International Panel:

Bridging Policy and Practice

A Focus on Teacher Preparation

Reflections from the 2002 Park City Mathematics Institute International Panel on Policy and Practice in Teacher Education

14-18 July 2002

Institute for Advanced Study

Joan Ferrini-Mundy, Gail Burrill, Glenda Breaux (Editors)
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Princeton, NJ

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Acknowledgements

The International Panel could not have been the success that it was without the extraordinary efforts of a number of individuals.

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We are grateful to our funders, the Wolfensohn Family Foundation, the Bristol-Myers Squibb Foundation, and International Commission on Mathematics Instruction, for continuing to support the idea that international dialogue among teachers and researchers can be an important step in beginning to think globally about mathematics education.

Joan Ferrini-Mundy
Gail Burrill
Project Directors
June 2004
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Introduction

Teacher preparation and quality are matters of international interest. To explore common issues and concerns regarding the initial preparation (pre-service) and ongoing (in-service) professional development of mathematics teachers, an International Panel on Policy and Practice in Mathematics Teacher Education convened in the summer of 2002. This seminar—sponsored by the Institute for Advanced Study/Park City Mathematics Institute (PCMI), and funded by the Wolfenson Family Foundation, the Bristol-Myers Squibb Foundation, and the International Commission on Mathematics Instruction—allowed the participants to engage in a stimulating five-day discussion about these important issues in the education of mathematics teachers.

Teams of two educators from each nation—a university mathematics educator or policy-maker and a secondary school mathematics teacher—met to discuss pre-service and in-service
education policy and practice pertaining to prospective and current mathematics teachers. The goals for this summer were to:

- promote open discussion of the goals, content, and delivery of pre-service and in-service education for mathematics teachers, as well as the policies that govern these in each nation,
- identify common issues faced across national contexts, and
- identify pre-service and in-service programs and practices that work well in a particular nation and may work well in others.

The seminar, led by Joan Ferrini-Mundy and Gail Burrill, both from Michigan State University, was organized to stimulate conversation and productive exchange of information that could serve as a basis for continued efforts to address issues in mathematics teacher preparation and development. The 2002 seminar followed the 2001 seminar on mathematics education policy and practice, where teams from the same eight nations were in attendance.

**Background**

The eight nations represented in the seminar were Brazil, Egypt, France, India, Japan, Kenya, Sweden, and the United States (See Appendix B for a list of participants). Participants presented an overview of the national policy in their country on pre-service and in-service teacher education from countries where such a policy exists. In countries where there is no national policy, such as the United States, the participants described trends and highlighted regional variations in pre-service and in-service teacher education policies. Participants from each nation shared an example that provided details about a specific program for teacher pre-service and in-service education.
The nature and features of each nation’s policies and practices were filtered through the experiences of the individual members of the two-person teams. This document is meant to be a “story” that describes an international conversation about issues in mathematics teacher preparation and professional development. The team members whose views are expressed in this report were not functioning in any way as official representatives of their nations of origin. Thus, the views expressed by the members of these teams and the information contained in this report are not intended to reflect the status of mathematics teacher preparation and professional development in each nation. Although there is some discussion of the national teacher education context, each individual brought a unique perspective to the discussions. As such, issues of region, locality, or other circumstances may have influenced individual views and opinions. It is not the intention of the PCMI, or this report, to claim that the views expressed are indicative of the national situation in each country.

The topic for discussion at the 2002 seminar was the focus of the presentation given in 2001 by the team from Egypt (www.mathforum.org/pcmi/int2001report/page26.html). Three themes arose from their presentation and the discussion that followed—1) the need to connect pre-service training to the realities of practice, 2) the need for continuing education for in-service mathematics teachers, and 3) the need for interesting innovations in teacher training and mathematics education. These themes were the foci in the 2002 seminar. The primary goals of the 2002 seminar were to consider approaches to pre-service and in-service education that are prevalent or successful in a particular country and the potential of these approaches as solutions to issues and challenges faced across the eight countries.
The seminar discussion was framed by nine questions, identified in advance, covering a broad spectrum of issues related to both policy and practice in mathematics teacher education.

1. What should prospective teachers learn about teaching in general, and specifically about teaching mathematics?

2. Should a country have a standard system for educating prospective teachers, or is there an argument to be made for differentiating programs within a country?

3. How can in-service programs be improved in countries with large numbers of teachers?

4. How can the education system deal with uneven communication across the system and large numbers of teachers who have varying backgrounds and degrees of expertise?

5. What is the role of university math educators in the community of teachers (i.e., What interface exists and how can it be improved)?

6. How can we increase collaboration across educational levels?

7. How can we divide the responsibility for pre-service and in-service education?

8. How can we monitor and ensure high quality programs?

9. How might math education programs be redesigned to deal with teacher shortages?

Additional issues raised by the participants related to the selection of criteria for evaluating pre-service and in-service programs, adapting these to the demands of each education system, responding to pressure to examine teacher success by way of student achievement, and responding to the increasing desire for interdisciplinary approaches to education.

The discussion began with team members from each of the eight participating nations sharing a practice from their country that might be promising in helping to answer core questions about preparing teachers to teach. Presentations focused on teacher education programs that
support teacher readiness (i.e., pre-service), ongoing professional development (i.e., in-service), or both. Each presentation was approximately thirty minutes long and included an overview specifying the rationale for the approach, the context in which the program is used, who uses the program, the educational level at which it is used (e.g., elementary, secondary), and advantages or strengths of the program, along with any disadvantages. Because the theme of the work was “Bridging Policy and Practice,” the presentations involved reflections from both of the team members about the program. While listening to the presentations, participants were encouraged to keep the following questions in mind:

1. What mathematics do teachers need to know in order to teach well, and how does that 
   mathematics fit into the set of knowledge teachers need to know?

2. How and where do teachers learn that mathematics (e.g., in mathematics settings in
   universities, working in classes with children, strengthening curriculum materials)?

3. How might research help us better prepare teachers, and what do we actually know about
   teacher education and how it works?

   During the round-robin discussion that followed each presentation, participants were
   asked to highlight any features of the approach described that seemed promising or might work
   (or could be adapted) to their setting. They were also asked to highlight any features that would
   be challenging or very difficult to implement in their country. The table below briefly
   summarizes the national context within which each approach to pre-service and in-service
   education is situated. The content that follows the table describes the situation in each nation in
   more detail.
### Table 1: Context of Pre-service & In-service Teacher Education

<table>
<thead>
<tr>
<th>Country</th>
<th>National Standards</th>
<th>Licensing &amp; Certification</th>
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<tbody>
<tr>
<td>Brazil</td>
<td>Yes</td>
<td>Typically, students who have passed their teacher education courses and their supervised teaching activities are qualified to teach. If they want to teach in a public school, they take a civil service exam. In cases of teacher shortages, exceptions may be made to the requirements.</td>
</tr>
<tr>
<td>Egypt</td>
<td>Yes</td>
<td>There are no official procedures for licensing and certifying teachers. Teachers are qualified to teach when they complete the appropriate teacher education program for the subject or grade level.</td>
</tr>
<tr>
<td>France</td>
<td>Yes</td>
<td>The methods of certification vary to some degree as they are determined by the requirements of the place where teachers will teach. However, there are some common features in the certification process. Typically, prospective elementary school teachers take the Regional Competitive Exam (RCE). Prospective middle school teachers usually take a National Competitive Exam (CAPES). Prospective high school teachers typically complete a competitive examination called Aggregation, however some high school teachers take the CAPES to obtain certification in the subject area. Passing the relevant national exam allows prospective teachers to teach anywhere in the country. At the end of a year of training, prospective teachers take the Accreditation Exam given under the auspices of the University Institute of Teacher Training (IUFM) and the Ministry of Education. Teachers must pass this exam to earn a credential. They must also write and defend a dissertation (i.e., degree paper) called &quot;Le Mémoire Professionel&quot; in front of a board of examiners.</td>
</tr>
<tr>
<td>India</td>
<td>Yes</td>
<td>Prospective teachers must receive a Diploma in Education (D.Ed.) or a Bachelor of Education (B.Ed.) certification in order to teach in public schools. Teachers with a D.Ed. qualify for primary schools while those with a B.Ed. qualify for high school education. Teachers are qualified when they complete the appropriate teacher education program for the subject or grade level.</td>
</tr>
<tr>
<td>National Standards</td>
<td>Licensing &amp; Certification</td>
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<tr>
<td><strong>Japan</strong></td>
<td>Students must successfully complete the teacher-training program developed by the university to get a teaching license. The programs typically include courses and lesson study. After receiving a license, students must pass the “examination for appointment” developed by the board of education.</td>
<td></td>
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<tr>
<td><strong>Kenya</strong></td>
<td>Teachers complete six months of student-teaching, during which they are visited by lecturers (who may have taught them during training). Lecturers visit ten times during the six-month period. During this period, teachers spend nine weeks independently teaching a subset of the week’s lessons and assessing student learning. The lecturer observes, provides feedback and advice, and provides an assessment of the teacher’s capability. In later visits, the lecturer uses the earlier reports to assess progress. At the end of the six-month period, the reports are used to determine whether or not the student-teacher can become a classroom teacher.</td>
<td></td>
</tr>
<tr>
<td><strong>Sweden</strong></td>
<td>There is no formal certification process. A student who has graduated from a university teacher education program is automatically qualified for a teaching job. The programs typically require courses, a degree paper, and a period of school practice (i.e., student-teaching experience) which is integrated into the courses and evaluated during the university education program. Upon completion of the program, the teacher applies directly to the schools for employment. The local headmaster decides if a teacher is qualified for teaching a specific subject and at a specific level. The decision is based on recommendations from the university from which the teacher graduated. All courses and the degree paper are examined to determine a prospective teacher’s qualification, and the recommendations are inscribed in the diploma.</td>
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</tbody>
</table>
Table 1: Context of Pre-service & In-service Teacher Education (continued)

<table>
<thead>
<tr>
<th>National Standards</th>
<th>Licensing &amp; Certification</th>
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<tbody>
<tr>
<td>USA</td>
<td>Each state has its own certification process. Many require a nationally standardized teacher’s exam. The score needed to earn a passing grade varies widely. Some states now write their own exams for teachers, and these vary. Some states accept certificates from other states, but may add their own requirements – like courses in the history of the state in which the applicant is applies. In cases of teacher shortages, exceptions may be made to the requirements. Most states require different certificates for elementary and secondary school. Some also have special certificates for middle level schools.</td>
</tr>
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The following tables describe the features of in-service and pre-service education for mathematics teachers in each nation. The tables are arranged alphabetically.

Table 2: Summary of Pre-service & In-service Education in Brazil

<table>
<thead>
<tr>
<th>Pre-service Requirements &amp; Programs</th>
<th>In-service Programs</th>
</tr>
</thead>
</table>
| Training leads to a university level teaching degree in mathematics. Requirements:  
  • Courses in mathematics (in most cases these are the same as those for future mathematicians)  
  • Courses in pedagogy (in many cases these are general courses, shared with future language, geography, etc., teachers)  
  • Teaching Practice (altogether, about 700 hours of supervised activity, not necessarily in classrooms)  
In some institutions, but not all, a monograph is also required. | No formal provision  
Usually in the form of courses for teachers in the public system. These courses are not offered on a systematic schedule.  
Teachers in the public system get three paid hours per week for pedagogical meetings in school. There was a recent effort to use those hours for working groups or other forms of collaborative work. |
### Table 3: Summary of Pre-service & In-service Education in Egypt

<table>
<thead>
<tr>
<th>Pre-service Requirements &amp; Programs</th>
<th>In-service Programs</th>
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<tbody>
<tr>
<td>There are three pre-service programs for teacher education:</td>
<td>These are usually short-term programs associated with changes in curricula. There is some criticism of their planning, methods of teaching and evaluation, and some related administrative procedures. Nevertheless, some programs are exceptional. One example, which is presented later, aims to change teachers’ practice in the classroom by engaging them in collaborative efforts with inspectors and by promoting reflection and critical analysis of their own classroom practice.</td>
</tr>
<tr>
<td>1. The bachelor degree (B.S. or B.A. in subject matter and education) to prepare secondary (preparatory and secondary) teachers.</td>
<td></td>
</tr>
<tr>
<td>2. The bachelor degree to prepare primary school teachers.</td>
<td></td>
</tr>
<tr>
<td>3. After one year full-time or two years part-time educational preparation, persons holding university degrees or equivalent degrees can earn a general diploma in education.</td>
<td></td>
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### Table 4: Summary of Pre-service & In-service Education in France

<table>
<thead>
<tr>
<th>Pre-service Requirements &amp; Programs</th>
<th>In-service Programs</th>
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<tbody>
<tr>
<td>After completing a three-year degree, prospective teachers apply for admission to the University Institute of Teacher Training (IUFM) and take the Regional Admission Test.</td>
<td>Each year, each regional educational authority issues a &quot;plan académique de formation&quot;/academic training framework that lists all the training sessions planned, along with criteria for teachers’ application. This training framework is designed cooperatively by the inspectorate and representatives from teachers’ unions. The local University Institute of Teacher Training (IUFM) implements the training set out in this plan. Local authorities fund the training to the degree that they are capable.</td>
</tr>
<tr>
<td>During year one, all elementary teacher preparation is done in the IUFM. After year one, secondary teachers specialize. They take subject matter courses in the University linked to the IUFM and pedagogical and didactical training in the IUFM.</td>
<td>In mathematics, Universities of Research in Mathematics Education (IREMs) play an important role. The IUFMs delegate a large part of the mathematics training to the IREMs. In addition, IREMs organize other training sessions not detailed in the official plan.</td>
</tr>
<tr>
<td>In year two, for the entire school year they assume full responsibility for teaching a class. Each teacher-student has two pedagogical advisors who serve as mentors. One advisor is a fellow teacher in the school. The other is a pedagogical advisor, a trainer from the IUFM, who attends some of the new teacher’s classes and advises the teacher-student on theoretical issues, especially those linked to the dissertation. The new teacher also attends some of the advisor’s classes.</td>
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</table>
Table 5: Summary of Pre-service & In-service Education in India

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<tr>
<th>Pre-service Requirements &amp; Programs</th>
<th>In-service Programs</th>
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<tbody>
<tr>
<td>The governmental school system requires prospective teachers to acquire either a Diploma in Education (D.Ed.) to teach at primary level of schooling or a Bachelor of Education (B.Ed.) to teach at secondary level of schooling.</td>
<td>In-service training of teachers is provided by:</td>
</tr>
<tr>
<td></td>
<td>• The State Department of Education</td>
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<td></td>
<td>• Colleges of Education</td>
</tr>
<tr>
<td></td>
<td>• Educational Societies / Associations</td>
</tr>
<tr>
<td></td>
<td>• Voluntary Agencies</td>
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<td></td>
<td>• Commercial Organizations</td>
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<tr>
<td>In-service training is often conducted via short-term instructional courses, workshops, summer courses, etc. Many agencies see the need for such teacher enrichment programs. Many teachers take part in these courses, which contain a mix of mini-courses and expository lectures.</td>
<td>Each state has a State Council of Educational Research and Training (SCERT) that is entrusted with the responsibility of arranging in-service training courses. Some states have dedicated State Institutes of Science Education (SISE) that arrange training courses for science and mathematics teachers. In particular, when a new curriculum is implemented, massive training programs are arranged all over the state.</td>
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<td></td>
<td>District Institutes of Education and Training (DIET) undertake training courses for practicing teachers in their districts. Where DIETs are not in existence, many of the colleges of education are entrusted with the responsibility. Colleges of education have the major task of pre-service training for prospective teachers and also work towards conducting training courses for practicing teachers.</td>
</tr>
<tr>
<td></td>
<td>The efforts of DIETs and colleges of education are more concentrated at the Primary Level. Training of secondary level teachers is done either by SCERTs and SISEs as stated above.</td>
</tr>
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</table>
### Table 6: Summary of Pre-service & In-service Education in Japan

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<tr>
<th>Pre-service Requirements &amp; Programs</th>
<th>In-service Programs</th>
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<tr>
<td><strong>To become a teacher</strong>, the candidate must successfully complete a teacher education program. He or she must also pass an examination on math, liberal arts, psychology, etc., and an interview on the prospective teacher’s perspectives or beliefs about teaching.</td>
<td><strong>There are two types of training.</strong> The first is <em>public training</em> for which the government or board of education pays. The second type is <em>private training</em>, which is paid for by the teacher, research society, or other private source.</td>
</tr>
<tr>
<td><strong>In Japan, the standards produced by the Personnel Training Council guide the programs in university, but the details of the programs vary.</strong></td>
<td><strong>There are three types of public training.</strong> These are new teacher training, experienced teacher training (after five years and after ten years), and dispatched training (i.e., masters courses).</td>
</tr>
<tr>
<td><strong>In the case of Yokohama National University, the program integrates mathematics, mathematics education, and learning about practice throughout the 4-year program.</strong></td>
<td><strong>In the case of Kanagawa Prefecture:</strong> New teacher training occurs 90 times in a year. It occurs 60 times at the school site and 30 times at the board of education. Training sessions vary in length. Some are hours long, while others are days long. The lead teacher provides individual guidance to the new teachers. The training is extensive and covers various topics and provides additional training in classroom management. It also includes lesson study.</td>
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<tr>
<td>The program has core and optional elements. All math education majors take the same core courses regardless of the grade level they plan to teach.</td>
<td>Experienced teacher training occurs five or six times in the sixth year of teaching. Training is group-based and is devoted to themes such as classroom management, student guidance, and addressing specific problems such as bullying. In the eleventh year of experience, training occurs three to five times.</td>
</tr>
<tr>
<td><strong>Dispatched training may be public or private. It is available to teachers who apply and gain admission. The training may involve study abroad (for comparison purposes) or training in specific skills that may be useful to the teacher (e.g., additional teaching methods, foreign language study, or uses of instructional technology). A lot of the training involves teacher collaboration.</strong></td>
<td>All prefectures use lesson study to address issues in teachers’ professional development, which may be a component of each type of training described above.</td>
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### Table 7: Summary of Pre-service & In-service Education in Kenya

<table>
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<tr>
<th>Pre-service Requirements &amp; Programs</th>
<th>In-service Programs</th>
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<tr>
<td>An admission exam is required to obtain permission to teach. To gain admission to the exam, prospective teachers must have completed eight years primary school (for elementary teaching) and an additional 4 years of secondary school (for secondary teaching).</td>
<td>The Kenya Education Staff Institute (KESI) focuses mainly at the secondary school level, and provides in-service training for heads of schools or education institutions and their deputies, heads of departments in schools, and for teachers. This body has been in place for the last twenty years, and has become very active in the last five years.</td>
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<tr>
<td>During teacher training, students attend lectures and then go into groups of 5 to 8 to meet with a lecturer and discuss the lessons in more detail. The program includes courses that compare education in East African countries and some countries outside of Africa and discussion of general issues in education and issues of current importance at the time of the training. Prospective teachers also learn about the culture and beliefs of the many different ethnic groups in Kenya so that they are prepared to teach in any part of the country whether or not they belong to that culture. After completing their courses, students must successfully complete nine weeks of independent teaching and student assessment.</td>
<td>For heads of schools or education institutions and their deputies, KESI has provided in-services in areas such as school management, roles and responsibilities of major stakeholders, codes of regulations for teachers, the legal provisions in education, financial management, auditing, curriculum supervision and internal inspection. KESI has also provided in-services in guidance and counseling, and the management of national examinations.</td>
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<tr>
<td>The Kenya Education Staff Institute (KESI) focuses mainly at the secondary school level, and provides in-service training for heads of schools or education institutions and their deputies, heads of departments in schools, and for teachers. This body has been in place for the last twenty years, and has become very active in the last five years.</td>
<td>KESI has also provided in-services geared towards the heads of science, mathematics, humanities, and the heads of other departments in secondary schools.</td>
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<tr>
<td>In the primary schools, another body called Primary School Management or &quot;PRISM&quot; provides similar training for the school heads, deputies, and senior teachers. One in-service course for teachers is a three-week residential training course where teachers learn to conduct research and report their findings to a larger audience.</td>
<td>In the primary schools, another body called Primary School Management or &quot;PRISM&quot; provides similar training for the school heads, deputies, and senior teachers. One in-service course for teachers is a three-week residential training course where teachers learn to conduct research and report their findings to a larger audience.</td>
</tr>
<tr>
<td>Both KESI and PRISM operate under the direction of the Ministry of Education.</td>
<td>Both KESI and PRISM operate under the direction of the Ministry of Education.</td>
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<tr>
<td>Pre-service Requirements &amp; Programs</td>
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<td>-----------------------------------------------------------------------------------------------------</td>
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<tr>
<td>Teacher education, including teaching practice, is part of university education. The total length</td>
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<td>of the comprehensive program is 4.5 years for teachers at the primary and secondary level.</td>
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<td>There are many options and gradually increasing freedom of choice of courses within the program.</td>
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<td>The student could choose to take extra courses and prolong the education.</td>
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<td>All prospective teachers take one common course lasting 1.5 study years, which includes 10</td>
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<td>credits of practice/fieldwork/teaching (1 credit = 1 week full-time, 1 study year = 40 credits).</td>
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<tr>
<td>This course contains pedagogy, psychology, the school system and its history, goals and curricula</td>
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<td>for the school, and other general topics.</td>
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<td>The teaching subjects and the didactics of subjects are covered within one or two</td>
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<td>“orientations”, each lasting for 1 study year (40 credits). An orientation could cover more than</td>
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<td>one subject at lower levels. Normally at the high school level one orientation is one subject, for</td>
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<tr>
<td>instance mathematics. Each orientation contains 10 credits of teaching practice.</td>
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<td>In addition there are “specializations” each lasting one semester (20 credits). For mathematics</td>
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<td>teachers, one option would be more mathematics with a didactical emphasis, or pure mathematics</td>
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<tr>
<td>courses (which are the same as those taken by mathematics majors). Part of one specialisation must</td>
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<td>be a degree paper, often a research-like study based on the teacher’s classroom experience.</td>
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<tr>
<th>In-service Programs</th>
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<tr>
<td>Every new teacher has a mentor among his or her colleagues, and each teacher has the right and obligation to</td>
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<td>fulfil in-service training.</td>
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<tr>
<td>Teachers are expected to complete 13 days per year of in-service training, but the form of the in-service</td>
</tr>
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<td>training is left to the discretion of the provider and varies from school to school.</td>
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<tr>
<td>Most of the in-service days are used for common activities at the beginning and end of the school year. Some</td>
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<td>schools make individual in-service training plans for each teacher that attempt to balance the needs and</td>
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<td>goals of the teacher with the needs and capacities of the school. Most frequently one or more teachers</td>
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<td>participate in a short course, for half a day, one day, or several days. Teachers are encouraged to share what</td>
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<tr>
<td>they learned with their colleagues.</td>
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<tr>
<td>Short programs may be arranged at a local school or in the local community. Some commercial interests and</td>
</tr>
<tr>
<td>teacher training departments at universities also offer such programs for teachers.</td>
</tr>
<tr>
<td>More ambitious in-service programs also exist. A teacher may choose to attend some courses at the university.</td>
</tr>
<tr>
<td>If the course is relevant, completing the course may fulfill part of the 13-day in-service requirement.</td>
</tr>
</tbody>
</table>
Table 9: Summary of Pre-service & In-service Education in the USA

<table>
<thead>
<tr>
<th>Pre-service Requirements &amp; Programs</th>
<th>In-service Programs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Teacher education takes place in the universities. The requirements for entering a teacher education program in the US vary by institution, but the requirements for completing the program are strongly influenced by the state certification requirements. To teach high school mathematics, candidates typically major or minor in mathematics and complete some pedagogy classes. Program requirements vary from 20 to 40 semester hours in mathematics. In that 20+ hours students may have courses in calculus, linear algebra, probability and statistics, introduction to proof, and geometry. Some states have more requirements. For example, a major might add computer science, abstract algebra, analysis or others such as the history of math. Pedagogy would include psychology, methods, etc.</td>
<td>Requirements vary by state and/or district and are provided by a variety of sources including: • Districts • Universities • Professional Organizations District in-service training is often mandatory. Some states require “continuing education” courses to maintain or renew teaching certificates. Many courses offered in colleges of education and university extension programs fulfill these requirements. Professional organizations often provide workshops at their annual meetings.</td>
</tr>
</tbody>
</table>

Presentation and Discussion Summaries

The summaries that comprise this section contain descriptions of some approaches to teacher education taken in the eight participating nations, as well as the promises and challenges identified during the round-robin discussions that followed the presentations. These summaries are intended to 1) provide an overview of each approach, 2) capture “insights” expressed by the participants, 3) convey emerging themes that arose in the discussion of the issues, and 4) identify areas where more research is needed.
Carlos Francisco and Romulo Lins described the format and activities of Action-Research Groups (GPAs), Teaching Practice Courses for “working groups” of in-service teachers in Brazil, as well as a government-funded school development program where teachers are trained to conduct professional development activities in their schools. Carlos Francisco describes the GPAs and Teaching Practice Courses. He then answers questions from the other participants. Following this, Romulo Lins describes the FDE—Foundation for School Development—groups, and answers questions from the audience.

**Carlos Francisco**

The GPA group’s goal is to study the role of routines that lead to the failure of mathematics teaching in classrooms. The group focuses on teaching practice as an object of study. Members of the working group include mathematics and pedagogy undergraduate students (prospective teachers), mathematics graduate students (master’s and doctorate), public and private teachers of elementary and secondary schools, and professionals that act in different areas of mathematics education. Sub-groups are arranged according to the interest in a theme. Examples of themes that have been selected as foci include Didactic Material, Integral Numbers, Financial Mathematics (Business Math / Accounting), Analytic Geometry, Introduction to

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1 “Foundation for School Development” is a translation of the Portuguese phrase underlying the acronym FDE.

Members of the group work together to organize interventions related to several aspects of teaching, especially with regard to classrooms. The interventions arise from the teachers’ own actions and experiences. Groups operate on an action–reflection–action model that is based on concrete situations. The interventions that are developed pay special attention to classroom issues related to emergent social and political issues. Each work-group establishes its action strategy and reports its developed activities to members of all of the other groups in a general meeting weekly, which is called the “Big Group.” The “Big Group” is the forum for integrating all of the subgroups’ experiences.

The following paragraphs describe the Action-Research in-service program from the perspective of the Environmental Education Group, in which Francisco was a member. This group studies issues related to several kinds of environmental degradation and designs school-based problem-solving interventions related to this theme. The group aims to stimulate mathematics teachers to view and utilize mathematics as an instrument to interpret reality in a critical/reflective way. Education is conceived as a vehicle of social progress and mathematics as a means of promoting greater consciousness. In other words, this group does not simply aim to promote education in mathematics (i.e., mathematics learning) but education through mathematics (i.e., higher consciousness and greater social responsibility). Members of the Environmental Education Group include elementary and secondary teachers, undergraduate students, graduate students, and professors.
Some of the issues for which the Environmental Education Group has developed classroom-based interventions at the elementary school level include:

a) Deforestation and the concept of “green spaces”

b) Trash production (geometry), and

c) Biological diversity (statistics)

Members of the working groups take a “Teaching Practice Course” in mathematics. These courses provide a fundamental experience in the education of prospective mathematics teachers (i.e., undergraduate students). The characteristics of these courses are similar to those of the GPAs. For example, prospective teachers develop a theme for their work (with a professor’s help), decide the math content to be studied, and develop the work in the school (with a practicing mathematics teacher). In the first semester the prospective teacher develops work that will be carried out in the elementary school, and in the second semester work to be carried out in the secondary school.

In accordance with the action-reflection-action model, experiences that occur during the intervention are reported and discussed with all of the students that take part in the course during the year. The different situations are integrated and analyzed in order to look for alternatives for current educational practices that are failing.

At the end of the course, the prospective teachers prepare monographs in which they describe their experiences. To assist in the preparation of the monograph, prospective teachers take field notes when in the classroom. For example, a candidate might note characteristics of the school such as geographic and historic aspects, facilities, and staff. The prospective teacher may also generate a report on the intervention activities. Such reports generally contain
information about the resources available in the classroom, the students’ attitudes towards the work, the teacher’s attitude towards the work, classroom management strategies and successes, and the procedures used during the intervention. Field notes may also contain appendices that display the materials used.

Groups with characteristics like the GPAs work as bridges between schools and mathematics education programs. They stimulate the educational practice in a cooperative way, looking for alternatives to the current teaching practice. In addition, they provide teachers with continuous training by leading them to frequently reflect on and revise their practice. The implementation of groups with characteristics similar to the GPAs in schools can bring strength and autonomy to the schools and stimulate education professionals to face many of the challenges that are present in their lives as educators. The continuous search for solutions to problems or questions about a determined theme adds to the teacher’s responsibility for a didactic/pedagogical work contract inside the classroom and promotes the development of reflective mathematics educators.

Romulo Lins

GPA (Research Action Group) is an isolated group, but much can be learned from it. One strong feature is its location in the university. Another is that the people involved are going to be teachers, which can be an advantage and a disadvantage.

Another project in 1993 called the Foundation for School Development (FDE) tried to create a network of these groups. This foundation was linked to the state government of Sao Paulo. The groups were to address real questions and try to find real solutions to their problems.
Fifteen math educators, called multipliers, were trained to develop and lead groups in their own schools. There was no financial reward for this.

The principles of group formation and function were to:

a. inform decision making, and

b. develop a strategy for determining what is an important and a specific question that they wanted answered—Not what is the question about, but what is the question exactly—i.e., “How do I get them to see that I mean 10, not 12, when I say doziena,” rather than “I would like to know how to better teach positioning.”

During the process many of the multipliers said that they came to see that training teachers involved more than telling them what to do. It also involved providing a rationale and explaining the decision-making process so that they can learn to do it as well.

The process took place in three phases. Phase 1 focused on “internal” development. Phase 2 focused on forming groups (i.e. recruiting 10-12 teachers for their group). Phase 3 was to involve systematic research, but this never happened because it was scheduled to occur in an election year. The funding was pulled to support a more concrete agenda that was promoted in the election. Another problem was the central role of the university in teacher training.

Brazil has 300,000 math teachers. If 500 coordinators were available to oversee two groups each, then everyone could be reached. This project could operate on a local level or online. An infrastructure for disseminating work and materials that the groups produce is also needed.

Goals of the project are to promote reflective practice and cooperative work, raise awareness of complexity of decision making in teaching, improve teaching and professional
development materials, and create a real and dynamic balance between practice and policies. Teaching is quite heavily dictated by the materials available for teachers’ use. Teachers have all the power in classrooms and no power in policies. A tension exists between the ministry that makes policies and teachers who control classrooms.

**Promises and Challenges Related to the Approach in Brazil**

The seminar participants viewed Brazil’s approach positively but also expressed concern about logistics and power relations between teachers and administrators. When they considered the approach in relation to their experiences with in-service activities, they especially appreciated the higher level of active involvement that this afforded teachers. They also felt that an approach with a local focus was more likely to be relevant to the teachers struggling with particular mathematical issues or with regional social issues that can intrude in the classroom. However, when the participants considered the approach in relation to their experiences with group activities and local initiatives, they worried about how difficult it can be to promote constructive collaboration among people unaccustomed to this type of activity. In countries where there are national curricula, some participants also worried that this approach may be perceived as subversive. In general, the participants agreed that the success of this approach would depend quite heavily on the topics discussed, who is in control, and what the people in the educational superstructure may do to support, prevent, incorporate, or overtake the groups and the process.
Presentation 2: An Example of an Innovative Pre-service Teacher Education Activity in Sweden

Susanne Gennow
Danderyds Gymnasium

Gerd Brandell
Lund University

In addition to the information presented in the tables that describe the context and content of pre-service and in-service education in Sweden, the presentation described recent reforms to teacher preparation policy and programs and compared the current approach to the previous approach. The paragraphs below summarize these features of the presentation.

Teacher Education in Sweden (2001-2002)

Susanne Gennow

The revised teacher preparation program consists of one integrated program for all teachers (from pre-school to upper secondary level). Each university that offers a teacher preparation program designs it within the common frame. However, the system allows for a great deal of flexibility and student choice, so significant differences may exist among the programs offered at different universities. The shared elements of the preparation programs include three main features. These are: courses in general teacher studies that all students take, orientation courses that allow students to develop a teaching profile, and specialization courses that allow for greater depth or breadth. Students who intend to become mathematics teachers focus their orientation and specialization courses on mathematics and/or science courses. These courses also involve content in didactics/pedagogy.

The current program is similar in length and basic content to the previous program, but the content of the current program has been reorganized and focuses more attention on didactic
elements. Students still complete nine semesters of coursework and a degree paper. However, students preparing to teach lower and upper secondary level mathematics at Stockholm University now also complete a semester of student teaching and a period of mentored teaching after graduating from the program. To review full details about the reform, see Appendix C.

Gerd Brandell

The second part of the presentation included a video that portrays a group activity designed to encourage prospective teachers to connect their mathematical knowledge with pedagogical knowledge. This pre-service activity relates to recent reforms that aim to connect training with practice. In this example, teachers practice analyzing the mathematical demands of a real-world math problem, evaluate the content in the textbook for adequacy, and set expectations for what students at different grade levels might learn from the activity. They also discuss how their experience trying to complete the activity would influence the selection of materials for their students to use. The paragraphs below describe the features of the activity.

The Project

The project is presented through a video recording from one working session among teacher-students. The group work is part of a course in statistics. The teaching and learning in this and other courses has been changed as part of a development project called "To develop the ability of teacher-students to reason mathematically". The project began in 2001 and will last through 2003. It is funded by the Swedish Council for Renewal of Higher Education.

The members of the project group are from the department of mathematics and science at Kristianstad University, and the project leader is Barbro Grevholm, a newly appointed professor.
in Mathematics Education (Didactics of Mathematics) at Agder University, Norway, previously affiliated with Kristianstad University and Luleaa University of Technology. Grevholm and the students participating in the activity have kindly permitted use the videotape for the international seminar.

More information about the project is available in the project proposal, which can be accessed by going to the website at http://www.hgur.se/.

The Course

This is a 3-credit course in statistics for prospective teachers in their third year. The course is part of a bigger course (15 credits, or ¾ of one semester of full time study) in mathematics and mathematics education about statistics, geometry, and functions in which subject area and didactical aspects are integrated. The students are future teachers for years 4 - 9 in compulsory school. They have already completed their practice teaching at schools. The course work consists of lectures, laboratory work, problem-solving sessions, and individual work. These are complemented with co-operative learning in "natural study groups." The session described below is from one of these study groups.

The Session

The session took a little more than one hour, and the whole session was filmed so that it could be reviewed later. The participants are five teacher students in year 3. The task for the session was to answer four questions based on the following scenario, and report back to a lead teacher.
Scenario

In a television interview Birger Johansson, CEO of High-Tec says that the level of salary at his company is high. The thirteen employees have an average salary of 166.55 SEK per month. The mode is one million SEK. When the reporter asks about the median salary, Mr. Johansson says, "Well, it is 16 000 SEK per month, but that is not interesting in this connection."

Question 1
Is the manager speaking the truth? Can his information be true? How could the total picture of the salaries look?

Question 2
Three different statistical measures of location are mentioned. When is one or the other measure relevant to use? How did the director choose measures and why?

Question 3
How would you like to plan a teaching and learning sequence for statistical measures of location for students of years 5 and 9 respectively? Make a suggestion that you think is good and motivate why you choose this model. What knowledge of measures of locations do you find important for students?

Question 4
What did you learn from this task? How does it differ from earlier exercises on measures of location? Can students in compulsory school solve this type of task? Do you find such tasks in the mathematics books for school?
A 20-minute excerpt of the session was edited to show the participants attempting to answer three of the questions. Ultimately, they have to determine whether the expressed relationship between the values can be true, decide what the advantages are of considering each value, describe what they learned from the task of thinking about the issues, and talk about it in relation to students in grades 4-9.

The excerpt begins at a point, a couple of minutes into the session, where a participant says, “I don’t know what mode is.” Participants look through the materials to find out what mode is. They come away thinking that mode refers to the highest salary, rather than the most frequent salary. Next they define median, which they understand correctly. Later they return to the mode and find a definition in a different book. They come to a new misunderstanding that in order to be a mode, more than half of the salaries have to be equal to that number. Later they come to a correct understanding. When they discuss what students in years 4-9 would learn from this activity, they have very high expectations considering the difficulties they had as a group.

The film shows that they have an additional set of materials (texts) for students in grades 5-9. They compare the contents to the larger curriculum and use this to form their expectations. They also share recollections of their own statistical knowledge in those grades and discuss how textbooks are used when deciding what to expect. They introduce ideas from their own practice and critique the books.

**Promises and Challenges Related to the Approach in Sweden**

Seminar participants were intrigued by the plan for core experiences for all prospective teachers followed by specialization. The inclusion of pedagogy as well as content was considered desirable. The notion of a nationwide plan for preparing teachers seemed promising.
although some raised concerns about how this might work in areas where universities had a great deal of autonomy.

The video of pre-service teachers engaging in a real learning process provoked a rich discussion among the participants. They particularly appreciated the way the experience provided a model for continuing to learn after the students are finished with their formal coursework. Among the challenges raised were the facts that such experiences take a long time and, thus, make covering the many important concepts difficult and that experiencing the process themselves as learners may not translate into their own view of what teaching might be.

**Presentation 3: Some Experiences in Pre-service and In-service Teacher Education in Egypt**

*Fayez Mina*  
*Ain Shams University*

*Jean Michel Hanna*  
*French Center for Culture and Cooperation in Cairo*

Fayez Mina describes an experiment in teacher education reform conducted at Ain Shams University by himself and two of his colleagues—the late Professor Roshdy Labib, and Dr. Faisal Hashem Shams El-Din in 1982. Jean Michel Hanna then discusses an in-service program for primary school mathematics teachers and inspectors.

*Fayez Mina*

The experiment at Ain Shams University was based on teacher education reforms for prospective science teachers implemented in 1982. The reform aimed to integrate the theoretical and practical aspects of mathematics, promoting interdisciplinary study, eliminating repetitive
content, achieving the maximum consistency among the components of the program, and selecting, orienting, and supervising teachers’ trainers (in teaching practice) to support the experience as a whole. One important feature of the program was that it encouraged prospective teachers to think about schools as whole places, or societies—with facilities, activities, capacities, etc.—that they could play a role in developing. Other important features related to the desire to promote reasoning, independent learning, and active participation among teachers and students, and the need to know how to select teaching approaches, connect theories to their applications, and connect classroom activities to the real world.

One of the activities prospective teachers complete in the program is an assignment related to planning to teach an educational unit. Students were asked to critique one of the ten available textbooks or one of the five available teacher’s guides for any semester or academic year of primary education in Egypt. Students worked in groups to develop a flexible framework of criteria for analyzing the content of textbooks and teacher guides. They were then required to present and discuss the findings, focusing on the strengths and weaknesses of the material and how a teacher could capitalize on the strengths and overcome the weaknesses. Presentations and discussions of relevant reports constituted a regular part of class time, and the assignment was worth 20 percent of the course total. This was a short-term experiment that was not repeated, but there is some evidence that the experience had a long-term effect on the students.

Jean Michel Hanna

Jean Michel Hanna described an activity designed to promote teacher change. The activity can be considered an attempt to produce a practical solution to the problem of changing teachers’ practice. Principal features of the program involved a group of teachers and inspectors
working together over the course of three school years. Each school year represented a phase in the training. In the first phase, teachers studied mathematics using non-traditional methods. In the second phase, they observed, analyzed, and critiqued the classroom practice of some other teachers. In the third phase, they observed, analyzed, and critiqued their own classroom practice. The paragraphs below describe these phases in more detail.

**First phase**

The main purpose of the first phase was to encourage the trainees to modify their “model of teaching”. To achieve this goal, the instructor tried to foster a new relationship between trainees and mathematics through studying mathematics “differently” for enough time. Assuming that the trainees’ way of teaching is primarily influenced by the way they have been taught, the instructor paid special attention to the choice of content and used non-classical methods of treating this content, combining mathematics and pedagogy. Examples of the type of content used during this phase included working open problems, games and activities, and creating new problems and exercises. Examples of the teaching methods used included working in small groups, self-learning, and analyzing and evaluating the work that is done. At the end of this first stage (140 hours), trainees were expected to have new conceptions of learning and teaching mathematics. This is a necessary condition for the required modification but not a sufficient one.

**Second phase**

In the second phase, the work focused on teachers’ practice. In each session the trainees were shown a recorded classroom lesson, and then each analyzed this lesson according to some given questions, and individually wrote down comments. Afterwards, individual presentations
took place, followed by a general discussion. This format allowed everyone express ideas and conceptions explicitly, compare analyses, and hear and discuss the viewpoint of specialists in mathematics education according to the results of research in this domain. At the end of this second phase (100 hours) trainees were expected to have new criteria for judging the quality of mathematics teaching.

**Third phase**

The third phase was mainly directed at teachers and based on their self-image of their practice in classrooms, while inspectors participated in the common discussion using the same agreed criteria. Each teacher was asked to prepare a classroom lesson, discuss his or her preparation in front of the group, make any necessary modifications, and teach the lesson in a classroom in the instructor’s presence. Each lesson was videotaped. After each lesson the instructor and the individual trainees watched the video and discussed the comments and self-evaluations, especially any differences between the previously prepared plan and what actually happened in class.

**Results**

The participation of inspectors with the teachers made situations more realistic and helped each side to understand the point of view of the other side. Individual differences between trainees’ backgrounds were observed during the different phases of the program (especially the second phase). These differences made discussions much richer. During the training program, no particular type of teaching had been recommended. Each teacher started with what he or she thought was promising.
At the conclusion of the third phase, approximately 70 percent of the teachers made radical changes in their teaching practice. These modifications consisted mainly of changes in the nature of their questions to pupils and their way of responding to students’ answers. They were also more likely to adapt their methods to the pupils’ activities, make more imaginative choices regarding extension problems, and pay more attention to observing and interpreting pupils’ errors and behavior.

However, there were also some difficulties. For example, sometimes more experienced colleagues working in the same school opposed the changes and hindered their practice in classrooms. Also, the rigid programs and centralized system of education in Egypt made it difficult for teachers to be as responsive as encouraged in the training program. Parents’ expectations of teachers were also problematic at times due to an emphasis on helping their children to obtain higher grades on exams. In addition, the individual meetings with teachers in the third phase took a great deal of time—about 150 hours for 24 trainees.

Promises and Challenges Related to the Approach in Egypt

Seminar participants appreciated the description of a successful effort to promote teacher change. The goal of this program was similar to that in the in-service programs of most of the other nations. All agreed that teacher change is one of the more difficult elements of reform. They recognized the roles that realistic situations, self-critical inquiry, expert guidance, and collaboration with school administrators played in the process.

Because this training program is so time intensive, some participants expressed concern about how well it would work at the national level. Others worried about how to pay for the
necessary recording equipment (i.e. video cameras and media) and how to adapt the approach in schools without electricity.

Presentation 4: Pre-service Mathematics Teacher Education in Kenya

Beatrice “Betty” Shikuku
Booker Academy

Typically 400 students begin training as teachers in a given year. To be eligible, the student has to complete eight years of primary school and four years of secondary school. They used to need seven years of primary school, four years at O-level, and two years at A-level. If a student plans to teach math in Kenya, teacher training also includes other areas.

A candidate sitting for the teachers’ exam has to take a minimum of eight subjects. They must attain at least a B-average for six subjects. The best six subjects are selected, but mathematics is compulsory, as well as the native language, and English. Any other three courses can be used. Some required courses focus on adult education so that teachers can help with this in the field, both formally (e.g., in courses for adults) and informally (e.g., with parents trying to gain or refresh the skills they need to assist their children with their schoolwork). Other courses compare education systems and processes in countries in East Africa and countries around the world and discuss general and current issues of importance at the time of training.

Cultural issues are a common point of focus. Kenya has many different ethnic groups, and each has different beliefs. So during training, it is important for teachers to look into the social beliefs for these different groups so they can teach in any part of the country, whether they belong to that culture or not. For example, in the culture of some tribes, girls are not allowed to
sit next to boys, so they cannot share a desk. Knowing this contextual information is a crucial component of classroom logistics and management. Cultural knowledge also helps to prevent misunderstandings and discipline problems. For example, sometimes girls are not allowed to wear shoes or trousers. This is something a teacher must realize before insisting that a girl do either. The training provides teachers with this kind of knowledge before they begin teaching.

While in training, prospective teachers attend lectures, and then break into groups of five to eight people where they meet with a lecturer to discuss the lecture content in more detail. Teachers complete six months of student-teaching, during which they are visited by lecturers, who may have taught them during training. Lecturers visit 10 times during the six-month period. They observe, provide feedback and advice, and provide an assessment of the teacher’s capability. In later visits, the lecturer uses the earlier reports to assess progress. At the end of the six-month period, the reports are used to determine whether or not the student-teacher can become a classroom teacher.

Later, prospective teachers are sent to any of the schools in the country and expected to teach for nine weeks of the year. They must plan their work to cover the syllabus and allow time for testing. Their lesson notes must show the aim of the lesson, the content they are teaching, and the student activity. They execute the lessons and at the end of the term they prepare an exam, give it to students, and grade the papers. If the prospective teachers have trouble, they can ask the lecturer for help. At the end of the training, they are evaluated and a decision is made about whether they are prepared to teach. If they don’t teach well, they repeat the year until they can convince the board that they are ready to teach.
**Promises and Challenges Related to the Approach in Kenya**

Promising features of the approach were the cultural responsiveness of the teacher preparation program. Some also related to the length of the student-teaching component. Some of the countries have no supervised period of practice teaching. At the same time challenges related to potential logistical difficulties of conducting six months of observation and evaluation. Other concerns related to opposition from parents over their children being taught by unqualified teachers and possibly being less prepared for exams as a result.

**Presentation 5: Pre-service Mathematics Teacher Education in France**

*Antoine Bodin*  
*Université de Franche Comte IREM*  
*Vivianne Durand-Guerrier*  
*Institut Universitaire de Formation des Maîtres*

Antoine Bodin describes the educational experiences common to all prospective teachers. This presentation is followed by one by Vivianne Durand-Guerrier who describes a specific example of the mathematical preparation of primary level (e.g. elementary school) teachers.

*Antoine Bodin*

France has a common path for future teachers. After completing a three-year degree, prospective teachers apply to the University Institute of Teacher Training (IUFM) and take the Regional Admission Test. The ministry determines how many certificates are available in each subject area, which determines the number admitted. If there are 1000 positions, 1000 are admitted. The actual number depends on how much money is available. Every available position has about six to eight applicants, so the competition is intense. Those who are admitted attend the IUFM training for two years as teachers-students.
Year one

During year one, all elementary teacher preparation is done in the IUFM. Secondary teachers are more specialized and take both subject matter courses in the University linked to the IUFM and pedagogical and didactical training in the IUFM.

Prospective elementary school teachers take the Regional Competitive Exam, and prospective secondary teachers take the National Competitive Exam (CAPES) for certification in one subject area. At the secondary level – grade 6 to 12 – it is more common for a given teacher to be specialized in one subject matter and teach only in that subject. Passing the national exam allows recruited teachers to teach anywhere in the country, but the ministry determines exactly where they should teach. A more prestigious, highly competitive examination called "Aggregation" allows prospective teachers to teach at secondary and at university level. If they pass the exam, they enter the second year in the IUFM and become civil servants paid by the ministry.

Year two

In year two, prospective teachers are recruited to teach in the schools. During this time they are both teachers and students, so they are called teacher-students. For the entire school year they assume full responsibility for teaching a class. Each teacher-student has a pedagogical advisor who serves as a mentor. Teacher-students also have another pedagogical advisor for theoretical content who is a trainer from IUFM. This person attends some of the new teacher’s classes, and the new teacher attends some of the classes of this advisor. At the end of the year teacher-students take the Accreditation Exam, given under the auspices of the IUFM and the Ministry. Prospective teachers must pass this exam to earn a credential and, during this year,
must also write a dissertation (called "Mémoire Professionel") and defend it in front of a board of examiners. This dissertation is written under the direction of an IUFM advisor and is part of the qualifying process devised by the ministry’s inspectorate.

_Viviane Durand-Guerrier_

Elementary teachers receive special preparation in teaching mathematics. They do nine weeks of student teaching at three different grades. There is a period where they observe a special teacher who helps them. They try to create an appropriate classroom atmosphere for teaching a particular lesson and generate a mathematics problem to teach. Unfortunately, only one teacher in three has had the academic preparation that they need. One third of teachers are expected to become math teachers, but some do not like mathematics at all. One goal is to try to find ways to bring enjoyment back to mathematics for them.

A new program at the primary level, implemented in 2002, involves more space and geometry that the previous program. The main part of the work is to help pupils to identify important properties through problem-solving. Nearly no teacher does this in the classroom now. Passive observation or learning definitions should not substitute for this kind of work.

An example of the type of a problem solving activity in geometry that is given to prospective teachers includes the following:
### Instruction

<table>
<thead>
<tr>
<th>Determine all of the convex regular polyhedra</th>
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</thead>
<tbody>
<tr>
<td>1) Solve the problem; you may use manipulatives if necessary.</td>
</tr>
<tr>
<td>2) Create a poster with results and justification. Show how you solved the problem and describe the difficulties you encountered, if any.</td>
</tr>
<tr>
<td>3) Imagine a situation related to this problem for students between the ages of 7-8 and 9-10.</td>
</tr>
</tbody>
</table>

Frequent Answers and Questions arising from this activity include:

1) There must be an infinite number of polyhedra, as there are for polygons.

2) There are three polyhedra: one made of triangles, one made of squares, and one made of octagons.

3) Is it really impossible to make a convex regular hexagon? If so, why?

4) Some irregular polyhedra can be made of triangles and sometimes octohedra.

5) The first investigation rarely included icosahedra (20 triangles).

6) How can we be sure that we have found all of the possibilities?

Discussion arising from the Posters:

A theorem arises that states, “If you have six equilateral triangles with a common vertex and each shares an edge with at least one other triangle, then they necessarily give rise to a unique design.”

In the real world, this works if the triangles used as manipulatives are made of a rigid material.
Consequences of this finding include:

- No regular solid with hexagons can be constructed.
- No regular solid with more than six triangles meeting at one vertex can be created.
- No regular solid can be created if polygons with more than six sides are used.
- It may be possible to construct a regular solid out of five triangles meeting at a vertex.
- There is a need to continue with the activity, using manipulatives, in an effort to build an icosahedron. It is not obvious, but if no success is achieved, look for an explanation. Generally all groups succeed at the task.
- Students agree that the theorem should be accepted and that at least three shapes are needed to form a vertex. As a result, they can conclude that there are exactly five regular convex solids—the Platonic Solids. Rigorous proof can be found in the “Euclidean Elements” section of Book X.

This problem concerns surface geometry, which—although it has to be taught in elementary school—is generally considered to be very difficult. Cubes and tetrahedra are used so everybody can explore the problem. You can then either make conjectures and control, try again, or use both procedures. If you use plastic pieces, you can easily construct and deconstruct to explore the problem. Usually, nobody in the group knows an expert solution. To decide if the answer is correct or not, you need to assume a theorem that is validated during the process of solving. The problem phases clearly involve the process described by Brousseau: action, formulation, validation, and institutionalization.
This problem is interesting for several reasons. The first is that the mathematics is connected with real objects in a special way. We believe that mathematics is not a purely abstract matter. As a result, we think it is worthwhile to control the conjecture by building an object. We realize that even a simple problem may require more than “reflection” to solve. Action plays an important role. We are interested in geometry because it can be considered to be an experimental science. Euclidean geometry is a model that allows for predictions that can be tested in the real world. A wealth of geometrical knowledge that must be taught in French elementary schools involves Euclidean geometry. We believe that under certain circumstances, argumentation and proof are possible at the elementary level. Last, but not least we believe that mathematics is beautiful!

**Promises and Challenges Related to the Approach in France**

Seminar participants were pleased about the role that problem-solving plays in the program and with the high status, structure, and rigor of the problems used. However, there was some concern about the timing admission process. For example, in Japan, students have to decide whether or not to become teachers while they are still in high school. Also, in Brazil, the effort is to recruit prospective teachers before they complete their university degree. Participants were also concerned about the role that the exams play and about the relationship between the structure of the program and what happens in practice.
Presentation 6: Pre-service and In-service Teacher Education in Japan

Toshikazu Ikeda
Yokohama National University

Yoshiaki Kuwahara
Yokohama National University

In the following presentation Toshikazu Ikeda describes the structure of the pre-service teacher education program and Yoshiaki Kuwahara describes the features of in-service teacher education. Following these presentations, Toshikazu Ikeda describes of a specific activity called lesson study that is an important feature of in both pre-service and in-service teacher education.

Pre-service Teacher Education
Toshikazu Ikeda

In Japan, each prefecture has one teacher training university. At Yokohama National University, the education program and human sciences programs merged. In 2000, changes in the pre-service training program included an increased number of mathematics education methods courses. The mathematical aims of the program relate to mathematical reasoning and conceptual knowledge. All who take a mathematics education major take the same courses regardless of the grade level they plan to teach. The program has core and optional elements and includes instruction in the use of graphing calculators. One of the options is called “math for the real world.” In this course groups of students (12 groups with 5 members) each select a problem. They then solve the problem and prepare a presentation. Students are strongly encouraged to give presentations. They then assess each other’s presentation.
In-service Teacher Education
Yoshiaki Kuwahara

In-service teacher education may be provided by a public or private agency. The government pays for public training, while private training is paid for by the teacher, research society, or other private source. There are three types of public training: new teacher training, experienced teacher training (after five years and after ten years), and dispatched training (master’s courses).

New teacher training occurs ninety times in a year—sixty times at school, thirty times at the board of education. The length of the training varies. Some sessions last one hour, while others last for days. The lead teacher in charge of the new teachers gives them individual guidance. There is also extensive training where new teachers attend lectures on various topics. Lesson study is conducted as well, and teachers also get additional training in classroom management.

Experienced teacher training occurs five or six times in the sixth year of teaching. Training occurs in groups, and is devoted to themes such as classroom management, student guidance, or addressing specific problems such as bullying. In the eleventh year of teaching experience, training occurs three to five times.

Sometimes a company offers dispatched training. Teachers must apply and be tested to gain admission for training. Sometimes teachers go abroad to receive language training (e.g., English teachers) or go to other countries where there are Japanese schools. In one type of dispatched training they may go to inspect the schools in other countries or to a master’s course in teaching at a university. A lot of the training involves teacher collaboration. Many teachers

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2 Each prefecture has a board of education, which is a very important part of the system.
don’t like technology and don’t want to use it, so some of the online training activities used in 2002 tried to get teachers to use technology.

Lesson Study
Toshikazu Ikeda

Lesson study is a collaborative learning process that is common in in-service training but is also used in pre-service at the end of student teaching. It is difficult to become a teacher in Japan. Two or three out of ten applicants succeed in becoming teachers. They must take an examination on mathematics, liberal arts, psychology, etc. The process also involves an interview on the prospective teacher’s perspectives or beliefs about teaching.

Before WWII classrooms in Japan were teacher-centered. After WWII instruction became more student-centered. This is one reason why lesson study became so significant. There are five styles of lesson study. The goal of lesson study is to increase the shared area and identify the intersection (or strongest positive relationship) between the teacher, children, and material. At beginning of class, the teacher presents a problem. Later students are given a problem of their own to solve.

In one example, students are asked which position in a display can be represented by a specific number (e.g., 3). Some students mark the position from the left, some from the right, and some give the quantity in the set from left or from right. Then the teacher asks students to explore and explain the variety of responses. The goal is to get students to understand that the number “three” can refer to order and to set.

If the teacher rejects the students’ ideas (e.g., when a student response to 13 divided by 5 is “If I had two more the quotient would be three”) students won’t like mathematics because they
won’t feel that their ideas and thinking are valued. Good instruction builds from student ideas. If the ideas are incomplete or incorrect, the teacher needs to explore them and create opportunities for students to discover this. At the end of the lesson, the teacher summarizes the discussion and then puts a panel on the board that illustrates the mathematical idea/goal.

**Promises and Challenges Related to the Approach in Japan**

The participants found the approach to be very promising. They especially liked the ways that the program integrates mathematics content, general pedagogical content, and content specific to teaching mathematics. Also, many liked the group-based structure of the activity and the way the activation phase was used to motivate teachers. In addition, some thought that the clearly defined schedule for training was promising. However, many participants expressed concern about how difficult it would be to implement this practice in other countries without changing some cultural components, for example, acceptance of collaborative efforts.

**Presentation 7: Pre-service and In-service Education in India**

*Sudhakar Agarkar*
*Tata Institute of Fundamental Research*

*Shailesh Shirali*
*Rishi Valley School*

In this presentation, Sudhakar Agarkar describes the structure of pre-service teacher education and the roles played by various governmental and non-governmental institutions. This is followed by a presentation by Shailesh Shirali that provides some historical background on the education system in India. Using examples from the school where he works, Shailesh describes the relationship between pre-service teacher education and teacher’s classroom practice.
Pre-service Teacher Education

Sudhakar Agarkar

Three types of institutions are responsible for pre-service teacher education in India. These are government institutions, institutions that are government aided but privately managed, and institutions that are privately managed and financed. Unaided private institutions also prepare teachers for pre-primary education and higher secondary education.

Structure of Pre-service Teacher Education

<table>
<thead>
<tr>
<th>Stage</th>
<th>Required Qualification</th>
<th>Duration</th>
<th>Diploma/Degree</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-primary</td>
<td>12 years of schooling</td>
<td>1-2 years</td>
<td>Certificate in pre-school education</td>
</tr>
<tr>
<td>Primary (grades 1-7)</td>
<td>12 years of schooling</td>
<td>1-2 years</td>
<td>Diploma in Education (D.Ed.)</td>
</tr>
<tr>
<td>Secondary (grades 8-10)</td>
<td>Graduation</td>
<td>1-2 years</td>
<td>Bachelor of Education (D.Ed.)</td>
</tr>
</tbody>
</table>

Notes: A few government institutions run four-year integrated courses after 12 years of schooling. They offer B.Sc.Ed. Degree.

A person with B.Ed. Degree can pursue his/her studies to get M.Ed. and then Ph.D. in education.

Due to teacher shortages, more than ten percent of practicing teachers have not gone through a teacher education program. These teachers are offered an opportunity to get a diploma/degree through Distance Education. Open universities provide such courses. The number of untrained teachers is expected to decrease dramatically in the near future because a
large number of untrained teachers are nearing retirement. The teachers who replace them will be more likely to be trained.

Recent efforts to strengthen teacher education have included the following:

1. Establishment of National Council for Teacher Education (NCTE)
   NCTE was established in 1993 to achieve planned and coordinated development of the teacher education system. It has been entrusted with the regulation and proper maintenance of norms and standards.

2. Establishment of District Institute of Education and Training (DIET)
   DIETs are expected to provide guidance to practicing teachers on a continuing basis. Some of these institutions are already functional. The plan is to establish a DIET in each district of the country.

3. Establishment of an Institution of Advanced Study in Education (IASE)
   Centers / Institutions to undertake advanced study in education have been established in selected universities.

4. Organizing training courses for teacher educators.
   This program has been initiated to arrange training courses for teacher educators.

5. Material development for teachers and teacher educators.
   This program develops teachers’ handbooks and training modules.

In India, in-service education is conducted by the State Department of Education through the State Council of Educational Research and Training (SCERT) and the State Institute of Science Education (SISE). Colleges of Education organize pre-service courses, but a few selected institutions are also entrusted with the responsibility of in-service training. Educational
Societies/Associations such as the Atomic Energy Education Society and Bhartiya Vidya Bhavan organize in-service training courses for their members. Voluntary Agencies and organizations working in the area of education also arrange in-service courses for teachers.

Research and development projects at the Homi Bhabha Centre for Science Education have led to five programs to strengthen teacher education. The first was a remedial program for rural schools (1987-90). The goal of this program was to show teachers in rural areas how to incorporate a remedial instructional strategy to facilitate the learning of mathematics. The second program, Instructional Reforms through Voluntary Agencies (1990-93), equipped the members of the voluntary organization to undertake in-service training, follow-up, and monitoring. The third program, Capacity Building within the System (1993-96), trained resource personnel drawn from the school inspectors, active school-headmasters, and innovative teachers to provide on-spot guidance to practicing teachers. The Quality Improvement Program for Ashram Schools (1996-present) acquaints teachers with methods and materials to overcome learning hurdles faced by tribal students in Ashram Schools (residential schools on the lines of ancient Indian Gurukul system). The fifth program, Training of Teacher Educators in Mathematics (1997-99), familiarized teacher educators with the needs and requirements of practicing teachers and provided them concrete guidelines.

Although integrated science is taught in India, teacher preparation programs still teach isolated methods courses. Researchers hope that the teachers will read the research and implement it in the classroom. This does not happen often, so it is the responsibility of researchers to go to teachers and explain how beneficial the research can be.
Education in India follows the “10 + 2 + 3” model. This means that students receive 10 years of basic schooling (i.e., until the high school level). This is followed by 2 years of “intermediate” or “plus two” education (this is when one starts to specialize), and 3 years of undergraduate education (or 4 years in the case of professional courses like Engineering).

The Indian education system is very examination-driven. Not only are there the usual school-leaving examinations but also a whole host of entrance examinations that have a very direct bearing on the future careers of children. The “examination mentality” has, inevitably, had a strong negative influence on just about everything connected with education in India: textbooks, style of teaching, and teacher preparation.

Also, as is perhaps the case elsewhere, teaching today is not a particularly well-regarded profession in India, although it used to be at one time. The highly regarded professions are in medicine, engineering, management, the civil services, computer software, law, and architecture. Teaching would seem to be nearly the last option for most young people who are thinking about their careers. The highly capable students mostly opt for the high-status professions listed above. It seems like the least capable students opt to take up teaching as a profession. An important element that inevitably plays its part in this vicious cycle is the low level of teacher salaries (which are certainly much lower than, say, those of engineers and doctors). Unfortunately, this state of affairs follows a self-fulfilling path to its own detriment.

The Governmental school system requires prospective teachers to acquire a Bachelor of Education (B.Ed.) certification. There seems to be a widespread feeling among teachers, however, that expertise in teaching really comes only from hands-on experience. Theories of
teaching and B.Ed. degrees do not carry much weight. At one time the course could be done entirely by correspondence. Now a ban has been imposed on such programs. However, on the whole it would seem that the influence of the B.Ed. program on the Indian educational scene has not been very significant. There are, however, some colleges of education where a good degree in education may be obtained.

If the B.Ed. degree does not do what it ought to do, then the only option left is in-service training—via short-term instructional courses, workshops, summer courses, etc. Many agencies see the need for such teacher enrichment programs. Many teachers take part in these courses, which contain a mix of mini-courses and expository lectures. It seems that the primary levels tend to get left out of such programs. The focus is by and large on the high school and “plus two” levels.

Teacher education in my own school

Rishi Valley School has a strongly religious and philosophical orientation, and owing to this we get many unsolicited applications each year from individuals who have not been trained to teach at the school level but who may have excelled in some other field before turning their sights to education. Indeed, many of our teachers do not possess a B.Ed. degree at all. As a result, we rely very heavily on the mentor system, hands-on learning, subject specific workshops, and teacher conferences involving our sister schools.

The Council with which we are formally affiliated conducts many workshops each year for teachers as well as Heads of Schools. Some of our mathematics teachers have attended these workshops and have come back with good reports on them. Others have attended workshops conducted by the well-known mathematics educator PK Srinivasan. He has devised a new way
of teaching algebra called the design/pattern language approach. Many of our teachers have been exposed to this.

I have personally conducted numerous workshops for practicing mathematics teachers. My approach, based on what I feel are the most common areas of lacunae in teacher preparation in India, is described below. The feedback I have received from those who have attended the workshops has been quite enthusiastic.

List of “must-do” items for workshops on mathematics teaching–1: “Hands-on Activity”

- Problem solving (not only theoretically! Participants labor over problems in a simulation of the “Moore method”),
- Transformation geometry (an introduction to Klein’s Erlanger program, non-Euclidean geometry, groups in geometry, etc.)—done via problems,
- The “burden of proof”—proof in its numerous forms, e.g., proof by contradiction; the contrapositive; done once again via problems,
- Investigations in mathematics—initiating “research” at the high school level through free open-ended inquiry,
- Paper folding (in proving some theorems of triangle/circle geometry, and for understanding and manipulating fractions); also other “hands-on” activity—working with straw models, etc.,
- The role of writing in mathematics (learning to write with precision and economy),
- Software packages such as Derive™ and Mathematica®, Maple™, Geometer’s Sketchpad®, Cinderella, etc.
List of “must-do” items for workshops on mathematics teaching—2: the “Culture of Mathematics”

- Manifestations of hidden order in mathematics—encountering the unexpected (number theory and geometry are good areas here);
- Mathematics in nature (spiral and radial forms, in particular);
- Acquiring a historical perspective of elementary mathematics (the works of Archimedes, Apollonius, Bhaskaracharya, Fibonacci, Cardano, Tartaglia, Madhava, Fermat, Descartes);
- Classics in mathematics—reading the great texts (e.g., Hermann Weyl’s “Symmetry”, portions from Newton’s “Principia” and Euclid’s “Elements”);
- Great theorems of mathematics, e.g., Newton’s proof of the Law of Areas; Archimedes’ proofs for the volume-of-a-sphere formula; Oresme’s proof of the divergence of the harmonic series; Archimedes’ quadrature of the parabola;
- Humor (!) in mathematics (Leacock’s article).

An important guiding principle in the design of workshops is that the exposure must not be limited only to expository lectures (and this holds however inspiring they may be) but must also involve hands-on learning. Teacher-trainees must struggle, in the classroom and while doing homework assignments, just as their students do. After all, mathematics is not a spectator sport!

Teachers who have been through the workshops report that what makes them successful and worthwhile is precisely the “struggle” aspect. Therefore the sessions on Problem Solving, Investigations, Transformation Geometry (which too is taught through problems) and Proof
acquire particular significance, and need to be designed very carefully. Brief notes are included below on the units on problem solving and investigations. (The materials used in the units on proof and transformation geometry are in Appendix D).

**Problem solving**

If it is vital that students should tackle hard problems as part of their mathematical education, then it is equally vital that teachers should tackle hard problems—*as part of their preparation!* What is nice about problem solving is that it puts students and teachers at the same starting point and the same level. A feeling of democracy gets established. The value of tackling challenging hard problems, for student as well as teacher, is immense. The following quote, from Benjamin Finkel—founding editor of “The American Mathematical Monthly” expresses this beautifully.

> “The solution of mathematical problems has an educational value which cannot be overestimated. It is the ladder by which minds ascend into the higher fields of original research and investigation. Many dormant minds have been aroused into activity through the mastery of a single problem.” (American Mathematical Monthly, No. 1, 1894)

However, we need to keep in mind David Hilbert's advice on the matter:

> A mathematical problem should be difficult so as to entice us, yet not be completely inaccessible, lest it mock our efforts…. (Bulletin of the American Mathematical Society, 1902, Foreword)
Investigations

What was said above for problem solving holds just as well for mathematical investigations. The difference is that here the problems are of an open nature. The problems to be tackled must not look too formidable. Hilbert’s comment is very apt here. The important thing is that the teacher-participants experience mathematics not simply as something to be learned from the texts. They need to understand that it is not a “fait accompli” subject where everything that is worth doing has already been done by some great mathematician who lived several hundred years back. They need to feel that there is a possibility of teachers adding to the subject, even if only in some small way.

It seems that the design and execution of good workshops is much more promising than the design of even a challenging B.Ed. program. Good workshops expose teachers to real mathematics through problem solving, investigations, and other hands-on activity. These courses also expose teachers to the culture of mathematics—its history, its human side, and its humor.

Perhaps more energy should be put into in-service training and teacher enrichment programs rather than in pre-service training. However, it is important to note that these initiatives tend to work well only with certain kinds of teachers. Teachers who tend to really benefit are those who have a genuine desire to learn more, are intrinsically motivated, and are not afraid that struggling to solve a problem will make them seem less competent than their colleagues.
Promises and Challenges Related to the Approach in India

This conversation raised new points for the seminar participants and added dimension to topics that came up on the first day when reviewing 2001—training mathematics educators and the role and relationship of pre-service to in-service. For some, Sudhakar Agarkar’s presentation resurfaced another concern from 2001 and again this year—linking research to the training of teachers. The approaches described by Sudhakar Agarkar and Shailesh Shirali reintroduced issues about how the pieces work together and raised the question of whether the approach to pre-service education should be different from that for in-service education. The efforts they described for strengthening teacher education seem to make a serious effort to close the gap.

Many people found it was promising that so many different groups and organizations participate in the process of designing and providing pre-service and in-service teacher training experiences. The desires for broader participation and greater cooperation have been expressed by many of the seminar participants both in 2001 and 2002. Many also found it promising that one result has been greater attention paid to the experiences of teachers as they grapple with authentic mathematics and their potential contribution to the subject. Among the challenges, some participants mentioned the potential difficulty of finding enough people qualified to run the sort of workshops described. Another challenge was the potential difficulty of selecting appropriate problems in which teachers could engage.
Johnny Lott presents the features that the various teacher education programs have in common, then presents a specific example of how the teacher education program is structured at the university where he works. Linda Antinone follows with an interactive presentation of an in-service teacher education activity that involved demonstrations of uses for instructional.

Pre-service Teacher Education

Johnny Lott

A four-year university degree is universally required for teaching in public primary through secondary schools in the US. Some programs have a four-year degree in mathematics followed by a fifth year where students take education courses. Under this model, mathematics is often in the same program as that of mathematics majors who don’t plan to teach. Because of teacher shortages many other ways coming into teaching exist—often with as little as a college degree and two classes in pedagogy.

The 1989 and 2000 Standards from NCTM (http://www.nctm.org/standards/) led to changes in state standards, which affected many teacher education programs. Reforms in mathematics at the university level, primarily the calculus reform project (like Harvard Calculus\(^3\)), led to changes and reforms in some mathematics programs. Secondary and primary

\(^3\) Harvard Calculus is a colloquial reference to curriculum developed by a consortium based at Harvard University and published in 1994 by John Wiley & Sons, Inc.
school programs have also started changing. Technology has also led to major changes in teacher education programs in some cases. Changes are being made in teacher pre-service and in-service programs throughout the United States to center more on thinking about how students learn and how to shape teaching to enable student learning to take place. A central focus across K-12 mathematics education is to provide equitable opportunities for all students to learn challenging and high quality mathematics.

**A pre-service example from the University of Montana**

*Math Modeling with Technology*

This is a third year course that students take after one year of calculus, linear algebra, a statistics course (and possibly introduction to proof). Some students would have also had a computer science course. The details of the math modeling with technology course are as follows:

We want to teach the way we want our students to teach, so we arrange the classroom setting and instruction in specific ways.

**Classroom Setting**

- Mathematics Department Computer Lab (16 computers, max of 32 students). Every student has access to a computer, no more than 2 students per computer.
- A presentation computer with projector

**Class Instruction**

A mixture of lecture, technology demonstration, group work, group presentation (primary student presentation form), and individual presentation (occasional student presentations).
Types of Technology

- Graphing Calculators (the department bought them and loans them to students so that they can all have one even if they can’t afford to buy one. Students were encouraged to purchase their own)
- Data collection devices with calculators
- Microsoft® Word (word processing with equation editor)
- Microsoft® Excel (spreadsheet)
- Maple™, Mathematica®, or Derive™ (Computer Algebra Systems)
- Dynamic Geometry Software (Cabri™ and Geometer’s Sketchpad®)
- MATLAB® (Linear algebra software). Most students have used this program in earlier classes, so it is not really a focus in the course
- Fathom™ (statistics software) program used for demonstration. The program was difficult for us. We are having trouble finding a program that we like.

Types of Assignments

Writing assignments, technology homework, and group projects are the three types of assignments. All assignments must be turned in via the Internet.

Examples of Assignments

- Writing Assignment: Rattlesnake Head
  - The head of a rattlesnake can accelerate 50 m/sec.² in striking a victim. If a car could do as well, how long would it take for it to reach a speed of 60 mph from rest?
- Spreadsheet Assignment: Construction Elevator
✓ An open construction elevator is ascending on the outside of a building at a rate of 8 ft/sec. When the floor of the elevator is 80 ft. above the ground, a ball is dropped from 160 ft. above the floor of the elevator. How long does it take the ball to reach the floor of the elevator?

♦ TI-92™ Assignment: Melting Snowball

✓ A snowball of radius 12 in. is melting so that the radius is changing at the rate of 0.15 in./hr. What is the volume of the snowball when the radius is 12 in.? How long will it take for half of the volume of the snowball to melt away? How long will it take for the entire snowball to disappear?

♦ Maple™/Mathematica® Assignment: Conjecture

✓ Use a spreadsheet to make a conjecture about the following question:

bullet For which natural numbers, $a$, is the expression $\lim_{x \to \infty} e^{(10^a x)}$ finite? Prove or disprove your conjecture.

♦ Assignments comparing the outputs from different types of technology. (Forces students to examine the limits and advantages of each type of technology and become familiar with the quirks of each).

✓ Use Maple™ /Mathematica®, to graph the following equations. Compare the graphs found with comparable ones found on the TI-92™.

a) $f(x) = 3[x-2]$

b) $f(x) = (x^3 -3)/(x-1)$

(Explain any asymptotic behavior.)

▪ Geometer’s Sketchpad® Assignment: Heat Deflection
✓ In the SIMMS module Patty O’Conic, the suggestion is made that a hyperbolic heat reflector in a space heater is a good type of reflector to deflect heat to many parts of a room. If you consider a heat ray to act like a light ray, and a conic section to be locally linear, make a conjecture about how the heat is deflected and prove your answer. This may be done with calculus without all the assumptions listed.

**Final Assessment (using open-ended problems)**

A good approach to solving open-ended problems involves the use of technology. The following problem has been used with high school students and college students. Many times, the high school students are better at solving it.

**Problem**

According to a newspaper report, the trees in a certain land area are being cut at a rate of 15% per year. The lumber company claims that it replants 2000 trees every year in this area. Discuss the future tree production of this land area if this plan continues.

**An in-service example from the Fort Worth Independent School District**

**Connecting Mathematics and Science Institute**

*Linda Antinone*

Texas requires every student to take one year of algebra, one year of geometry, and one year of either advanced algebra or modeling. When I took algebra in high school, it was mainly for college bound students who were abstract thinkers. Now, many of our students are concrete thinkers. Many of them work from examples to the big picture rather than from the big picture
to the specific examples. We are trying to find ways to help students understand symbols and graphs.

We have employed an interdisciplinary approach that features mathematics, physics, and chemistry. The technology we used included Texas Instruments Incorporated Graphing Calculators, a TI Calculator-Based Ranger™ (motion detector), a TI Calculator-Based Laboratory™ System (data collection system with probes), and computers. We used several different instructional strategies during the lessons. For example, we used whole group discussion and data collection, small group data collection and analysis, hands-on activities, week-long investigations, group presentations, and sharing results of group investigations.

One activity we completed was called “Modeling in the Real World.” Another was called “Ball Drop.” Other activities related to motion, cooling, and sound waves. One of the group projects we did was to determine the accuracy of the common, although counterintuitive, assertion that hot water freezes faster than cold water.

For some of these activities we use a calculator with a motion detector. Based on the motion, it plots a graph that appears on the overhead display. This is important for exploring the meaning of graphs. It provides a real-time example of the relationship between variables (e.g. time and distance) and the features of graphs (axes, slope, maxima, and minima). Another activity involves starting with a graph and then trying to move in a way that would replicate the graph. The cooling activity involves putting a temperature probe in hot liquid and leaving it there as the liquid cools. The calculator graphs the cooling rate. The starting and stopping points on the graph show that there is a relationship between the rate of cooling and the size of the difference between liquid temperature and room temperature. Students are to find a function
that describes the relationship. These efforts to get students involved in using and interpreting data helps them make connections between representations and their meanings in the real world, and we hear much less complaining that students are bored.

In the future we expect that changes with respect to the use of technology will happen rapidly. Teacher shortages may cause the biggest changes in teacher preparation requirements. We also predict that in-service will change faster than pre-service because testing is driving practicing teachers to change faster. Tests like the SAT®4 (a university entrance examination), and some state tests, are allowing—even expecting—calculator use. Since teachers are held accountable for students’ performance, they are pushed to learn how to use—and teach with—the technology. Changes to undergraduate mathematics resulting from the Harvard Calculus program have also encouraged teachers to change their attitudes about how using technology in high school will impact college performance.

**Promises and Challenges Related to the Approach in the USA**

Many seminar participants found the use of technology to be promising, especially to the extent that it facilitates interdisciplinary lessons and the study of commonly neglected topics such as modeling. Some noted the potential of the technology to propel testing towards more meaningful content. Some also mentioned the potential of technology to motivate students to engage with the mathematics and to think about the real-world meaning of the representations and symbols they use. However, some expressed concern that the technology might receive more attention than the mathematics.

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4 The SAT was formerly an acronym for Scholastic Aptitude Test, but the test is no longer an aptitude test, and the letters SAT are no longer an considered an acronym. See [www.collegeboard.com/newsat/index.html](http://www.collegeboard.com/newsat/index.html) for details about the new format.
Some of the challenges the participants expressed related to the expense associated with the technology, especially in poor communities and highly populated countries. Other concerns related to the difficulty of training enough teachers to teach effectively with calculators and to developing activities that teachers could use to explore important mathematics with students. Some also mentioned the possibility of backlash from parents, resistance from teachers, and discontinuities between students’ earlier and later experiences learning mathematics.

**Conclusion**

After all of the presentations concluded, the members of the international panel proceeded to discuss what each had come to understand about the promises and challenges of each approach, similarities and differences between the challenges faced in each country, and potential next steps in working to resolve the issues. On the final day of the meeting, the members of the panel broke into two teams to discuss the issues further and prepare a summary document with recommendations on how to best proceed. After leaving Park City, many of the participants continued to work together to explore the situation in each country and refine the document. The product of their efforts is presented in Part II of this document.
Part II
Mathematics Teacher Preparation: Cases of In-service Teacher Education via Collaborative Communities

General Introduction

1) After the discussion described in Part I, the group concentrated on examining the questions originally presented for the seminar: What kind of subject matter preparation, and how much of it, do prospective teachers need? Are there differences by grade level? Are there differences by subject area?

2) What kinds of pedagogical preparation, and how much of it, do prospective teachers need? Are there differences by grade level? Are there differences by subject area?

3) What kind, timing, and amount of clinical training ("student teaching") best equip prospective teachers for classroom practice?

4) What policies and strategies have been used successfully by universities, school districts, and other organizations to improve and sustain the quality of teacher education?

5) What are the components and characteristics of high-quality alternative certification programs?

To focus the conversation and to relate it to more closely to the participants’ experiences, the group chose to consider in-service teacher education through collaborative communities. These decisions were made for a variety of reasons but primarily because differences across countries in the area of in-service training could be generally grouped and considered by looking at how in-service was provided through collaborative communities. In-service teacher education had a common meaning across the countries, although not practiced in the same manner by all. And while in-service teacher education was deemed necessary by all, variations in culture and practice brought the group to a common understanding that if how the training was provided, by whom, and through what agencies came to be called collaborative
communities, then a common ground was established for discussion. A collaborative community generally will mean that teachers are involved in the planning and implementation of in-service.

Even with this understanding, collaborative communities might have slightly different meanings in different countries. To make the interpretation clear, each country presented a “case” for the country. These cases were used to consider similarities and differences in the collaborative communities of each country which led to the organization of the work. The description below begins with a brief discussion of the methodology used in developing the ideas. Second, the material is organized by an overview of In-service Training through Collaborative Communities presented in a chart with different countries listed with the possible commonalities. Third, there are brief case studies from several countries followed by, fourth, general conclusions and implications of the work.

**A Note on the Basic Methodology Used**

*Prepared by Shailesh Shirali*

In July 2002, the Park City Mathematics Institute (PCMI) organized its 2nd International Seminar on Mathematics Education Teacher Preparation. In the area of in-service, participants were asked to address the following question: What policies and strategies have been used successfully by universities, school districts, and other organizations to improve and sustain the quality of teacher education?

In preparation for the later specific discussions on in-service, each country was asked to bring along posters for display, research studies, text books, and so on that would help other members get a sense of the particularities of teacher education in their country. Further, each
country was asked to give a presentation, exploring the questions listed above (as relevant for their country, of course). Each presentation was followed by a discussion. Members of the audience were asked to comment on what they found "promising" about the presentation (i.e., aspects which they felt held some promise in the context of the situation in their own country), and what they found "challenging" (i.e., aspects that would pose difficulties in the context of their country). This in turn was followed by a general discussion, centering on questions like the following:

• Where is the power located, i.e., who decides the content and timing of the programs?
• What are the unexamined assumptions that lie behind the ideas and policies? What kind of preparation do prospective teachers need (mathematical and non-mathematical)?
• How do local mathematicians interact with policy makers? Are programs assessed in any way, and if so by what criteria?
• Are policy decisions informed by any research studies?

Case studies of programs from each of the countries were examined to study the principles and assumptions that underlie the programs, and the research base that is their underpinning. Also examined were the question of what prospective teachers need to know, mathematical as well as non-mathematical (culture, traditions, etc), and how one can go about assessing a particular program.
Overview of In-service Teacher Education via Collaborative Communities

Prepared by Toshikazu Ikeda and Yoshiaki Kuwahara, with participation from all countries

Background and Focus

The overview of in-service teacher education in the eight countries considers programs promoted by a collaborative community. These may not be all of the models used for in-service in any of the countries singly but do summarize all as much as possible. As noted earlier, the meaning of collaborative community may vary slightly from country to country as is illustrated in the case studies. However, if the program is implemented with teachers’ negotiation, we regard this teachers’ group as a collaborative community as shown in Figure 1.

![Figure 1](image1)

If the program was implemented without teachers’ negotiation, we regard this teachers’ group as a non-collaborative community as shown Figure 2.

![Figure 2](image2)
In this section, external aspects of in-service were used to survey the trends of eight countries, and, in each case, to examine the following two questions:

1. At what level (school, district, state, etc.) is the in-service teacher education program that is planned by a host organization implemented?

2. Who organized the program?

For common consideration among the countries, a basic table was formed as shown in Figure 3. Because the system in each country is quite different, it was difficult for some countries to follow this framework. As a result, some countries needed to modify the basic table, or to write a short description instead of using the table.

- **Horizontal items:** (1) Who or what is reached?

  At what level is the program that is planned by a host organization implemented? (Within school/within district/within state/ et cetera).

- **Vertical items:** (2) Who organized the program?

<table>
<thead>
<tr>
<th>Horizontal Item</th>
<th>Nation</th>
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<td>Individual, Commercial/Private</td>
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</table>

**Figure 3. Basic table to survey the states in eight countries**
To facilitate use of the table, specific symbols were inserted into each cell if there exists such a program. The specific symbols are classified into four items as seen in the following key.

1. Voluntary (Free) \(\Rightarrow VF\)
   - Some teachers interested in a particular topic set by host organization participate; teachers do not have to pay.

2. Voluntary (Paid) \(\Rightarrow VP\)
   - Teachers participate if they are interested in a particular topic set by a host organization; teachers pay.

3. Compulsory (Free) \(\Rightarrow CF\)
   - All teachers participate but do not pay.

4. Compulsory (Paid) \(\Rightarrow CPA\)
   - All teachers participate and pay.

**Survey in eight countries**
The tables and short descriptions for each of the eight countries follow.

### The Case of Brazil
*Prepared by Carlos Alberto Francisco and Romulo Lins*

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<thead>
<tr>
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<th>Nation</th>
<th>State</th>
<th>District</th>
<th>School</th>
<th>Individual</th>
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<td>University</td>
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</tbody>
</table>
The Case of Egypt

Prepared by Jean Michel Hanna and Fayez Mourad Mina

The in-service education program in Egypt in the present context is as follows: The program is implemented without teachers' negotiation, in a non-collaborative community. Almost all of these programs are Compulsory Free (CF).

The Case of France

Prepared by Antoine Bodin and Vivanne Durand-Guerrier

Each year, each regional educational authority (Academy) issues a framework called "le plan académique de formation" (academic training plan). The "plan académique" is designed via collaboration between teachers unions, representatives, and the inspectorates. This framework lists all the training sessions planned, along with criteria for teachers' application.

The local University Institute of Teacher Training (IUFM) provides the training that is decided upon in the plan. Basically, the local authorities provide the funding, and the IUFM implements the plan. In recent years a drastic decrease in the funding available for in-service training, and an increase in inspectorate’s power (to the detriment of the IUFM initiative) has occurred.

Things are a bit different for primary and secondary teachers. At primary level, local primary inspectors use the "plan académique" but have more autonomy than inspectors at the secondary level to design training and to make it compulsory for all teachers that are under their direction.
In mathematics, the important role played by each region’s IREM (University of Research in Mathematics Education) is worth noting. The IUFMs delegate a large part of the mathematics training to the IREMs. In addition, the IREMs organize other training sessions not detailed in the official plan. They also represent the National Association of Mathematics Teachers (APMEP), which, like the IREMs, also have regional organizations.

The Case of India
Prepared by Sudhakar Agarkar and Shailesh Shirali

<table>
<thead>
<tr>
<th>Organizer/Level</th>
<th>Nation</th>
<th>State</th>
<th>District/City</th>
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<tr>
<td>Commercial Organizations</td>
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<td>VP/CP</td>
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In-service teacher education in India has been and remains a highly unorganized activity. While pre-service teacher education like D.Ed. and B.Ed. certification is compulsorily, no further requirement holds for teachers once they actually enter the teaching profession.

However, a few in-service programs do get held, though in a highly decentralized manner. Unfortunately, the overwhelming reality about in-service teacher education in India is that there are so many schools and so many teachers that all efforts prove inadequate. For
significant progress to be achieved, India will probably need to find radically new uses of
technology and the media, and radically new organizational structures.

The Case of Japan
*Prepared by Toshiakzu Ikeda and Yoshiaki Kuwahara*

<table>
<thead>
<tr>
<th></th>
<th>Nation</th>
<th>State (prefecture)</th>
<th>District (City)</th>
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<td>Principals, administrators, Headmasters</td>
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<tr>
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</table>

The Case of Kenya
*Prepared by Beatrice Shikuku*

The program of in-service education in Kenya is targeted towards Heads of Schools or Department Heads and not much towards teachers. As a result, little in-service teacher education exists within a collaborative community.

The Case of Sweden
*Prepared by Gerd Brandell and Suzanne Gennow*

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<tr>
<th></th>
<th>Nation</th>
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There is no compulsory (paid) in-service training policy for teachers in the regular school system.

The Case of the United States
*Prepared by Linda Antinone and Johnny W. Lott*

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<thead>
<tr>
<th></th>
<th>Nation</th>
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<td>Commercial/Private</td>
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*This varies from state to state.

Some Trends in In-service Teacher Education in the Eight Countries

Comparing the tables and short descriptions, can suggest some similarities and differences in the general aspects of in-service teacher education program. Most countries treat teachers’ negotiation in in-service teacher education with some exception (Egypt, Kenya). Programs organized by associations are implemented at the national and state level in some countries (USA, Japan, India) but not in other countries (Brazil, Sweden). Teachers’ motivation to attend in-service teacher education with teacher negotiation might be classified into three types.

(a) Attendance is compulsory.

(b) Attendance is required for promotion or salary increase.

(c) Teachers have no obligation to attend but choose to do so.

Case Studies

A Brief Description of the Idea of Working Groups of Teachers and Their Relation with Pre- and In-service Teacher Education in Brazil

Prepared by Carlos A. Francisco and Romulo Lins

Working groups of teachers (WGTs) consist simply of an organized group of teachers, with one or more coordinators, preferably chosen by the members of the group. WGTs should be the place where teachers discuss professional matters with the dual objective of improving their current teaching in a practical way and of improving their teaching in a lasting way. The issues around which work will happen are determined by group members, which may highly improve the level of commitment and interest, while at the same time it guarantees that the discussions are not some kind of formal exercise. WGTs greatly benefit from their membership in a network of WGTs, as this membership optimizes access to other people’s contributions and to a variety of materials. For instance, members are exposed to others’ suggestions on how to treat a topic or how to deal with a given situation and have greater access to books and other texts, games, didactical material, web resources, et cetera.

WGTs should be at the center of in-service professional development processes because they embody cooperative work and learning, offering self-organized professional support for the teachers involved. It is clear that being a member of a WGT is not something to which most
teachers will be accustomed. They have to somehow learn to work cooperatively. For this reason, two aspects of WGTs are important: (a) the creation of networks of WGTs should be done in a way that does not make it mandatory for all teachers; and (b) pre-service education of teachers includes a component in which future teachers will develop their ability to work cooperatively.

Point (a) suggests that strategies must be developed and carefully discussed to stimulate the creation of networks of WGTs. One strategy could involve projects like the Foundation for School Development (FDE) Project presented by Professor Romulo Lins. Another strategy could involve a group proposed by one or more teachers (difficult in Brazilian experience) or professors (as in the origins of GPA, the action-research group that Professor Carlos Francisco identified. An additional strategy could involve organizing regular short workshops for teachers (day-conferences) in which the possibility of forming groups would be gradually introduced and discussed, as control of the workshops moved from the “leader” to the members.

Funding is, of course, an issue here, but in each situation this has to be handled according to local conditions. It seems important that local educational authorities are somehow involved in stimulating teachers to belong to WGTs. One suggestion is that every teacher education center could be associated with at least one WGT, so part of the teaching practice would consist of students taking part in the group as junior members. It is important that the WGT be a real one as that would provide one way of immersing student-teachers in the profession’s culture, at the same time that allows them to face real problems and solutions coming from real teachers.

In Brazil, it is important that a network of WGTs is seen by the groups as successful overall with respect to the two objectives mentioned—solutions to more or less immediate
problems and a lasting professional development. With that in mind, it seems highly useful that networks have newsletters, a web site and a network conference.

The coordinators or leaders of the WGTs in a network should form a group themselves to discuss the advances and the problems in the functioning of different groups and possibly to transform this reflection into a form that can be disseminated and serve to help the formation of other WGTs or networks. The content here is not the same as in the groups—issues and problems coming from the teachers’ practice—but issues and problems related to the functioning of the groups. It seems important that groups of coordinators invite an experienced teacher educator to act as a supervisor of some sort, more in the sense of a psychoanalyst than in the sense of a school inspector.

It is not possible to foresee what content will be discussed or produced in particular WGTs. This is bound to be a major source of anxiety for those teacher educators with an inclination to and a belief in “objective intervention produces objective development (if done correctly).” It is the form of WGTs that carries most of the responsibility for the expected positive development that will happen, precisely because in them actual concerns and questions will compose the real situation that has to be addressed. It is against that background that decisions on whether to use workshops, longer courses, lectures, to study one or more books, to search the internet or simply to drop the topic, for instance, will be made. Also, those actual concerns and questions will bring in, distilled through eyes of the teachers, educational policies and testing issues, for instance.

Content in WGTs can be partially induced if educational agents offer them material to be discussed, be it curricular guidelines, assessment guidelines or other types of material. But it
would be up to the groups to decide what to do about those materials, as much as it is up to them to make decisions in their classrooms/school.

Finally, WGTs and networks of them, promote the notion of autonomy as a socially negotiated and collectively developed and possessed value, rather than that of autonomy as an individually acquired and individually possessed virtue. It is only by working cooperatively to deal with their real issues and concerns that teachers will develop a legitimate understanding and an adequate value for getting their students to work in a similar fashion in their classrooms.

The Case of In-service in Egypt

Prepared by Fayez Mourad Mina and Jean Michel Hanna

1. In-service teacher education

Principal features of in-service education in Egypt are characterized as follows. In-service teacher education in Egypt is generally planned in the absence of teachers. It is usually structured as a pyramid with leaders and inspectors at the central level, then teachers at the governorate levels. Methods used in in-service are mainly based on lectures to large groups, followed by sessions with smaller group (with some exceptions, such as: using videotapes of real lessons as material in in-service teacher education, classroom observation and analyzing teacher performance).

In-service education is usually related to changing programs or establishing new textbooks. Many centers organize training programs for teachers or for supervisors. Some centers that offer these programs include The Ministry of Education, The Center for Curriculum and Instructional Materials Development, The National Center for Examinations and Educational Evaluation, and The National Center for Educational Research. Additional centers...
that provide these programs include The General Directorate for In-service Training, The Regional Training Centers, The Television and Radio Broadcasts, and other institutions or organizations that depend on Universities or cultural centers.

Several problems exist in in-service teacher education in Egypt. These problems include an absence of harmonization between different centers working in teacher education and fragmentation of teacher education responsibilities, a lack of qualified or effective trainers, and a lack of active roles for head teachers at the school level. In addition to these problems, higher priority is given to the number of teachers receiving training rather than the quality of the training. There is no formal evaluation of training programs, training rarely focuses on the teacher performance, and teachers receive little real feedback. Adding to these difficulties is the costs of traveling to training centers and lodging during the work.

2. Pre-service teacher education

Basic Assumptions

The teacher education system is a sub-system of the larger educational system, which in its turn is a sub-system of societal, regional, and global systems. Nevertheless, there are common achievements, problems, and needed changes to be found all over the world. Teaching is, or must be, professionalized, regardless of the educational stage at which one teaches. This implies a minimum of requirements to be a teacher that include continuous in-service teacher education.

Teachers’ organizations, National Government Organization’s (NGO), educational authorities and other societal agencies can support the profession of teaching in many different ways. One way would be to restrict teaching at all levels to “licensed” teachers (whether for
Mathematics Teacher Education Around the World: Bridging Policy and Practice. Reflections from the 2002 International Panel on Policy and Practice in Mathematics Teacher Education

governmental schools, private schools, higher education, or NGOs educational program), and for teachers’ organizations to have a voice in current educational issues and the development of education.

Teacher education should cope with, and contribute to, recent developments in science (basically “complexity”), education (especially continuous concurrent self-education), psychology (e.g., cognitive psychology and multiple intelligences), and in the area of study and their implications for teaching (e.g., in case of mathematics; the paradigm shifts in mathematics and mathematics education). Teacher education should play a role in solving social problems, e.g., illiteracy, discrimination and so on, and attempt to deal with diversity through education. As a result of the two previous assumptions, we can look at the teacher on the one hand as an educational facilitator and as an active citizen in the society on the other.

Teaching and learning in programs of pre-service teacher education should be conducted in an atmosphere comparable to what ought to be in schools (in its ideal form) associated with training on analyzing and teaching particular curricula (professionalization of teacher education). These activities constitute some of the basics of pre-service teacher education. As well, intensive discussion and analyses of reality of schools, curricula and teaching, and the role of the teacher in their development are essential to teacher education, whether pre- or in-service education.

Teacher education should help teachers consider possible future developments in all respects. An “ideal case” 20-30 years from now, could be as follows: Almost all curricula are introduced in an integrated form in terms of problem solving, where problems mostly relate to everyday life. Calculators and computers are accepted tools in the classroom. Students submit
“evidence” to justify their conclusions rather than “logical exercises” in terms of logical proofs. At the secondary level, a student selects a certain number of “integrated” problems and produces an article/piece of research in a “transdisciplinary” area. In such a vision teachers would be educated to have a “transdisciplinary” background, be able to work in “teams” to teach integrated transdisciplinary units and take part in collecting data and research work. In addition, they would need to be able to work in the framework of the “methodology of complexity.” They would need to be able to use non-traditional methods of teaching including group work, based almost on self-education, employing advanced technology to collect data in an “encyclopedic form.” They would also need to be able to use non-traditional means of evaluation, such as open-book exams, extended assignments, self-evaluation, and so on.

To achieve these goals, in-service teacher education should be continuous and constitute an integrated part of teacher education. In-service teacher education should also meet the actual needs of teachers (as they identify them) and be conducted in ways that motivate teachers toward greater involvement in their profession.

Some Basic Ideas and Concerns

The different regions of the globe have many common problems (e.g., environmental problems fundamentalism, addiction, etc.). Some keys to their resolution lie in the behaviors and values of individuals and institutions. School curricula, and thus teacher education programs, should address them, side by side with other concerned societal institutions.

In addition to those global and regional problems, each society has its own specific problems, (e.g., overpopulation, illiteracy at different levels, problems in some particular economic sectors, some aspects of discrimination, etc.). These problems must be reflected in
school curricula as well as in teacher education programs. Although they have to be shared by all societal agencies (e.g., family, school, media), the school has an important role to play. Some means of evaluation of both the processes and products of teacher education should be established. Informal means used in this respect have proved to be effective in this concern (e.g., questionnaires, interviews, content analysis, self-conception of graduated teachers, judgments of social institutions). Some of the important points in this respect are to have an organized way to attempt such an evaluation, to get feedback from the process, and to use the feedback to improve teacher education.

Much more attention must be paid to the preparation of teacher educators. In addition to the general requirements for appointing faculty members in different universities, teacher educators must have special characteristics, such as cultural and knowledge background, involvement in societal activities at different levels, and intentions to help their students and people in general. In addition continuous plans for training and follow up must become part of the system.

This includes a strong system of support for teachers, especially in their first year(s) of work. In addition to in-service training sessions, this system might take the form of “supervision” at different levels (e.g., head teacher or supervisor). To do this effectively might require changing the concept of supervision, its goals and administration from a judgemental concept to a supportive one. Generally speaking, supervision might be seen as some kind of “consultancy” helping to link school and actual teaching, research agencies for daily problems, and so on.
Suggested Policies for Teacher Education in Egypt

Minimum requirements to become a student-teacher are to have successfully completed secondary education with evidence of the desire and ability to be a teacher. The minimum requirement to recruit a teacher could be that he or she gets a bachelor’s degree, with *educational preparation* as one of its major components. Different approaches can be used to deal with unqualified teachers; for example, open education and training programs can provide training to practicing teachers who were hired before the increase in minimum requirements. Teachers syndicates, professional organizations, educational authorities, NGOs, and the public at large, can play a great role in supporting the profession of teaching through establishing systems for “licensed teachers,” providing continuous in-service teacher education and qualifying studies, holding meetings, conferences, and seminars, issuing publications, ensuring appropriate salaries for teachers, etc.

Teacher education curricula should be oriented towards the following aspects:

- “Transdisciplinarity”, whether in thinking, taking frameworks for teaching – even in a particular subject, collecting data, school activities, etc.
- The mentality and behavior of a researcher. So, classroom research, the employment of “non-traditional” techniques in educational research, practicing research as an integrated part of study, “problem solving,” etc. must be attempted within teacher education programs.
- The intensive use of technology in learning, especially self-learning. Student-teachers must experience situations where their tutors are just “facilitators”.
- Training on employing non-traditional means of teaching and evaluation, as well as organizing school activities.
• Adopting the new methodology of science, especially with regard to the holistic view, “uncertainty”, “non-linearity”, “conditional prediction”, aims of science (to achieve better understanding of phenomena), etc.

• Being involved in professional and social activities at different levels.

• Achieving an appropriate level of cooperation among teacher education institutions on the one side and educational authorities, schools, and professional organizations on the other. Some of the areas of cooperation are curriculum planning, programs of both pre- and in-service teacher education, “experimental schools”, recruitment of teachers, policies, publications, etc.

Suggested Research

Particular Considerations in Teacher Education in the Area of Mathematics

Although the above mentioned parts of this overview are essential for mathematics teacher education, some particulars should be added and seriously considered in any process of planning, designing or implementation of pre and in-service programs of teacher education and/or in any relevant activity. The most important of these particular considerations seem to be as follows:

• Paradigm shifts in mathematics and mathematics education, especially from seeing mathematics as the study of formal systems to seeing it as a living body and from seeing mathematics programs as “a large collection of concepts and skills to be mastered in some strict particular order” or the formal teaching of mathematics to seeing these programs as human activities (Romberg, 1994; Travers, 1994).
• Mathematics as one of the existing disciplines. So, it cannot be seen apart from the contemporary and future trends of knowledge which are characterized by complexity, e.g., transdisciplinarity, refusal of the reductionistic approach, uncertainty, non-linearity, etc.

• Cohesion of knowledge and its applications. So, mathematical “modeling” will be an essential part of mathematics programs at all levels.

• Development of future “new mathematics” in order to deal with the “behavior of systems” (e.g., chaos theory and catastrophe theory). One of educational implications of such a need is to train students – at all levels - to be aware of the embodied assumptions of the mathematics they are dealing with and its limitations.

• Revision of the process of “mathematical proving”. After Gödel’s theory and the collapse of positivism, it was considered that thought might not be controlled by logic, rather the contrary (i.e., logic is controlled by thought).

Some aspects to avoid present criticism to theories of “mathematical truth”, an to attempt to build-up a new vision to it, should be considered (Mina, November 2002): Reality should not simply confined to “physical reality”, but should be extended to include “virtual reality” as well as the content of “conditional propositions”. Human behavior can be more easily explained assuming that the mind constructs mental models of reality, rather than by assuming the existence of a “mental logic”. Mathematical systems are open and have been influenced by other systems, introducing change in all of their components.
In-service Training for Mathematics Teachers in India
Prepared by Sudhakar Agarkar and Shailesh Shirali

Introduction

India has the second largest population in the world. The number of school-going children is also naturally very large. There are more than 4 million schoolteachers in the country. The majority of them have entered into the profession either with a Diploma in Education (D.Ed.) or a Bachelor of Education (B.Ed.) degree. Once they enter into profession there is no mandatory requirement for them to undergo any training. In order to update their knowledge and to acquaint them with newer teaching technologies, a few refresher courses are arranged for practicing teachers. In-service training of mathematics teachers is arranged at various levels by different organizations in the country. Here is a short summary.

Government Education Departments

Education is on the concurrent lists of the central as well as the state governments. The National Council of Educational Research and Training (NCERT) advises the central and state government education departments. Each state also has a State Council of Educational Research and Training (SCERT) that is entrusted with the responsibility of arranging in-service training courses. Some states have dedicated State Institutes of Science Education, which arrange training courses for science and mathematics teachers. In particular, when a new curriculum is implemented, massive training programs are arranged all over the state.

DIETs or Colleges of Education

To take care of teacher training on a continued basis, District Institutes of Education and Training (DIET) undertake training courses for practicing teachers in their districts. Where all DIETs are still not in existence, many of the colleges of education are entrusted with the
responsibility. Colleges of education have the major task of pre-service training for prospective teachers and also work towards conducting training courses for practicing teachers. It must be mentioned that the efforts of DIETs and colleges of education are more concentrated at the Primary Level. Training of secondary level teachers is done either by SCERTs and SISEs as stated above.

**Teachers’ Associations**

In-service programs are often arranged by teachers’ associations. One such organization that hosts training programs once every year is the AMTI (Association of Mathematics Teachers of India). The programs are held in different parts of the country. Refresher courses and workshops on specific topics, exhibitions, expository lectures by eminent persons, lectures by students (forums for innovative students to present their work), and so on, continue. However the membership of the AMTI is rather small, and it tends to be active only in the southern part of the country. State level associations that arrange in-service training courses periodically for their members also exist. On many occasions these associations conduct courses on behalf of state government education department.

**Examination Boards/Councils**

India has different examination boards that frame the curriculum and conduct school leaving examination such as the Indian Council of School Certificate (ICSC), Central Board of Secondary Education (CBSE), and State Boards of Secondary and Higher Secondary Education. These boards often host workshops in various subjects including mathematics. They even arrange workshops for heads of schools focusing on human resource management and development of leadership skills. Occasionally, the examination boards commission a group of
experts to counsel or guide teachers in a particular region or group of schools. Such counseling sessions tend to be strongly focused on examination preparation and "clearing of doubts" (for the teacher, not the student!), so they are more like "remedial sessions" than "enrichment sessions."

**Educational Societies**

Some organizations that run more than one school organize annual teacher conferences, with the agenda featuring academic as well as non-academic concerns (student behavior; cultural trends in the country that are cause for concern; developing curricula for media literacy; and so on). The academic component focuses on the teaching of specific concepts, addressing the needs of slow learners and those with learning disabilities such as dyslexia, etc. Krishnamurti Foundation of India (KFI), Atomic Energy Education Society, Bharatiya Vidya Bhavan, etc. can be cited as examples of educational societies striving to keep their teachers up-to-date in their teaching.

**Voluntary Agencies**

In India there are a large number of voluntarily agencies that work for the betterment of school education. These agencies arrange training courses for practicing teachers sometimes with the help of education department, sometimes without their help. The work of these agencies usually remains limited to a certain region, and they focus on local specific problems. Since the members of voluntary agencies work as resource persons without any remuneration and teachers attend these courses on their own without demanding any conveyance charges, such course are often cost effective.

**Commercial Organizations**
The practice of arranging in-service training courses by commercial organizations is not very common in India. Nevertheless a few organizations mobilize their resources for improving teaching learning processes in the school system. Most of these efforts concentrate on the schools run by the organizations for the benefit of their employees. In addition, a few commercial organizations support the training programs for practicing teachers by providing facilities or funds. Recently, a few industries engaged in Information Technology have come forward to provide input to teachers in selected schools in the country. It is hoped that the involvement of commercial organizations in teacher development will increase soon.

**Some Observations**

As stated above in-service training courses are arranged at various levels by various organizations in the country. Unfortunately, the overwhelming reality about in-service teacher training in India is that there are so many schools and so many teachers that all efforts prove inadequate. One strategy might be to find radically new uses of technology and the media and to establish radically new organizational structures. In-service training in India has been and remains a highly unorganized activity. While pre-service training takes place in the D.Ed./B.Ed. certification courses that prospective teachers compulsorily have to take, no such requirement holds for teachers once they actually enter the teaching profession. The need for in-service programs is perhaps not seen clearly enough by those in charge, despite the changing technologies (ready access to computers, internet connectivity, software packages to do algebra, dynamic geometry packages, graphic calculators, etc.) and changing social realities (nationalistic and communal tensions, widespread environmental degradation, globalization, etc.). The National Council of Teacher Education (NCTE) is now looking into this matter seriously.
Teachers are typically not supported if they do take the initiative to participate in these programs (in terms of remuneration, substitute teachers being arranged to take their classes, etc.). On the contrary, many schools actually discourage teachers from taking time off for these programs. Because there are no arrangements available for teacher substitution, the burden of "keeping the children busy" simply falls on some other teacher's shoulders.

Teachers who do take part in in-service programs carry back a "certificate of participation" but little more than that. Some schools may give an extra increment in salary at the end of the year, based on such certificates. No contact is maintained between the teachers and the resource providers following completion of the workshop or program, i.e., there is little by way of follow-up action.

In-service programs often get held more for "clearing one's doubts" than for professional enrichment or for learning anything new. As noted earlier, most of the in-service programs are essentially local initiatives; there is little or no horizontal communication between the groups that take such initiatives, and most of them are unaware of related activities taking place elsewhere in the country, and perhaps even in the state.

**The Case of Japan: A Case of Lesson Study**

*Prepared by Toshikazu Ikeda and Yoshiaki Kuwahara*

1. **Lesson Study as Teacher Training**

Lesson study plays an important role in teacher training. It is executed in three steps; discussion about a lesson plan, observation of an actual classroom teaching, and analytical discussion about the classroom teaching. Lesson study is treated as one of the tools to assess the classroom teaching of a pre-service teacher. In examinations to become a teacher,
demonstration of classroom teaching is gradually posed to students. Lesson study is the most popular method for in-service education, especially in elementary school and junior high school.

Lesson study is classified into five styles (as shown in Table 1) by focusing on the following two points; scale of lesson study and by whom lesson study is organized. Lesson study of style 1 is called “Konai Kenkyukai” in Japanese. Teachers who work in the school have to attend a lesson study. Some teachers attend all three steps in the process of a lesson study as contributing members. Other teachers observe an actual classroom teaching, and attend an analytical discussion about the classroom teaching.

Table 1. Five styles of a Lesson Study in Japan

<table>
<thead>
<tr>
<th>Style 1</th>
<th>Style 2</th>
<th>Style 3</th>
<th>Style 4</th>
<th>Style 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>In a school</td>
<td>In a City/Prefecture</td>
<td>In a City/Prefecture</td>
<td>From all of the prefectures</td>
<td>In a Prefecture, From all of the prefectures</td>
</tr>
<tr>
<td>Principal &amp; Teachers</td>
<td>Teachers themselves</td>
<td>Board of Education</td>
<td>School attached to University</td>
<td>Academic Society &amp; Company</td>
</tr>
</tbody>
</table>

Lesson study of style 2 is called “Ku-ken” or “Shi-ken” in case of Tokyo or Yokohama in Japanese. Lesson study of style 3 is organized by the board of education that asks teachers to participate in it. Style 4 is organized by the schools attached to university, and style 5 is organized by Japan Society of Mathematical Education (JSME), Society of Elementary Mathematics Education (SEME), and so on. Teachers are not required to attend a lesson study of style 2 through style 5.
The aim of lesson study is to let the teacher become an able teacher, however the details of the aim depend on the previous styles. Table 2 shows the main aim of each style of lesson study and methods used to disseminate it.

**Table 2. Main aims of lesson study and methods to disseminate**

<table>
<thead>
<tr>
<th>Style</th>
<th>Main Aims of L.S.</th>
<th>Main Methods to disseminate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Style 1</td>
<td>to attain the school objectives</td>
<td>Announcement</td>
</tr>
<tr>
<td>Style 2</td>
<td>to promote professional development</td>
<td>Convey from older teachers to younger teachers</td>
</tr>
<tr>
<td>Style 3</td>
<td>to develop and spread new content and approaches</td>
<td>Call for attendance at the beginning of semester</td>
</tr>
<tr>
<td>Style 4</td>
<td>to develop and spread new content and approaches</td>
<td>Announcement Homepage</td>
</tr>
<tr>
<td>Style 5</td>
<td>to cultivate activity of lesson study</td>
<td>Announcement, Journal, Homepage</td>
</tr>
</tbody>
</table>

When we consider “teacher, students, material” as three components of a lesson study, it is expected that teachers will increase the intersection between each of two components as shown in Figure 4 (Ikeda, Tsubota, Ohno and Hashimoto, 2002).
Concretely, teachers can learn the following two points by participating a lesson study.
First is learning to see the material. Second is learning to see the students. Learning to see the
material and learning to see the students are strongly connected. It is important for teachers to
connect both of them and discover appropriate methods to meet both of challenges.

(1) Points related to seeing the material

1. Can the teacher identify the essential mathematical points of the materials?
2. Does the teacher’s opening question deprive students of the opportunity to deeply
   consider the essential mathematical points?

(2) Points related to seeing the students

1. Does the teacher recognize what the students do and do not understand?
2. Do students understand the meaning of teacher’s opening question?
3. Does teacher ignore students’ ideas for “selfish reasons”?
4. Can the teacher accept and evaluate students’ ideas appropriately?

(3) Points related to seeing both the material and the students

1. Can the teacher develop the material by considering both the essential mathematical
   points and the students’ interests?
2. Can students make their own problems based on the original problem that the teacher
   presented at the beginning of the lesson? Further, are these problems concerned with
   essential mathematical points of the material?
3. Can students discover the essential mathematical points through their cooperative
   discussion? Further, can the teacher represent their ideas about these essential points in
   a summary of the lesson?
2. A sample of Lesson Study

“Annual Lesson Study by the Board of Education in the case of Hiratsuka city, Kanagawa”

This sample illustrates Style 3 of Table 1.

Initial Statements
A. Who initiates the training?

School Curriculum & Guidance Office of Board of Education

B. Who or What is reached at what level?

In the city (District)

C. Who plans the program?

This program is implemented once a year, and the schools take turns holding the Lesson Study.

Date & Time: Board of Education decides.

Place: Board of Education nominates a school in the city.

The contents & program: Arranged by the Mathematics teachers who demonstrate the lesson.

The theme: The Mathematics section of the HJERC (Hiratsuka city Junior high school Education Research Committee) determines the theme.

D. Who funds the training?

Funding is usually not required, but if necessary, the training is funded by the nominated school.

E. Who participates?

Representatives of the mathematics teachers in the city

F. Are the participants paid or supported?

Supported.
G. What is the typical length of the program?

It takes about 2 months.

H. What is the depth / breadth of coverage topics?

It depends on the theme that is determined by the Mathematics Department of HJERC. The theme is strongly concerned with new approaches of the National Curriculum.

I. Who guides and advises?

Teachers’ Consultant, Subject Guidance Teacher of Mathematics and the Principal of the nominated school guide.

J. Is any contact maintained between organizers/resource persons and participants after the program?

As the school in which the Lesson Study is held alternates, the contact is maintained.

Focus, Reason, Research Base (if it exists)

A. Legal place of this program

There is no particular research base, but Japanese public school teachers have a duty to participate in teacher training programs according to the Article 19 of the Law for Special Regulations Concerning Educational Public Service Personnel.

B. What are the reasons for the choice of this sample

In Japan, almost all Boards of Education lead or guide the annual Lesson Study, which is the typical in-service teachers training in Japan.

C. History

This type of Lesson Study was introduced in 1960s.
Process of Planning and Implementation

A. The Structure of the annual Lesson Study in Hiratsuka

![Diagram](image)

B. Planning (Collaborative Work)

(a). The decision of the research theme

The annual Lesson Study is built around a particular theme. The Mathematics Department of the HJERC, whose members are composed of the chief mathematics teachers in each junior high school, fixes a research theme for the year. The theme is fixed according to new approaches and content that are emphasized in the National Curriculum.

*Example of the theme*

- 2000 “Team Teaching Method“
- 2001 “Content of Mathematics as elective subjects.”
- 2002 “The Teaching Method and “Hyoka” of Mathematics “
(b). The Planning of the Lesson

The mathematics teachers in the nominated school cooperate with each other to make the Lesson Plan.

1. After determining a demonstration teacher, the mathematics content, unit, and so on, are determined by the teachers.

2. Discussion about a tentative lesson plan developed by the demonstrate teacher.

3. Trial lesson by other teachers according to the tentative lesson plan.

4. Improvement of the lesson plan by exchanging ideas among mathematics teachers.

5. The lesson plan is completed and presented to the Board of Education.

(c). The typical contents of annual Lesson Study

On a weekday afternoon, the participants gather at the nominated school.

1. Observation of the classroom teaching

2. Lesson debriefing and discussion
   
   (1). Greeting (the principal of the nominated school)

   (2). Opinion exchange about the classroom teaching

   (3). Opinion exchange about the theme

   (4). Guidance by the supervisors

**Effectiveness**

A. Merits of Lesson Study

1. Lesson study appears to help teachers improve their teaching, deepen their mathematics insight, overcome the problem that was focused in the lesson, and understand the contents of the National Curriculum.
2. Teachers also have the opportunity to learn about the effective approaches and contents that are executed in other prefectures or schools.

3. Teachers have the opportunity to experience the atmosphere at other schools.

B. Advantages for teachers

There no economical profit or increased qualification for teachers, but teachers have a legal obligation to participate.

C. Advantages for students

Students can get a chance to understand mathematics more easily and deeply in a class because of a teaching improvement made by their mathematics teacher.

D. Advantages for policy

1. It is possible for policy makers to disseminate the essential point of the National Curriculum.

2. The supervisor can learn about the present situation at each school, potential problems that can be addressed, assess teachers’ motivation to apply the ideas learned in the Lesson Study in their own class.

3. General Conclusion

Many teachers think that it is important and interesting to attend a lesson study. Actually, many teachers attend the lesson study. However, teachers who attend an analytical discussion tend to discuss only the advantages and disadvantages of the actual lesson. It is necessary for teachers to discuss the issues that are useful in future lessons. For example, it is expected that teachers should discuss the following questions: “Are there any alternative teaching methods for this topic?” “If you have a chance to teach the same topic next time, how
do you want to treat it?” “What are the points learned in this lesson that will be useful in a future lesson?” and so on. If the previous questions were discussed in an analytical discussion after the classroom teaching, it might become possible for teachers to reconsider a lesson plan based on the discussion. When we consider in-service education, it is important for teachers to reflect on actual classroom teaching and reconsider a lesson plan for their own training.

References

The Case of Kenya
Prepared by Beatrice Shikuku

Overview of In-service Teacher Training

In almost all countries in the world, teachers undergo formal training at university or teacher training colleges. They are assessed, graded, and sent to schools to start their teaching career. In Kenya, like in most other countries, the teachers start their teaching careers near the age of twenty-five years, and most remain in the teaching profession until they retire at approximately fifty-five years of age.

During these thirty years of teaching, many changes take place within the country, hence the need to provide in-service training for the teachers. Here in Kenya, for example, the education system has changed from 8.4.2.3 to 7.4.2.3 and now to 8.4.4, within the last twenty years. With each change in the system comes a corresponding change in the syllabus and curriculum. Every teacher, therefore, needs to update his or her training in order to cope with the changes.
There is also the question of evolving culture in our societies. Children from the same village, seated in the same classroom today would be very different from those in the same classroom thirty years ago. We have had, and will likely continue to have, changing technology, intermarriages, influences from television, and computers. Now, with cellular phones and very easy communication around the world, the forces of change may be even greater. All of these developments leave their mark on both the teacher and the learner.

There are other issues that cannot be ignored as well. Among these are global climatic change, and scientific advancements, the impact of HIV and AIDS, increased drug abuse, and the general wave of disrespect among the youth. These factors render a teacher, trained even ten years ago, almost ineffective in the school environment unless given additional support. One potential solution to this problem lies in providing in-service opportunities to teachers in order to equip them with the skills necessary to teach successfully. It is even more important that mathematics teachers participate in in-services more regularly since mathematics is at the very heart of the evolving technology and the changing culture.

In Kenya the government has launched a training program for secondary head teachers and principals to help curb the increasing number of student disturbances in schools. The program is coordinated by the Kenya Education Staff Institute (KESI). The main duty of KESI is to provide in-service training for teachers. This body has been in place for the last twenty years, and has become very active in the last five years.

KESI first focused their efforts at the heads of schools or education institutions and their deputies and provided in-services for them in several areas. Among these were school management; roles and responsibilities of head teachers, boards of governors, parents and
teachers; the code of regulation for teachers; the legal provisions in education, financial management, auditing, curriculum supervision and internal inspection; guidance and counseling; and the management of national examinations. For example, the aim of one in-service is to help prepare the heads of schools to respond to students who are in need of support and/or discipline. This is a two-week course that is now compulsory for all heads of schools and their deputies. It is usually residential, and the participants pay for their accommodations and training.

After training all the heads of schools, KESI then provided in-services for the heads of departments in schools. The training for the heads of departments is not compulsory; however it is a requirement for any promotion, thus ensuring that all teachers are motivated to participate in in-service training provided by KESI. This training was geared towards the heads of science, mathematics, humanities, and others. Participants in these in-services also pay for their two-week residential training, which usually takes place during the school holidays.

While KESI deals mainly with secondary school head teachers, deputies, and heads of departments, in the primary schools, another body called "PRISM" (Primary School Management) provides similar training for the primary school heads, deputies and senior teachers. The PRISM In-service Course, is a three-week residential training course. The participants also paid the costs of training and accommodations for this in-service. Once again, the training is not compulsory but is a requirement for any promotion. After the three-week training through PRISM, the teachers concerned are expected to conduct research and write a report within a six-month period. They then return to the training center for one week to present their individual reports and receive their certificates.
It should be noted that both bodies—KESI and PRISM—are under the Ministry of Education, in the Kenya Government.

The Case of Sweden
Prepared by Gerd Brandell and Suzanne Gennow

In Sweden the local communities run the school. The various teachers’ unions and the Swedish Association of Local Authorities (the local communities) have a general agreement concerning teachers’ right and obligation to participate in in-service training. This general agreement is then specified in an agreement at the local level. Every community has a local agreement with the union about teachers’ total working time, not only their teaching time. This time includes 13 days per year of in-service training, but the form of the in-service training is left to the discretion of the provider and varies from school to school. Most of the in-service days are used for common activities at the beginning and end of the school year. These activities are compulsory.

Some schools have started to make individual in-service training plans for each teacher. The plan is supposed to reflect the areas in which the teacher needs to develop as well as the areas in which the teacher wishes to develop himself or herself and his or her teaching. The plan is then compared with the school’s needs, and the in-service training program is adjusted to fit both the teacher and the school. Questions like, “Are there already teachers at the school with these qualifications? Can they give the in-service training?” are addressed in the negotiations.
Most frequently one or more teachers participate in a short course, for half a day, one day or some days. Then they often come back with new ideas and experiences and report to their colleges and maybe even engage them in developing the teaching. This can be more difficult for a single teacher. Therefore some schools have the policy to send at least two teachers to the same program. Such shorter programs may be arranged at the local school or in the local community at some other school or at some other place. Some commercial interests also offer such programs for teachers as well as teacher training departments at universities.

More ambitious in-service programs also exist. In this case it is always up to the teacher to decide if she or he wishes to take part. A teacher may attend some courses at the university and, in this case, she or he probably has to use her or his spare time to complete part of the course work. If the course is relevant, a teacher may agree with the head of the school to count some of the work as part of the 13 days of service that are specified in the agreement. Current examples are courses in discrete mathematics for upper secondary teachers offered at different universities. Many teachers are interested in discrete mathematics since a course in this area has recently been introduced into the upper secondary curriculum. Departments at universities (teacher training departments) also offer courses in mathematics education at a more advanced level than pre-service programs. Such a course would normally require a minimum of 25 days of full-time work. Sometimes a local community supports teachers from their schools to make it possible for them to attend such courses, but there are many communities in Sweden where the budget or struggling economy does not allow for this type of support for teachers.
The Case of the United States: One Model of Commercial Professional Development

Prepared by Johnny W. Lott, and Linda Antinone

One highly successful model of professional development used in the United States for over 15 years is the Teachers Teaching with Technology ($T^3$) model developed through Texas Instruments and under the original direction of Ohio State University (OSU) mathematics professors, Bert Waits and Franklin Demana. Waits and Demana co-wrote materials for *Precalculus: A Graphing Approach* and, with high school teachers, co-taught the course during the 1987-1988 academic year.

In the summer of 1988, the first Computers and Calculators in Precalculus ($C^2PC$) Institutes were offered with more than 80 teachers from around the nation participating in a weekend, a one-week, or a two-week institute on the OSU campus. These teachers used handheld graphing calculators to study the power of visualization in the teaching and learning of mathematics. Growth in this type of institute was rapid, and in the summer of 1993 Waits and Demana helped 34 high school teachers develop materials for algebra, precalculus and calculus institutes, and the name for the institutes was changed to the current Teachers Teaching with Technology™.

Growth in the $T^3$ program was almost instantaneous with more than 2000 teachers participating in the summer of 1993 and more than 3000 in the summer of 1994. With such wide acceptance, the program was moved to the University of Texas at Arlington in Arlington, Texas. Since that time, institutes have been developed in geometry, statistics, middle school mathematics, and elementary school mathematics, primarily from within the teachers in the project, but also with some outside help from faculty advisors. The menu of institutes was
further expanded to include the North Carolina School of Science and Mathematics, developing *Modeling and Data Analysis* as a $T^3$ affiliate institute.

As a result of the explosion of course offerings, in 1995 there were more than 6,000 teachers participating in 211 institutes in 42 states and Puerto Rico. Also in 1995 a team from Pennsylvania State University developed a second affiliate institute around using computer algebra systems in the teaching of algebra courses. A team at Ohio State University developed a similar institute for calculus. Next came a chemistry/biology institute, an elementary institute, as well as institutes for advanced statistics and analytical geometry, and for dealing with data in middle school math and science. In 1997, another affiliate institute was added, *Integrated Mathematics on the TI-92* (IM92). Systemic Initiative developed by the Montana Mathematics and Science Project (SIMMS). By the end of August 1997, $T^3$ had directly served more than 30,000 classroom teachers.

This type of work has continued and is enhanced by a technology conference that is held annually. The difference between this work and other professional development programs is that $T^3$ is a joint commercial and school/university/association venture. In the case of the SIMMS Project, a curriculum development, and its work in producing the integrated mathematics institute, some seed money was provided by Texas Instruments to bring writers and developers together. The materials for high school classes had previously been prepared by the project under the direction of the Montana Council of Teachers of Mathematics (MCTM). A week-long institute, complete with detailed books of participant and instructor materials, was developed by melding the expertise of curriculum developers, the technology of Texas Instruments, and reviewers in other places. The institute was then advertised and offered to the
public through the $T^3$ program. The materials for the institute are owned by MCTM. Texas Instruments provides advertising and arrangements. Participants pay to attend the institute which can be offered at various locations throughout the country.

Details of the week-long institute on integrated mathematics follow:

Day 1—Overview: Calculator Basics and Graphing

Day 2—Data Analysis and CBLs

Day 3—Geometry

Day 4—Algebra

Day 5—Text Editor Problems/Solutions

Each day has a specific menu of problems designed to ensure that participants consider mathematics and how technology could be used to enhance the learning of mathematics. Also, though each day has a specific topic, the material is integrated across content areas, but the specific day concentrates on problems that have the specific content as the primary vehicle for solution.

In this commercial model, participation is voluntary, and participants pay to attend. To aid the effort, MCTM typically has worked to provide instructors and aides, and Texas Instruments has provided technology. It has been a productive union of two very different groups that provide professional development to teachers at the secondary level. This model could potentially be useful in other parts of the world.


[Note: Much of the history of the Teachers Teaching with Technology institutes comes from this web site.]
General Conclusions and Implications for Research
Prepared by Shaliesh Shirali and Johnny W. Lott

The discussions leading to this document were typically rich and productive and led to many insights for the participants. It was very instructive for members to hear about how matters are organized elsewhere in the world; for example, to learn that:

(1) In Brazil, several (semi-formal) working groups of teachers appear to have formed to support one another and to discuss matters of pedagogy; the state supports them in this enterprise. Areas of concern include pressing social problems such as street violence and drugs. There is a recognition of the fact that attempts to reform teaching practice must necessarily address these concerns, as these problems may impact the lives of both students and teachers, both in school and out.

(2) In Egypt, videotaping of teacher trainees' practice lessons has been successfully carried out and led to the changes in teaching philosophy and behavior that were set as goals of the training.

(3) In France teacher training is a highly centralized program, with prospective schoolteachers having to pass a competitive examination in pedagogy and subject matter and write a paper in some area of pedagogy. The program for pre-service teachers is characterized by a high level of rigor, but nothing comparable seemed to exist for in-service training.

(4) In India, teacher training is typically pre-service. In-service training tends to be ad hoc and conducted by local or private bodies rather than by any central authority. Typically the focus is on the high school level; primary levels tend to get left out. Many teachers take part in these courses, which contain a mix of mini-courses and expository lectures. Though many voluntary
and governmental bodies are involved, their efforts get diluted because of the very high population of the country.

(5) In Japan, in-service training is a yearlong affair, with programs of short duration going on all the time. There are programs for teachers after 5 years of teaching, after 15 years of teaching, at regular intervals throughout the teacher’s career, devoted to academic topics as well as themes such as classroom management, student guidance, problems of growing-up, bullying, and so on.

(6) Kenya has a strong system of pre-service teacher training, with rigorous procedures for assessment. Training includes discussion on issues of current importance, e.g., learning about the many tribes of the country and their culture and traditions. However, there is nothing comparable for in-service training.

(7) In Sweden, prospective teachers must write a paper (as in France), and career teachers are obliged to (and indeed have the right to) go through in-service training.

(8) The United States has a wide variety of programs, with each state offering its own certification. Districts require in-service training of teachers, and some states require them to take continuing education courses for renewal of teaching certificates. Professional organizations, for example, the National Council of Teachers of Mathematics (NCTM) regularly host workshops for practicing teachers. Additionally, many universities offer in-service programs on their own initiative.

(9) In the United States, many commercial ventures provide professional development to teachers for a fee. The commercialism of this implies would be rejected in some of the participating countries, while others saw it as having possibilities for their own system.
With the diversity of the countries at the seminar, it is not surprising that there were many
different models of in-service. In the discussion of in-service, representatives found cultural
issues in some countries that affect teacher preparation and in-service across countries. Among
those issues is the fact that many children do not have access to a full education—so many
children that it is unknown how many, and in some cases, schools could not handle them if all
were to suddenly appear at some point. Other issues include the fact that in some countries,
schools are used as one of the safe places for children—social issues outweigh curriculum and
teaching methods found in other countries. In some countries education is socialized with all
aspects of education paid for by the government—either state or national. In other countries, the
level and amount of money available for schools and teachers is minimal. In some countries,
mathematics is more important than social or pedagogical issues. With these backdrops, many
variables must be considered in any type of common research agenda—so many variables that
generalized study may be impossible.

Given these constraints, some suggestions did emerge as productive areas of research.
These included:

1. use of lesson study on varying scales in countries not currently using it;

2. use of working groups of teachers to identify local problems and issues and providing a
   venue for discussion and possible solution;

3. use of commercial professional development on smaller scales in countries where this is not
done;

4. study of examinations and their effect in countries with strong examination systems to
   provide guidance for other countries entering that arena;
5. study of types of pedagogy used in in-service around the world and the effectiveness of different types.

The diversity of the countries present led to a broad and often unsettling sense of the issues related to in-service teacher education from a world-wide perspective. The opportunity to begin a discussion across countries and representatives from the secondary school community and from the university teacher preparation community was both profitable and promising. In the short term, the insights and perspectives gained by the participants will enrich their own work and dialogue. In the long term, continued conversations and mutual efforts may help the notion of collaborative communities become a viable way of bringing together educators within countries as well as those across countries to address problems that in this increasingly shrinking world are part of the work of all mathematics educators.
Appendix A

International Panel: Bridging Policy and Practice

Agenda

Daily break schedule:

<table>
<thead>
<tr>
<th>Morning</th>
<th>Lunch</th>
<th>Afternoon</th>
</tr>
</thead>
<tbody>
<tr>
<td>10:00 - 10:15 a.m.</td>
<td>12:00 - 1:00 p.m.</td>
<td>3:00 - 3:15 p.m.</td>
</tr>
</tbody>
</table>

Friday - Saturday, July 12-13

Arrival in Park City

Saturday, July 13

6:00 p.m. Meet in lobby of Lodge to depart for picnic and concert at Deer Park Amphitheater. Nancy DeMello and Carol Hattan will oversee outing.

Sunday, July 14

Give poster material to Glenda Breaux before 8:00 a.m.

8:30 - 12:00 p.m. Work Session I

Welcome Herb Clemens, Chair, PCMI Steering Committee
Introductions: Joan Ferrini-Mundy and Gail Burrill
Reflection on last summer: Gail Burrill
Overview of the week: Joan Ferrini-Mundy

9:30 - 10:00 a.m. Brazil (1/2 hour presentation)

10:15 – 10:45 a.m. Brazil (1/2 hour discussion)

10:45 - 11:45 a.m. Sweden (1/2 hour presentation, 1/2 hour discussion)

1:00 - 4:30 p.m. Work Session II

1:30 - 2:30 p.m. Egypt (1/2 hour presentation, 1/2 hour discussion)
2:30 - 3:00 p.m. Kenya (1/2 hour presentation)

3:00 - 3:15 p.m. Break

3:15 - 3:45 p.m. Kenya (1/2 hour discussion)

3:45 - 4:30 p.m. Taking stock: What might we do together, getting clear about what we will accomplish.

6:00 p.m. Welcome dinner at Grub Steak Restaurant (across from Lodge)

**Monday, July 15**

8:30 - 12:00 p.m. Work Session III

8:30 - 9:00 a.m. Recap from Sunday

9:00 - 10:00 a.m. France (1/2 hour presentation, 1/2 hour discussion)

10:15 - 11:15 a.m. Japan (1/2 hour presentation, 1/2 hour discussion)

1:00 - 4:30 p.m. Work Session IV

1:00 - 1:30 p.m. Recap from morning

1:30 - 2:30 p.m. India (1/2 hour presentation, 1/2 hour discussion)

2:30 - 3:00 p.m. United States (1/2 hour presentation)

3:15 - 3:45 p.m. United States (1/2 hour discussion)

**Tuesday, July 16**

8:30 - 12:00 p.m. Work Session V
Discussion of all examples.

1:00 - 4:30 p.m. Work Session VI
Selection from examples

4:30 - 5:30 p.m. “Tea in the Tent”, PCMI participants meet with international guests.
**Wednesday, July 17**

8:30 - 12:00 p.m. Work Session VII  
Working groups

1:00 - 4:30 p.m. Work Session VIII  
Working groups

**Thursday, July 18**

8:30 - 12:00 p.m. Work Session IX  
Working and sharing

1:00 - 4:30 p.m. Work Session X  
Next steps

PCMI closing dinner in tent

6:00 Reception

6:30 Dinner

**Friday, July 19**

Guests depart for home from Salt Lake City Airport.
## Appendix B

### International Panel: Bridging Policy and Practice

#### 2002 Participants

<table>
<thead>
<tr>
<th>Name</th>
<th>Affiliation</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sudhakar Agarkar</td>
<td>Tata Institute of Fundamental Research</td>
<td>Maharashtra, India</td>
</tr>
<tr>
<td>Linda Antinone</td>
<td>Paschal High School</td>
<td>Ft Worth, TX USA</td>
</tr>
<tr>
<td>Antoine Bodin</td>
<td>Université de Franche Comte IREM</td>
<td>Besancon, France</td>
</tr>
<tr>
<td>Gerd Brandell</td>
<td>Lund University</td>
<td>Lund, Sweden</td>
</tr>
<tr>
<td>Gail Burrill</td>
<td>Michigan State University</td>
<td>East Lansing, MI, USA</td>
</tr>
<tr>
<td>Viviane Durand-Guerrier</td>
<td>Institut Universitaire de Formation des Maîtres</td>
<td>Lyon, France</td>
</tr>
<tr>
<td>Joan Ferrini-Mundy</td>
<td>Michigan State University</td>
<td>East Lansing, MI, USA</td>
</tr>
<tr>
<td>Carlos Alberto Francisco</td>
<td>State School Secondary Joaquim Ribeiro</td>
<td>Rio Claro, Brazil</td>
</tr>
<tr>
<td>Susanne Gennow</td>
<td>Danderyds Gymnasium</td>
<td>Danderyds, Sweden</td>
</tr>
<tr>
<td>Jean Michel Hanna</td>
<td>French Center for Culture and Cooperation in Cairo</td>
<td>Cairo, Egypt</td>
</tr>
<tr>
<td>Yoshiaki Kuwahara</td>
<td>Yokohama National University</td>
<td>Yokohama, Japan</td>
</tr>
<tr>
<td>Toshikazu Ikeda</td>
<td>Yokohama National University</td>
<td>Yokohama, Japan</td>
</tr>
<tr>
<td>Romulo Lins</td>
<td>State University at Rio Claro</td>
<td>Rio Claro, Brazil</td>
</tr>
<tr>
<td>Johnny Lott</td>
<td>National Council of Teachers of Mathematics</td>
<td>Missoula, MT, USA</td>
</tr>
<tr>
<td>Fayez Mina</td>
<td>Ain Shams University</td>
<td>Cairo, Egypt</td>
</tr>
<tr>
<td>Beatrice N. Shikuku</td>
<td>Booker Academy</td>
<td>Mumias, Kenya</td>
</tr>
</tbody>
</table>
Shailesh Shirali
Rishi Valley School
Rishi Valley, India

**Staff**

Jean Beland
Michigan State University
East Lansing, MI, USA

Glenda Breaux
Michigan State University
East Lansing, MI, USA

Nancy DeMello
University of Utah
Salt Lake City, UT, USA

Catherine Giesbrecht
Institute for Advanced Study
Princeton, NJ, USA

**Guests**

Herbert Clemens
University of Utah
Salt Lake City, UT, USA

Rachel Gray
Institute for Advanced Study
Princeton, NJ, USA

Elaine Wolfensohn
The World Bank
Washington, D.C., USA
Appendix C

International Panel: Bridging Policy and Practice

Teacher Education Reform in Sweden

The school system in Sweden

Pre-school, up to 5 years of age
Pre-school class, age 6
Compulsory school, school year 1-9, age 7-15
Upper Secondary School, school year 10-12 age 16-19

Teacher education before 1988

Teacher school year 1-3
2.5 years (5 semesters)
Requirement 2 years of upper secondary school
all theoretical subjects

Teacher school year 4-6
3 years (6 semesters)
Requirement 2 years of upper secondary school
all theoretical subjects

Teacher school year 7-9
University degree in 2 or 3 subjects, 3 study years
Minimum one study year in at least one subject
Institute/department of education one year (40 credits), out of which 20 is practice in school

Teacher, upper secondary school
University degree in 2 or 3 subjects, 3 study years
Minimum 1.5 study years in at least one subject
Institute/department of education one year (40 credits), out of which 20 is practice in school

Teacher education, 1988-2001

Teacher for School year 1-7
Two programs: Mathematics/Natural Science or Swedish/Social Science
3.5 years, 140 credits
Requirement for the Math/Science program is Science program from upper secondary school

Mathematics Education Around the World: Bridging Policy and Practice. Reflections from the 2002 International Panel on Policy and Practice in Mathematics Education
Ma/Science-program, school year 1-7
1988 – 2001 program
Mathematics 15 credits (0.75 semesters) plus minimum level of science
Institute/department of education delivers 40 credits (one year), out of which 20 credits is
practice in school
Subject area, education and practice are integrated
A degree paper (10 credits)

Teacher for school year 4-9
1988-2001 program
Two programs: Mathematics/Science or Swedish/Social Science
4.5 years, 180 credits
Requirement for the Math/Science program is Science program from upper secondary
school

Ma/Science-program, school year 4-9
1988 – 2001 program
Mathematics 30 credits (1.5 semesters) plus minimum level of science subjects
Institute/department of education delivers 40 credits (one year), out of which 20 are
practice in school
Subject area, education and practice are integrated
A degree paper (10 credits)

Teacher for upper secondary school,
1988-2001 education
2 or 3 subjects
4.5 years, 180 credits
Minimum 80 credits (2 study years) in at least one subject
Institute/department of education delivers one year (40 credits), out of which 20 are
practice in school
Subject area, education and practice are integrated
A degree paper (10 credits)
Mathematics courses for teachers for lower and upper secondary level
1988 – 2001 Education
Example from Stockholm University

<table>
<thead>
<tr>
<th>Basic course I</th>
<th>Basic course II</th>
<th>Additional course</th>
<th>Deepening course</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 semester, 20 credits</td>
<td>1 semester, 20 credits</td>
<td>1 semester, 20 credits</td>
<td>1 semester, 20 credits</td>
</tr>
<tr>
<td>Introduction course (5)</td>
<td>Algebra &amp; combinatorics (5)</td>
<td>History of Math (10)</td>
<td>4 courses (5 each)</td>
</tr>
<tr>
<td>Linear algebra (5)</td>
<td>Calculus 3 (5)</td>
<td>Choice of 2 courses (5 each) among 12 optional courses</td>
<td>a degree paper (10)</td>
</tr>
<tr>
<td>Calculus 1 (5)</td>
<td>Statistics (5)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Calculus 2 (5)</td>
<td>Numerical Methods (5)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Teacher Education starting in 2001-2002

ONE integrated program for all teachers, from preschool to upper secondary level
Different options within the program
Great flexibility, student can make successive choices
Each university designs the program within the common frame – big differences between universities

Three main parts
(Teacher education starting in 2001)
One common course for all students, 1.5 study years, 60 credits
One or two orientations (the profile of teacher), each orientation is minimum 1 study year, 40 credits
One or more specializations giving depth or breadth, each specialization is 20 credits

Part 1
Common course for all teacher students, general teacher studies
(Teacher education starting in 2001)
1.5 study years, 60 credits
General education, psychology etc
School practice, 10 credits
Interdisciplinary subject studies
(Degree project, 10 credits, may also be contained in one of the specializations, part 3)
The course may be split up into parts and interwoven into the rest of the education
Part 2

Orientation towards a subject or a field of subjects or competencies
(Teacher education starting in 2001)

Minimum one year, 40 credits including 10 credits of school practice

Examples of orientations including mathematics
(Luleå University of Technology):
Mathematics for younger children (year 1 – 5), 40 credits
Mathematics for older children (year 6 – 9), 40 credits
Mathematics for upper secondary school, 60 credits
Mathematics and computer science, 80 credits
Mathematics and physics or math and chemistry 100/120 credits

Part 3

Specializations
(Teacher education starting in 2001)

A specialization is one semester, 20 credits

It may either deepen one of the orientations (most often one subject area) or it could be a new subject area or some competency (like mathematics for children with special needs)

There may or may not be a didactical perspective integrated into the specialization

Stockholm University, structure of mathematics teacher education
(Starting 2001)

Pre-school, compulsory school (primary, school year 1-6):

Common course for all, 60 credits
Orientation, may be mathematics, 40 credits
Two specializations, one may be math, 2*20 credits
Total 140 credits (3.5 year)

Stockholm University, structure of mathematics teacher education
(Starting 2001)

Lower secondary level, year 7 – 9

Common course for all, 60 credits
Two orientations, one is mathematics, 2*40 credits
Two specializations of which one is a deepening of one of the orientations, 2*20 credits
Total 180 credits (4.5 year)
Stockholm University, structure of mathematics teacher education

(Starting 2001)

Upper secondary school
Common course for all, 60 credits
Two orientations, one is mathematics, 2*40 credits
At least two specializations to deepen the directions, 2*20 credits
180 credits (4.5 year)

Stockholm University Orientation
“Mathematics for lower and upper secondary level”
(Starting 2001)

One study year, 40 credits
Mathematics with didactics I (20 credits)
Contents:
Arithmetic, algebra and geometry, 5 credits
Didactics of mathematics 5 credits
Vectors and calculus 5 credits
History of Mathematics 5 credits

Mathematics with didactics II (20 credits)
Contents:
Problem solving with algebra, geometry and combinatorics 5 credits
Didactics of mathematics 5 credits
Calculus 5 credits
Probability and Statistics 5 credits

Comparison of “old” and new education
Mathematics teacher for lower (year 7-9)
and upper secondary level
Example Stockholm University

1988-2001
Semester 1 and 2, studies in mathematics (40 credits)
Semester 3 general education and practice
Semester 4-8, studies in mathematics and other subject areas
Semester 9, general education and practice

A degree paper
2001- (years 2-9 planned)
Sem 1, general education with 10 weeks practice, no teaching (teacher student)
Sem 2 and 3, mathematics with didactics, common for lower and upper secondary school
Sem 4-8, courses from the three parts
Sem 9, school practice and a degree paper

Examination process
The student must pass all courses
The school practice as teacher during the education is evaluated and the student must satisfactory pass
The degree paper is examined and must be accepted

There is no formal certification process

Beginning teaching
Every new teacher has a mentor among the colleagues
Teaching is about 500 hours/year (1 hour = 60 minutes), same as for other teachers
A teacher acts as mentor for a group of students, and gives information about results of studies, has contact with parents and so on
A teacher has the right and obligation to fulfil in-service training
Appendix D

International Panel: Bridging Policy and Practice

Teacher Education Reform in India

Number of Teachers in Millions

<table>
<thead>
<tr>
<th>Stage</th>
<th>Male</th>
<th>Female</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary</td>
<td>1.23</td>
<td>0.64</td>
<td>1.87</td>
</tr>
<tr>
<td>Middle</td>
<td>0.77</td>
<td>0.44</td>
<td>1.21</td>
</tr>
<tr>
<td>Secondary</td>
<td>0.56</td>
<td>0.31</td>
<td>0.87</td>
</tr>
<tr>
<td>Higher Secondary</td>
<td>0.43</td>
<td>0.22</td>
<td>0.65</td>
</tr>
<tr>
<td>Total</td>
<td>2.99</td>
<td>1.61</td>
<td>4.60</td>
</tr>
</tbody>
</table>

Legend: Primary - Grades 1 to 5
Middle - Grades 6 to 8
Secondary - Grades 9 and 10
Higher Secondary - Grades 11 and 12

Number of Training Institutions and Enrollment

<table>
<thead>
<tr>
<th>Stage</th>
<th>No. of Institutions</th>
<th>Enrollment (in millions)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary</td>
<td>1270</td>
<td>0.11</td>
</tr>
<tr>
<td>Secondary</td>
<td>0868</td>
<td>0.11</td>
</tr>
<tr>
<td>Total</td>
<td>2118</td>
<td>0.22</td>
</tr>
</tbody>
</table>
### Number of Trained and Untrained Teachers (In Millions)

<table>
<thead>
<tr>
<th>Stage</th>
<th>Trained Teachers</th>
<th>Untrained Teachers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary</td>
<td>1.531 (88)</td>
<td>0.209 (12)</td>
</tr>
<tr>
<td>Middle</td>
<td>1.025 (88)</td>
<td>0.160 (12)</td>
</tr>
<tr>
<td>Secondary</td>
<td>0.812 (89)</td>
<td>0.100 (11)</td>
</tr>
</tbody>
</table>

Note: Figures in parentheses indicate percentages.

### Drop-out Rate (Grades 1 to 8)

<table>
<thead>
<tr>
<th>Year</th>
<th>Boys</th>
<th>Girls</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1990-91</td>
<td>59.10</td>
<td>65.10</td>
<td>60.90</td>
</tr>
<tr>
<td>1999-00</td>
<td>51.96</td>
<td>58.00</td>
<td>54.53</td>
</tr>
</tbody>
</table>

### Teacher-Pupil Ratio

<table>
<thead>
<tr>
<th>Year/State</th>
<th>Primary</th>
<th>Middle</th>
<th>Secondary / Higher Secondary</th>
</tr>
</thead>
<tbody>
<tr>
<td>1980-81</td>
<td>1:38</td>
<td>1:33</td>
<td>1:27</td>
</tr>
<tr>
<td>1990-91</td>
<td>1:43</td>
<td>1:37</td>
<td>1:31</td>
</tr>
<tr>
<td>1999-00</td>
<td>1:43</td>
<td>1:38</td>
<td>1:32</td>
</tr>
</tbody>
</table>
Needs and Requirements of Practicing Mathematics Teachers in India

1. **Guidance with respect to content**
   Mathematics curriculum has undergone drastic changes in recent years. Many schools do not get specialist teachers. Hence conceptual clarification is required.

2. **Guidance in Handling Challenging Problems**
   Textbooks usually include a few challenging exercises. Many teachers avoid handling them. Guidance is needed to deal with such problems.

3. **Enhancement of Student’s Initial Preparation**
   Teachers dealing with disadvantaged students often experience that the initial preparation of students is inadequate. They need to be acquainted with appropriate remedial measures.

4. **Language of Mathematics**
   Mathematical description makes use of technical terms, symbolic languages, etc. Equipping the teachers to explain them properly is necessary to facilitate learning by school children.

5. **Making Learning of Mathematics Interesting**
   Mathematics is perceived as a dull and dry subject. It is a challenge to make it interesting and enjoyable. Guidance is needed to face the challenge.

6. **Enhancing Pupil Participation in the Classroom.**
   Abstract nature of mathematics usually hinders active participation of pupils in the classroom. It is necessary to bring out relevance to their daily lives to enhance their involvement. Teachers need guidance in this regard too.

What needs to be done?

1. **Revamping Pre-Service Courses**
   The curriculum of pre-service courses needs to be modified to suit to present content and national interest.

2. **Strengthening Mathematics Teachers’ Associations**
   These associations exist at state as well as at national levels. Many of them are, however, inactive. They need to be strengthened so that they meet frequently and arrange discussion sessions among their members.
3. Organization of Periodic In-Service Courses
   Presently, in-service courses are very few. Courses should be arranged at local level so that expenses are kept to a minimum. Help should be sought from voluntary organizations and teachers’ association.

4. Opportunities for life-long learning
   Media based packages need to be developed so that teachers can get inputs through distance mode. Open universities in India are trying this direction.

5. International exchange and networking
   International exchanges need to be encouraged among teachers to enable them to learn from each other. Moreover, networking needs to be established for the exchange of ideas. Such an effort has been initiated by commonwealth countries.

6. Special training of teachers dealing with
   a. Handicapped children
   b. Socio-economically deprived children
   c. Gifted children
   d. Slow learners

7. Reward for Innovative Teachers
   Efforts of innovative mathematics teachers should be recognized. CASTME (Commonwealth Association of Science, Technology and Mathematics Educators) follows the practice of giving awards to schoolteachers, an activity that should be undertaken at various levels and by different organizations.

8. Bridging Research and Practice
   In order to ensure that the findings of research studies are implemented in the classroom there is a need to undertake feasibility studies. Over-dependence of material and manpower resources should be avoided. Encouraging teachers to undertake action research would be a good strategy.