latter is

[2] Strictly speaking there is no curriculum during this period but arrangements between educators

newer and less well developed than the former. It regulates teachers in such a way that they become more professionalised and therefore more respected. These strategies include strengthening teacher-preparation programmes, requiring extensive participation in professional-development activities. In addition they give more teachers more voice in decision making, as in site-based management. Though control and empowerment strategies seem to be opposite, Porter, Archbald, and Tyree suggest their combination (ibid, p.294).

In addition one should also argue that the integration of new technologies in teaching and learning need to give time to teachers to organise their plans in order to help learners to be more innovative. The curriculum is there as a guide that includes general outcome of the teaching/learning.

Drawing on Fowler and Potter, a formal curriculum is a written document on which many have deliberated and about which official decisions have been made. Of course the formal curriculum is "operationalised," or put into practice by the teachers when teaching it. Other forms and meanings are attached to the formal curriculum by those who operationalise it and even by those who experience it- namely the students. Therefore a formal curriculum is not a static entity, but one whose potential lies in wait of interpretation of practitioners and students (ibid, p.296).

Since September 2005, MINEDUC have launched the review of sciences and mathematics curricula at lower secondary education, which is an ongoing process. The new science curriculum proposes student centered methodologies by introducing two new issues in teaching approaches:

- The learning situation. In this, each chapter or topic to be taught is introduced by **a learning situation** whereby the teacher proposes to the students a situation or an event, or sometimes invites students to propose a topic, encourages them to think and debate around it. This will raise questions and curiosity about different issues that will be explained during the lesson development.
- Student's activities or Learning activities. For any concept to be taught, the teacher should start by presenting **learning activities** to be carried out by students (practicals, observations, exercises, etc.). Under the teacher's guidance, students will discover the concept.

This new curriculum was approved by the Textbook Approval Committee (TAC) at the beginning of 2006 and is now being implemented with the first year[3] of lower secondary school. In the same spirit the adaptation and revision of science curricula at upper secondary school is underway.

At present the Mathematics curriculum has been constructed but not yet approved. But as Earnest and Treagust (2002) noted taking into account the science curriculum frameworks, school conditions, physical conditions (electricity, water supply, quality of pupils' and teachers' desks, floor quality, ventilation) and limited financial resources, it is feasible to provide a core set of science education equipment to schools. Teachers will need time and training to familiarise themselves with the equipment and to prepare some demonstrations or practical work for students. Decisions about the use and allocation of supplies and equipment should allow a degree of flexibility and adaptation for each particular school's conditions.

[3] Sources for this paragraph :(1) Termes de références pour l'élaboration des nouveaux curricula pour l'enseignement des sciences, (biologie, physique et chimie), au 1er cycle du secondaire, Septembre 2005
(2)Curriculum de Sciences (BCP) au Tronc Commun, MINEDUC/CNDP, 2006
(3) Rapport des activités du séminaire d'évaluation des curricula de chimie au second cycle de l'enseignement secondaire tenu à Remera, du 26 au 28 Septembre 2006, CNDP

Many issues concerning the organisation of sustainable practical work in science could be solved locally with assistance from the community and parents. It is also important to find some of the consumable materials for science experiments locally from within the environment and using local teacher knowledge.

4.5 Assessment

Teaching and learning go hand in hand with assessment. We are aware of how assessment influences the teaching. "The Ministry of Education should give more importance to the teaching and learning science. Many primary school teachers are not interested in giving importance to science because it is not examined at the Year 6 National Examination," (Earnest and Treagust, 2002, p.11). This is a primary teacher's answer when interviewed by the researcher. What we can learn from this interview is the influence of assessment (exams in this case) on teaching and learning.

There are few studies, if any, available that examine the Rwandan assessment system. Diverse research projects in education (e.g., Shepherd, 2004; Assessment Reform Group, 2002) are focusing on how to integrate assessment into learning process i.e., how assessment can help teachers and learners to improve respectively their teaching and learning.

Concerning the uses or primary purposes of assessment, Shepherd (2004) enumerates different types of assessment including formative and summative assessments.

Formative assessment takes place all the time in the classroom (when pupils are beginning and progressing through their work). When you ask teachers how often he/she assesses students, you are answered 'the class size (average 40-45 at secondary level) doesn't allow me to assess as much as I want.'

Summative assessment generally takes place at the end of a unit or a level or stage. Summative assessments sum up and make a judgement on pupils' knowledge, skills and achievement. Shepherd goes on to say that the main difference between formative assessment and summative assessment is that formative helps teachers and learners find daily ways to improve the work of pupils while summative tends to prove what a pupil has achieved. But we shall see shortly that depending on its use, summative assessment may also be formative.

Note that formative assessments prepare learners for summative assessment since formative assessments provide feedback to individuals during the learning process by providing search and retrieval practice. When pupils must provide answers to questions about material they have learned, their brains must search their memories and retrieve the information. These memory processes help solidify the learner's knowledge and help maintain that information in an accessible state for later recall. Search and retrieval practice is often used for practice tests, summative assessments, self-assessment of knowledge, skills and attitudes of the purpose of learning (ibid.).

In terms of the learning process, the literature distinguishes assessment for learning and assessment of learning.

Assessment for learning is about making assessment a part of the learning process i.e. its design is to serve the purpose of promoting pupils' learning. Sadler (1998) highlights that in assessment for learning, the learners' task is to close the gap between the present state of understanding and the learning goal. Self-assessment is essential if the learner is to do this. The teacher's role is to communicate appropriate goals and promote self assessment as pupils work towards the goals. Feedback in the classroom should operate from teacher to pupils and from pupils to teacher.

What is needed for teachers to make assessment more effective is

- providing effective feedback to pupils;
- involving actively pupils in their own learning;
- adjusting teaching by taking account of the results of assessment;
- recognising the profound influence assessment has on the motivation and self-esteem of pupils, both of which are crucial to learning;
- considering the need for pupils to be able to assess themselves and to understand how to improve (Hodgen, 2006).

Assessment of learning generally tends to be designed to serve the purposes of accountability or of ranking or of certifying competence. However summative assessments at the end of a unit or the end of term may be for learning in the sense that they can also help pupils and teachers to decide where learners are in their learning, where they need to go and how best to get there (Hodgen, 2006). In addition summative assessments may be used as formative in the following ways: pupils should be engaged in a reflective review of the work they have done to enable them to plan their revision effectively. They should be encouraged to set questions and mark answers to help them, both to understand the assessment process and to focus further efforts for improvement. Pupils should be encouraged through peer and self-assessment to apply criteria to help them understand how their work might be improved. Under these conditions, summative tests should be positive for the learning process (Suffolk Advisory Service, 2004, p.7).

Briefly, we can claim that any assessment becomes formative when the information is used to adapt teaching and learning to meet student needs. Quoting Boston (2002), 'When teachers know how students are progressing and where they are struggling they can use this information to make necessary instructional adjustments, such as re-teaching, trying alternative instructional approaches, or offering more opportunities for practice. These activities can improve students' success*.″*

4.6 Concluding remarks

To sum up our discussion, the curriculum should not be overloaded to allow teachers enough time to engage with students. The teaching should focus more on developing scientific thinking than on content. They must go beyond what is done in their classrooms.

"An almost progressive orientation situates the French position on the place of mathematics in students' lives inside and outside of schools. …teachers are told they must never lose sight of the fact that every new concept and technique must be based on what the children have already learned and the experiences which they have already had" (Fowler and Poetter, p. 297).

A new curriculum should be accompanied by other teaching resources such as textbooks, computers with appropriate mathematical software, etc. The implementation of a curriculum with integrated ICT in teaching requires regular teachers training to improve their technical skills as well as their pedagogical approaches. One way for this task is self-training or peer-learning. "Where staff work together supporting one another in experimentation and change, then the acquisition of skills and knowledge is easier" (Leask and Pachler, 1999; p.195).

The curriculum must encourage teachers to focus on formative assessment rather than summative assessment.

Finally we can notice a big gap between the Education for All Plan of Action promoting mathematics, sciences and technology, and the actual situation in the classroom. We hope the effort which is being made in pre-service and in- service teacher training will reduce the gap in the future. But on the other hand as Earnest and Treagust observed it must be acknowledged that teachers, school administrators, educational professionals and students at all levels in Rwanda are very motivated and enthusiastic. They live and work in hard conditions, have limited pedagogical training, especially in modern methods of teaching, but try to do their best for Rwandan children. The challenge lies in the education system's ability to respond to these constraints (Earnest and Treagust, 2002).

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