Competitive Edge:
A Cross-National Examination of Mathematics Achievement in 53 Jurisdictions

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Abstract

The purpose of this paper was to examine the cross-national performance of fourth- and eighth-grade students in mathematics on the Trends in International Mathematics and Science Study (TIMSS) 2003. The TIMSS assessment data were used to identify nations that have a competitive edge in the critical area of mathematics.

The Trends in International Mathematics and Science Study (TIMSS) is an ambitious international assessment that provides comparative data on student achievement among participating countries and benchmarking jurisdictions. TIMSS 2003 assessed the mathematics knowledge of more that 360,000 fourth- and eighth-grade students in participating countries in the 2002-2003 school year. Data were collected from students in the countries in the southern hemisphere from September – November, 2002. In countries in the northern hemisphere, data were collected from February – July, 2003.

TIMSS 2003 provides an array of data that may be analyzed and used to frame policy guidelines in education, especially in teaching and learning of mathematics. Data analyses portrayed interesting findings. Data from TIMSS 2003 showed that fourth-grade students in Singapore, Hong Kong, Japan, Chinese Taipei, and Belgium-Flemish outperformed the world. At the eighth-grade, Singapore, Korea, Hong Kong, Chinese Taipei, Japan, and Belgium-Flemish outsmarted the world.

The following recommendations, among others, may be of benefit to low performing countries in improving the achievement of their students in mathematics.

1. Low-performing nations should make their teacher education admission, curriculum, graduation, and certification requirements more challenging to teacher education candidates.
2. Teacher education programs should be designed with a fifth year post certification internship. During the internship, novice teachers will be gradually introduced to the teaching profession. This is obtained in medical and some other health professions. Teaching is as critical as the medical profession.
3. Teacher education systems should establish new teacher induction and support programs. These induction and support programs should include seminars and workshops, mentoring, observing veteran teachers in classrooms, team teaching, peer interactions, lighter teaching load, and assignment to less challenging classrooms. New teacher induction and support programs should be used as a means of reducing new teacher attrition rate, thereby increasing teacher retention.

Introduction

The shrinking of the world into a global village and the opening of international borders for free trade had combined to engineer the drive for an unprecedented economic and technological competition among nations. Nations have come to realize that economic and political survival will depend largely on competitive advantage a nation commands over others. Sustaining a competitive edge will be dependent on the availability of a skilled and efficient workforce that a nation has at its disposal.

The abundance of a skilled and efficient workforce at the disposal of a nation is dependent on the quality of students produced through K-12 pipeline, especially in the core area of mathematics and science. Mathematics is the vehicle for producing a skilled workforce needed to sustain a nation's competitive edge in today's global economy. The value-added of mathematics to the quality of a workforce is obvious. Chubb and Moe (1990) stated that mathematics is crucial to the future of sophisticated technology and international competition.

As a result of the importance of mathematics and science in international competition, many countries have turned to international assessments in mathematics and science administered by the International Association for the Evaluation of Educational Achievement (IEA) as a way of measuring their future competitive edge.

The IEA is an independent, international cooperative of national research institutions and governmental agencies that is based in Amsterdam, Netherlands. Through its comparative research and assessment projects, the IEA aims to:

(1) Provide international benchmarks that may assist policymakers from participating in identifying the comparative strengths and weaknesses of their educational systems,

(2) Provide high-quality data that will increase policymakers' understanding of key school- and non-school-based factors that influence teaching and learning in participating countries,

(3) Provide high-quality data that will serve as a resource for identifying areas of concern and action, and for preparing and evaluating educational reforms in participating countries,

(4) Develop and improve educational systems' capacity to engage in national strategies for educational monitoring and improvement in participating countries, and

(5) Contribute to development of the world-wide community of researchers in educational evaluation (IEA, n.d.).

The IEA assessed the mathematics and science performance of fourth- and eighth-grade students in 2003 (Gonzales et al., 2004). The assessments are used for cross-national comparison of mathematics and science achievement of students from participating countries.

TIMSS was designed to assess students' mathematics and science achievement midway through elementary school, midway through lower secondary school, and at the end of upper secondary school. Because children start and finish K-12 education at different ages, age and grade level were factors in deciding the students that were tested. Three populations of students were tested. Population 1 consisted of students in a pair of adjacent grades that contained most of 9-year-olds. The adjacent grades were grades 3 and 4 in the U. S. and most of the participating countries, grades 2 and 3, and grades 4 and 5 in some countries (NCES, 1997).

The students tested in population 2 were in a pair of adjacent grades that contained most of 13-year-olds at the time of testing. The adjacent grades were grades 7 and 8 in the U. S. and most of the participating countries, and grade 6 and 7 in a few countries (NCES, 1996).

TIMSS 2003

TIMSS 2003 was the third in a series of mathematics and science assessments conducted by the International Association for the Evaluation of Educational Achievement since 1995. The aim of TIMSS is to improve the teaching and learning of mathematics and science by providing data on student achievement in relation to different types of curricula, instructional practices, and school environments. Additionally, it provides opportunity for participating countries to obtain comparative information about their students' achievement in mathematics and science (Gonzalez et al., 2004; Martin, Mullis; Gonzalez, & Chrostowski, 2004; Mullis, Martin, Gonzalez, & Chrostowski, 2004).

TIMSS 2003 assessed the mathematics knowledge of more that 360,000 fourth- and eighth-grade students in participating countries in the 2002-2003 school year. Data were collected from students in the countries in the southern hemisphere from September – November, 2002. In countries in the northern hemisphere, data were collected from March – June, 2003 (IEA, 2004).

Forty-nine countries and the four benchmarking participants (Indiana, United States; the Canadian Provinces of Ontario and Quebec; and the Basque Country, Spain) participated in TIMSS 2003 assessment at the fourth-grade, eighth-grade, or at both grades. The participating countries were Argentina, Armenia, Australia, Bahrain, Basque Country of Spain, Belgium-Flemish, Botswana, Bulgaria, Chile, Chinese Taipei, Cyprus, Egypt, England, Estonia, Ghana, Hong Kong-SAR, Hungary, Indiana-United States, Indonesia, Iran-Islamic Republic, Israel, Italy, Japan, Jordan, Korea-Republic of, Latvia, Lebanon, Lithuania, Macedonia-Republic of, Malaysia, Moldova-Republic of, Morocco, Netherlands, New Zealand, Norway, Ontario Province-Canada, Palestinian National Authority, Philippines, Quebec Province-Canada, Romania, Russian Federation, Saudi Arabia, Scotland, Serbia, Singapore, Slovak Republic, Slovenia, South Africa, Sweden, Syrian Arab Republic, Tunisia, United States, and Yemen (Gonzalez et al., 2004; Martin et al., 2004; Mullis et al., 2004).

The Table that follows shows the average scale scores of fourth-grade students from 25 countries and 3 benchmarking participants in mathematics.

Table 1

Nations' Average Scale Scores in Mathematics (Grade 4)

Nation	Average
Singapore	594
Hong Kong-SAR	575
Japan	565
Chinese Taipei	564
Belgium-Flemish	551
Netherlands	540
Latvia	536
Lithuania	534
Russian Federation	532
England	531
Hungary	529
United States	518
Cyprus	510
Moldova, Rep. of	504
Italy	503
Australia	499
New Zealand	493
Scotland	490
Slovenia	479
Armenia	456
Norway	451
Iran, Islamic Rep. of	389

Table 1 (Continued).

Nation	Average
Philippines	358
Morocco	347
Tunisia	339
Benchmarking Participants	
Indiana, U. S.	533
Ontario, Canada	511
Quebec, Canada	506
International Average	495

Sources:

1. Gonzales et al. (2004). Highlights from Trends in International Mathematics and Science Study (TIMSS) 2003.
2. Mullis et al. (2004). TIMSS 2003 International Mathematics Report: Findings from IEA's Trends in International Mathematics and Science Study at the Fourth and Eighth Grades.

Note:

International Average is the average of the averages of the countries and the benchmarking participants.

The Table that follows shows the average scale scores of eighth-grade students from 45 countries and 4 benchmarking participants in mathematics.

Table 2

Nations' Average Scale Scores in Mathematics (Grade 8)

Nation	Average
Singapore	605
Korea, Rep. of	589
Hong Kong-SAR	586
Chinese Taipei	585
Japan	570
Belgium-Flemish	537

Table 2 (Continued).

Nation	Average
Netherlands	536
Estonia	531
Hungary	529
Malaysia	508
Latvia	508
Russian Federation	508
Slovak Republic	508
Australia	505
United States	505
Lithuania	502
Sweden	499
Scotland	498
Israel	496
New Zealand	494
Slovenia	493
Italy	484
Armenia	478
Serbia	477
Bulgaria	476
Romania	475
Norway	461
Moldova, Rep. of	460
Cyprus	459
Macedonia, Rep. of	435
Lebanon	433
Jordan	424
Iran, Islamic Rep. of	411
Indonesia	411
Tunisia	410

Table 2 (Continued).

Nation	Average
Egypt	406
Bahrain	401
Palestinian N. A.	390
Chile	387
Morocco	387
Philippines	378
Botswana	366
Saudi Arabia	332
Ghana	276
South Africa	264
Benchmarking Participants	
Basque Country, Spain	487
Indiana, U. S.	508
Ontario Province, Canada	521
Quebec Province, Canada	543
International Average	466

Sources:

1. Gonzalez et al. (2004). Highlights from Trends in International Mathematics and Science Study (TIMSS) 2003.
2. Mullis et al. (2004). TIMSS 2003 International Mathematics Report: Findings from IEA's Trends in International Mathematics and Science Study at the Fourth and Eighth Grades.

Note:

1. International Average is the average of the averages of the countries and the benchmarking participants.
2. Palestinian N. A. is Palestinian National Authority.

Discussion

Student achievement is influenced by many factors, among which are teacher quality, new teacher induction and support, and teacher professional development. A brief survey of education systems in TIMSS participating countries revealed interesting findings in teacher quality, new teacher induction and support programs, and teacher professional development. These findings may be used by policymakers and educators to improve the teaching and learning of mathematics.

Teacher Quality

Teacher quality may be the most important factor that promotes student achievement. Teacher quality is largely related to the rigors of teacher education admission, curriculum, graduation, and certification requirements. The rigor of admission requirements determines the caliber of candidates admitted to teacher education programs or any program for that matter. The TIMSS high performing countries have rigorous admission requirements. For example, Hong Kong and Japan require teacher candidates to sit for National Subject Area Examination before admission to teacher education program. In addition to the National Subject Area Examination, some universities in Japan have their own high-stakes examinations which teacher candidates must also take before admission to a teacher education program. In Korea, teacher candidates are admitted based on their performance on the Scholastic Assessment Test, teaching attitudes, and ethics. In average and low performing TIMSS countries, admission requirements lack the rigor that is obtained in high performing countries.

Curriculum, graduation, and certification requirements vary in both high- and low-performing TIMSS countries. However, curriculum rigor is more challenging in high-performing countries than in low-performing nations. For example, in Korea teacher candidates are required to take more than 40 credits in their subject areas, and Hong Kong requires prospective teachers to have a minor in mathematics or science.

Teacher Induction and Support

The transition from preservice teacher education to actual classroom teaching can be challenging and difficult. The challenging and difficult situation is a contributing factor for new teacher attrition during the first few years of teaching. As a result, teacher induction and support programs are used to provide beginning teachers the support needed during the transition from learning to teach to teachers of learners with the aim of reducing the rate of new teacher attrition.

Teacher induction and support programs are more structured in TIMSS high-performing countries. For example, in Japan new teachers spend at least 90 days of their first year of teaching in teacher induction activities. The induction activities include in-school and out-of school training, mentoring by veteran teachers, team teaching and observation, and interaction with peers. In addition, new teachers receive support from principals and other instructional staff. The support from principals includes placing new teachers in less challenging classrooms, to grades that are seen as less critical to educational development, and assignment of lighter teaching leads. All these measures are geared toward helping new teachers succeed (Nohara, 1997).

In TIMSS average- and low-performing countries, teacher induction and support programs are less structured, non-mandatory, and less durable unlike in high-performing countries. In average- and low-performing countries, new teachers are placed in classrooms without recourse to how challenging classrooms have become. New teacher assessment may be viewed as fault finding in low-performing countries rather than being an avenue for helping new teachers transition from teacher education to actual classroom teaching.

Teacher Professional Development

New teachers transition from teacher education to classrooms with limited knowledge (Ngwudike, 2001). Therefore, teacher professional development should be seen as part of teacher professional continuum. Wang, Coleman, Coley, and Phelps (2003), found that in TIMSS high-performing countries, beginning teacher induction and professional development are required. For example, Australia, England, Japan, and Singapore require new teacher induction, while England, Japan and Korea require professional development. In average performing countries such as the United States, new teacher induction varies and professional development is provided mainly at the district and school level.

Recommendations

The contrast between TIMSS high- and low-performing countries informed the following recommendations that follow:

1. Like TIMSS high-performing countries, low-performing nations should make their teacher education admission, curriculum, graduation, and certification requirements more challenging to teacher education candidates.

2. Teacher education programs should be designed with a fifth year post certification internship. During the internship, novice teachers will be gradually introduced to the teaching profession. This is obtained in medical and some other health professions. Teaching is as critical as the medical profession.

3. Teacher education systems should establish new teacher induction and support programs. These induction and support programs should include seminars and workshops, mentoring, observing veteran teachers in classrooms, team teaching, peer interactions, lighter teaching load, and assignment to less challenging classrooms. New teacher induction and support programs

should be used as a means of reducing new teacher attrition rate, thereby increasing teacher retention.

4. Teacher salaries should be higher or at least match the pay in other professions of similar training. This will increase the prestige of the teaching profession, thereby attracting more talented individuals to the profession. Moskowitz & Kennedy (1997) stated that teachers in Japan, Korea, and Chinese Taipei enjoy good pay and high status.

5. Teacher professional development should be viewed as part of a continuum of the teaching profession. Teacher education programs do not adequately prepare beginning teachers for all the challenges to be encountered in the classrooms. Therefore, professional development should serve as a vehicle for bridging that gap. Professional development should be used to introduce teachers to best practices in teaching and learning. Teachers should be a party in designing their professional development activities. The professional development activities should be based on the principles of adult learning and job embedded, and should serve as a mechanism for increasing the competency of teachers by improving their professional skills and dispositions.

6. TIMSS longitudinal data may be used by participating countries to understand the strengths and weaknesses of their education systems. TIMSS provides an opportunity for countries to learn what works better in other education systems while improving the teaching and learning of mathematics and science in their own countries.

Conclusion

The Trends in International Mathematics and Science Study (TIMSS) is an ambitious international assessment that provides comparative data on student achievement among participating countries and benchmarking jurisdictions. TIMSS conducts studies on a cross-national achievement in mathematics and science every four years. TIMSS collects contextual information on how mathematics and science learning takes place in participating countries. The next cycle of assessments will take place in 2011.

TIMSS 2003 provide an array of data that may be analyzed and used to frame policy guidelines in education, especially in the teaching and learning of mathematics and science. The analysis of the contextual information collected by TIMSS may be used to understand the context in which the teaching and learning of mathematics and science take place in high and low achieving countries.

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