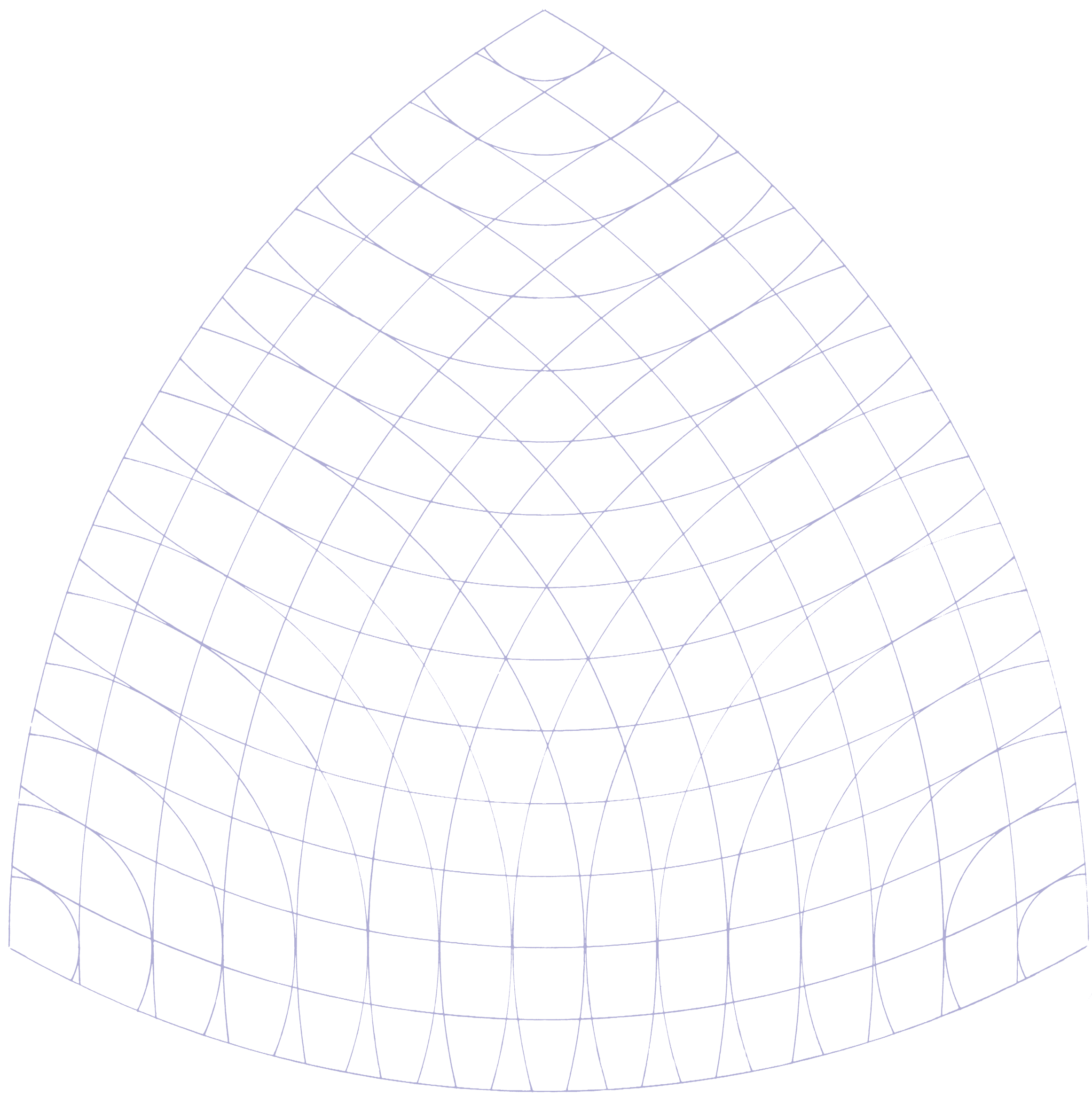
Contextual Framework



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Overview

For a fuller appreciation of what the TIMSS achievement results mean and how they may be used to improve student learning in mathematics and science, it is important to understand the contexts in which students learn. In addition to testing students' achievement in mathematics and science, TIMSS collects a range of information about the contexts for learning these subjects. The Contextual Frameworks encompasses five broad areas:

- Curriculum
- Schools
- Teachers and Their Preparation
- Classroom Activities and Characteristics
- Students

In particular, TIMSS examines the curricular goals of the education system and how the system is organized to attain those goals; the educational resources and facilities provided; the teaching force and how it is educated, equipped, and supported; classroom activities and characteristics; home support and involvement; and the knowledge, attitudes, and predisposition that students and teachers themselves bring to the educational enterprise. Just as the mathematics and science frameworks describe what should be assessed in those areas, the contextual framework identifies the major characteristics of the educational and social contexts that will be studied with a view to improving student learning.

The Curriculum

Building on IEA experience, the TIMSS contextual framework addresses five broad aspects of the intended curriculum in mathematics and science, from its formulation to its implementation.

Curriculum development involves consideration of the society which the education system serves, the needs and aspirations of the students, the nature and function of learning, and the formulation of statements on what learning is important. In understanding the intended curriculum, it is important to know who makes the curricular decisions, what types of decisions are made, and how decisions are communicated to the education community.

Formulating the Curriculum. When formulating a curriculum, developers take its situational context into account. Contextual considerations include the resources – national, regional, and local – available for education; the value society places on mathematics and science education; societal attitudes towards mathematics and science; and the degree to which educational attainment, broadly or narrowly defined, is linked to societal well-being and the nation's economic health.

Scope and Content of the Curriculum. Curricular documents define and communicate expectations for students in terms of the knowledge, skills, and attitudes to be acquired or developed through their formal education. The nature and extent of the mathematics and science goals to be attained in school are important to policy makers and curriculum specialists in all countries. Also important is how these goals are kept current in the face of scientific and technological advances, and how the demands and expectations of society and the workplace change.

Although mastery of the subject is a major focus of mathematics and science curricula in most countries, countries differ considerably in how the curriculum specifies that mastery should be achieved. For example, acquiring basic skills, applying mathematics to "real-life" situations, communicating mathematically, and problem solving in novel situations are approaches to teaching mathematics that have been advocated in recent years and are used to varying degrees in different countries.[1] In science, focus on the acquisition of basic scientific facts, the understanding and application of scientific concepts, emphasis on designing and conducting investigations, communicating scientific explanations, and the adoption of a thematic approach are teaching strategies that are recommended in some countries more so than in others.[2]

Organization of the Curriculum. The way the education system – national, regional, and local – is organized has a significant impact on students' opportunities to learn mathematics and science. At the school level, the relative emphasis on and amount of time specified for mathematics, science, and other subjects up through various grade levels can greatly affect such opportunities. Practices such as tracking, streaming, or setting can expose students to different curricula. In science, teaching the major components of science as separate subjects can result in different experiences for students compared with the science-as-single-subject approach.

Monitoring and Evaluating the Implemented Curriculum. Many countries have systems in place for monitoring and evaluating the implementation of curriculum and for assessing the status of their education systems. Commonly used methods include standardized tests, school inspection, and audits. Policy makers may use influences external to the school, for example national or regional standardized tests, to prescribe the implementation of the curriculum. Policy makers may also work collaboratively with the school community (or selected subpopulations) to develop, implement, and evaluate the curriculum.

Curricular Materials and Support. Apart from the use of standardized tests, inspections, and audits, countries can employ a range of other strategies to facilitate the implementation of the intended curriculum. These include training teachers in the content and pedagogic approaches specified in the curriculum. Such training may be an integral part of the teacher education curriculum, or it may be included in professional development programs. The implementation of the curriculum can be further supported through the development and use of teaching materials, including textbooks, instructional guides, and ministerial notes, that are specifically tailored to the curriculum.

1 Mullis, I.V.S., et al (2000), *TIMSS 1999 International Mathematics Report: Findings from IEA's Repeat of the Third International Mathematics and Science Study at the Eighth Grade*, Chestnut Hill, MA: Boston College.

2 Martin, M.O., et al (2000), *TIMSS 1999 International Science Report: Findings from IEA's Repeat of the Third International Mathematics and Science Study at the Eighth Grade*, Chestnut Hill, MA: Boston College.

The Schools

In the TIMSS contextual model, the school is the institution through which the goals of the curriculum are implemented. Accepting that a high-quality school is not simply a collection of discrete attributes but rather a well-managed integrated system where each action or policy directly affects all other parts, TIMSS focuses on a set of indicators of school quality that research has shown to characterize such schools.

School Organization. Whether as part of a larger national, regional, or local education system or because of decisions made at the school level, science and mathematics instruction is carried out within certain organizational constraints. For example, the time in terms of days per years and minutes per day allotted for schooling, and in particular for mathematics and science instruction, can influence achievement. It is also important to know about different types of schools, since some schools may specialize. For example, in countries with tracking, the school may be designated to emphasize either an academic or a vocational curriculum.

School Goals. Research on effective schools suggests that successful schools identify and communicate ambitious but reasonable goals and work towards implementing them. Commonly articulated school goals include literacy, academic excellence, personal growth, good work habits, and self-discipline.

Roles of the School Principal. The school principal typically fulfills multiple leadership roles. These include ensuring that the school, its operation, and its resources are managed optimally. The principal may guide the school in setting directions, seeking future opportunities, and building and sustaining a learning environment. He or she can facilitate the development, articulation, implementation, stewardship, and evaluation of a model of learning that is shared and supported by the school community. The principal may actively advocate, nurture, and sustain a positive school culture and an education program conducive to student learning and teachers' professional growth. The primary roles that the principal fulfills provide a useful indication of the administrative and educational structure of the school.

Resources to Support Mathematics and Science Learning. Curriculum implementation can be facilitated by allocating the facilities, materials, and equipment necessary to achieve the specified learning goals. Results from TIMSS indicate that students in schools that are well-resourced generally have higher achievement than those in schools where shortages in resources affect capacity to implement the curriculum. Two types of resources affect implementation of the curriculum. General resources include teaching materials, budget for supplies, school buildings and supplies, heating/cooling and lighting systems, and classroom space. Subject-specific resources may include computers, computer software, calculators, laboratory equipment and materials, library materials, and audio-visual resources.

Parental Involvement. Research has shown that effective schools have a high degree of congruence between parental, student, and school expectations. Parental involvement in school activities can be an important source of support in working to achieve student and school goals, and in forming positive student attitudes. Data from TIMSS reveal that schools with a high degree of parental involvement, particularly in the areas of checking homework, volunteering for field trips, and fund raising, generally have higher academic performance than those that do not.

Disciplined School Environment. Although a safe and orderly school environment does not itself guarantee high levels of student achievement, student learning can be more difficult in schools where student discipline is a problem, where students are regularly absent or late to class, or where they fear injury or loss of personal property.

Teachers and Their Preparation

Teachers are the primary agents of curriculum implementation. Regardless of how closely prescribed the curriculum, or how explicit the textbook, it is the actions of the teacher in the classroom that most affect student learning. What teachers know and are able to do is of critical importance. A recent review suggests that to ensure excellence, teachers should have high academic skills, teach in the field in which they received their training, have more than a few years of experience, and participate in high-quality induction and professional development programs.[3]

Academic Preparation and Certification. Aware of the key role played by the teacher in implementing the curriculum, many countries are focusing on improving education for aspiring teachers, particularly the mathematics and science prerequisites necessary for effective teaching in these subject areas.

The methods by which teachers are certified to practice vary widely across countries. They include the completing of specified courses, passing exams, and serving a probation period. In some countries there may be alternative methods of being certified, especially in subject areas with a shortage of teachers.

The relative emphasis on content knowledge and pedagogic approach of trainee teachers, and how teacher education programs keep abreast of the changes brought about by rapid advances in science and technology, are important features of teacher preparation programs. Methods used to enable teachers to become broadly educated, reflective, professional educators with a lifelong positive attitude toward

3 Mayer, D.P., Mullens, J.E., and Moore, M.T. (2000), *Monitoring School Quality: An Indicators Report*, NCES 2001-030, Washington, DC: National Center for Education Statistics.

learning may also be an important facet of teacher education. Collaboration between universities and schools and the use of teacher competency standards may also contribute to good academic preparation to teach. Innovative approaches to teacher education that capitalize on the opportunities provided by the Internet and modern information technology in general may also be important in preparing teachers.

Teacher Recruitment. The growth of technology in recent years has meant that education systems must compete with industry for the best mathematics and science candidates. The rapid advancement of mathematics and science necessitates that prospective teachers be capable of keeping pace with these fast-evolving fields. This calls for the attraction of top-level applicants who are capable of adjusting their teaching to the evolving demands of modern education. Employment contracts, incentives such as free college education, and other benefits are some methods used to recruit suitable candidates.

Teacher Assignment. TIMSS has shown that there is considerable variation across countries in the percentage of students taught mathematics or science by teachers with a major in the subject. While there can be both problems and benefits associated with teachers teaching "out of field," of interest is how such teachers acquire the subject-specific knowledge they need in order to teach effectively.

Teacher Induction. The transition from university to a school teaching position can be difficult. Consequently, in many countries a large percentage of new teachers leave the profession after only a few years of teaching.[4] The extent to which schools take an active role in the acculturation and transition of the new teacher may be important. Mentoring, the modeling of good teacher practice by peers, professional development activities, and induction programs designed by experienced teachers within the school may be important to aid the beginning teacher.

Teacher Experience. Studies have suggested that students learn more when taught by experienced teachers than they do when taught by teachers with just a few years' experience. However, the relationship between experience and achievement may be affected by many factors. For example, assignment policies within schools may result in the more highly skilled teachers getting specific classes, or older teachers getting higher-tracked classes. The need for long-serving teachers to engage in professional development, and the extent to which they do so, can also impact their effectiveness.

Teaching Styles. Researchers have identified a number of teaching styles.[5] Information on how teachers allot their time to such activities as lecture-style presentation, teacher-guided student practice, re-teaching and clarifying content and procedures, small group work, and independent practice, for example, provides useful evidence about the predominant pedagogic approaches in the classroom. Student reports of how much time they spend being shown how to do mathematics and science, working from worksheets or textbooks, working on projects, or discussing homework are also important indicators of teaching style.

TIMSS international reports have shown that the use of the board was an extremely common presentation mode in both mathematics and science classes. Other presentation modes, including teacher use of an overhead projector, teacher use of a computer to demonstrate ideas, student use of the board, and student use of an overhead projector are less frequent.

4 Moskowitz, J. and Stephens, M., eds. (1997), *From Students of Teaching to Teachers of Students: Teacher Induction Around the Pacific Rim*, Washington, DC: U.S. Department of Education.

5 Grasha, A. (1996), *Teaching with Style*, Pittsburgh, PA: Alliance Publishers.

Professional Development. Although investment in pre-service education of prospective mathematics and science teachers will likely pay dividends in the long run, efforts to strengthen the knowledge and skills of existing teachers must rely on professional development opportunities. Unless teachers participate in ongoing professional development activities, they risk being uninformed about key developments in education and in their subject areas that have occurred since they received their initial training. There is special concern that without access to high-quality professional development, teachers will be unable to benefit from the advances made in information technology. Consequently, teachers need to learn how to use computers and the Internet in their classrooms to good advantage.

The professional development of teachers is of central importance to any attempts to change or reform an education system. Teacher development activities include expanding an individual's repertoire of well-defined and skillful classroom practices through training, observation of or by other teachers, immersion or internship activities, teacher task forces, teacher collaboratives, subject-matter associations, collaborations targeted at specific initiatives, and special institutes and centers.[6] The frequency and type of development activities, the level of intellectual, social, and emotional engagement, and the degree to which the program is grounded in the larger contexts of school practice and the educational needs of the students are important indicators of successful teacher development programs.[7]

Classroom Activities and Characteristics

Although the school provides the general context for learning, it is in the classroom setting and through the guidance of the teacher that most teaching and learning take place. The classroom setting here is taken to include work assigned in the classroom but completed elsewhere, such as homework, library assignments, or field work. Aspects of the implemented curriculum that are most readily studied in the classroom include the curriculum topics that are actually addressed, the pedagogic approaches used, the materials and equipment available, and the conditions under which learning takes place, including the size and composition of the class and the amount of classroom time devoted to mathematics and science education.

Curriculum Topics Taught. A major focus of the implemented curriculum is the extent to which the mathematics and science topics in the TIMSS frameworks are covered in the classroom. TIMSS addresses this question by asking the mathematics and science teachers of the students assessed to indicate whether each of the topics tested had been covered in class, either in the current or previous years, and how many class periods were devoted to the topic. TIMSS characterizes the coverage and level of rigor of the mathematics and science courses taught in participating countries by describing the main focus of the work in the classes being tested.

6 Mullis, I.V.S., et al (2001), *Mathematics Benchmarking Report, TIMSS 1999 – Eighth Grade: Achievement for U.S. States and Districts in an International Context* (pp. 237-244), Chestnut Hill, MA: Boston College; Martin, M.O., et al (2001), *Science Benchmarking Report, TIMSS 1999 – Eighth Grade: Achievement for U.S. States and Districts in an International Context* (pp. 253-260), Chestnut Hill, MA: Boston College.

7 Little, J. W. (1993), "Teachers' Professional Development in a Climate of Educational Reform," *Educational Evaluation and Policy Analysis*, 15(2), 129-51, Washington, DC: American Educational Research Association.

Time. The amount of classroom instructional time devoted to mathematics and science is an important aspect of curricular implementation. TIMSS has shown that the efficient use of that time and the disruptive effects of outside interruptions are aspects related to effective teaching.

Homework. The reasons for assigning homework as well as the amount and types assigned are important pedagogic considerations. Homework serves to increase the time devoted to a subject. It can be used to reinforce and/or extend the concepts developed in a lesson.

Assessment. TIMSS results show that teachers devote a fair amount of time to student assessment, whether as a means of gauging what students have learned to guide future learning, or for providing feedback to students, teachers, and parents. The frequency of various types of assessment and the weight given to each are important indicators of teaching and school pedagogy. Types of assessment include external standardized tests, teacher-made tests requiring explanations, teacher made objective tests, homework assignments, projects or practical exercises, students' responses in class, and observations of students.

Classroom Climate. Classroom climate, or environment, characterizes the ambience, tone, atmosphere, and ethos of the classroom.[8] Student and teacher perceptions of the classroom environment influence learning behaviors and outcomes.[9] The extent to which students participate actively and attentively in class, the degree to which they like and interact positively with each other, the relationship between students and teacher, and the organizational clarity of the class are all important facets of classroom climate.

8 Fraser, B.J. and Walberg, H.J. (1991), *Educational Environments: Evaluation, Antecedents and Consequences*, New York, NY: Pergamon Press.

9 Lorsbac, A. W. and Jinks, J. L. (1999), "Self-Efficacy Theory and Learning Environment Research," *Learning Environments Research*, 2, 157-167, Boston, MA: Kluwer Academic Publishers.

Information Technology. The computer is rapidly transforming education as students prepare to enter the technological workforce. Information technology saves time and, more important, gives students access to powerful new ways to explore concepts at a depth that has not been possible in the past. Computers can trigger a new enthusiasm and motivation for learning, enable students to learn at their own pace, and provide students with access to vast information sources via the Internet.

While computers are undoubtedly changing the educational landscape, schools operate with finite resources, and the allocation of money, time, and space for technology may divert scarce resources from other priorities, such as increasing teacher salaries, teachers' professional development, lowering student-teacher ratios, and the provision of teaching resources including laboratory equipment and space. Further, the sustainability of school computer systems and the continuity of support staffing may be as important as the acquisition of the computers.

The effective and efficient use of computers requires suitable training of teachers, students, and school staff. Factors limiting computer use include the lack of appropriate software and hardware, software not congruent with the curriculum, lack of teacher training and support, and lack of funding for computer repair and maintenance.

The rapid growth in access by students in schools and at home to the informational resources of the Internet has the potential to revolutionize mathematics and science learning like nothing before. There is evidence to show that multiple layers of access to the Internet, for example at schools, in libraries, and at home, is important. For countries in which students do have ready access to the Internet, it is important that they be taught how to use the information, and how to evaluate its truth or worth.

Besides giving students access to the Internet, computers can serve a number of other educational purposes. While initially limited to learning drills and practice, they are now used in a variety of ways including tutorials, simulations, games, and applications. New software enables students to pose their own problems and explore and discover mathematics and scientific properties on their own. Computer software for modeling and visualization of ideas can open a whole new world to students and help them connect these ideas to their language and symbol systems.

Calculator Use. Calculator use varies widely among, and even within, countries, but generally is increasing steadily as cost becomes less of an impediment and mathematics curriculum evolves to take calculators into account. Many countries have policies regulating the access to and use of calculators, especially at the earlier grade levels. What those policies are and how they change over the grades can be important in understanding the curriculum.

Calculators can be used in exploring number recognition, counting, and the concepts of larger and smaller. They can allow students to solve numerical problems faster by eliminating tedious computation and thus become more involved in the learning process. Graphing calculators make it possible to switch from equations to graphs to data analysis, enabling problems to be approached either visually or numerically. How best to make use of calculators, and what role they should have, continue to be questions of importance to mathematics curriculum specialists and teachers.

Emphasis on Investigations. The emphasis on conducting projects and investigations varies widely across countries. An exploration of the frequency and the nature of a task can illuminate the learning at issue. In science, practical investigations are often an integral part of the learning process. The extent to which these activities are demonstrated by the teacher and conducted by the students also shows variation across countries.

Class Size. Class size can serve as an economic indicator, with smaller classes signifying greater wealth. However, smaller class sizes may be the result of government policies that cap class size. Further, class size may reflect selective resource allocation to, for example, special needs or practical classes. Whatever the reason for the class size, there is little doubt that it affects how teachers implement the curriculum.

The Students

Home Background. Students come to school from different backgrounds and with different experiences. The number of books in the home, availability of a study desk, the presence of a computer, the educational level of the parents, and the extent to which students speak the language of instruction have been shown to be important home background variables, indicative of the family's socio-economic status, that are related to academic achievement. Also important are the attitudes of parents and their involvement in their child's education. The extent to which employment, sports and recreational pastimes, and other activities occupy the student's time may also affect learning.

Prior Experiences. Students engage with mathematics and science with a host of prior experiences that affect their preparedness to learn. These include past learning in the subject, positive or negative interactions with past teachers, and the difficulty or ease with which the subject matter was learned.

Attitudes. Creating a positive attitude in students toward mathematics and science is an important goal of the curriculum in many countries. Students' motivation to learn can be affected by whether they find the subject enjoyable, place value on the subject, and think it is important in the present and for future career aspirations. In addition, students' motivation can be affected by the degree to which they attribute success and failure in the subject to internal or external factors.