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The data makes the difference

How Chinese Taipei used TIMSS data to reform mathematics education

SUMMARY

- Chinese Taipei has used successive cycles of TIMSS data as a guide for formulating educational policies, and an evidence base for evaluating their effects. Although Taiwanese students have performed well in TIMSS, the percentage of students reporting low confidence in and low enjoyment of mathematics is significantly greater than the international average.
- Trends in students' achievements and attitudes toward mathematics were used to design the After Class Support project, introduced in 2006, and subsequent TIMSS data inspired the Just Do Math program, a new approach to mathematics teaching and learning introduced in 2014.
- Both teachers and students are enthusiastic about the new methods, and reactions have inspired national discussion on curriculum change. Educators and policymakers will use TIMSS 2019 to evaluate the true success of the program.

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IMPLICATIONS

- All countries seek to identify strategies to improve student performance in mathematics. Policymakers and researchers need to delve into the available evidence and collaborate to develop appropriate solutions to national educational disparities.
- Students' confidence in their ability to do mathematics, and their level of enjoyment of the subject, has been found to strongly influence their mathematics achievement.
- TIMSS provides vital data for governments and researchers to compare and contrast differences in students' mathematics performance within and between countries.
- Innovative mathematics approaches can transform learning motivation for students of all abilities, and reignite teachers' enthusiasm for teaching.

ESTABLISHING POLICIES: TIMSS 2003 AND THE "AFTER CLASS SUPPORT" PROGRAM

The IEA's Trends in Mathematics and Science Study (TIMSS) is a time-series database, which, as stated on the IEA website, "provide(s) an early warning for necessary curricular reforms" in mathematics and science subjects, and offers an opportunity for schools and policymakers to reflect on the effectiveness of educational changes (see www.iea.nl/timss). This article demonstrates the strong connection between TIMSS and mathematics education reform in Chinese Taipei, showing how the TIMSS 2003 results (Mullis et al., 2004) led the Ministry of Education (MOE) in Chinese Taipei to develop the 2006 "After Class Support" policy (see Lin, 2008, for an in-depth description of the collaboration between government, researchers and educators to establish this key program).

MOE officials and academic researchers noted that the TIMSS 2003 official release in 2004 (Mullis et al., 2004) revealed two striking patterns in Chinese Taipei (Lin, 2008): (1) Chinese Taipei had more 8th grade students in the "Below Intermediate" group than the other four East Asian countries[1] (Table 1); and (2) the number of Taiwanese 4th and 8th grade students who did not enjoy and had low confidence in mathematics was much larger than the international average (Table 2). Although, according to international benchmarks, Taiwanese students had generally performed well in mathematics, these were alarming indicators for national policymakers and educators, who were particularly troubled that the percentage of "low confidence and low enjoyment" students at the 4th grade was twice the international average (Table 2).

Meanwhile, the increase in the number of 4th and 8th grade students categorized as "below intermediate" (termed "low achievers" in Chinese Taipei[2]), was another concern. Why did a significant percentage of the Taiwanese students report that they did not enjoy learning mathematics? What could the government and educational organizations do to tackle the issues of educational disparity and students' lack of interest and enjoyment in learning mathematics? The TIMSS data led to calls for a review of the implemented education policy in Chinese Taipei.

The first major action taken by the MOE and the then National Science Council (NSC; now termed the Ministry of Science and Technology [MOST]) was to invite experts in the education field to work together to incorporate the philosophy "take care of every student so that each child makes progress" into policy reforms. In 2006, the MOE worked with local schools and communities to create the After Class Support program, aimed at increasing elementary and secondary school students' interest and confidence in mathematics.

1 Although many countries participate in IEA's TIMSS, government and researchers in Chinese Taipei tend to evaluate Taiwanese students' performance relative to that of students in Hong Kong, South Korea, Singapore, and Japan, as the five East Asian countries have similar cultures and economies.

2 In Chinese Taipei, the students who do not reach the intermediate benchmark of the TIMSS assessment are defined as low achievers.

Table 1: Performance of the five East Asian countries who participated in TIMSS 2003 and 2011

Country	Year	Percentage of students at each international benchmark category (%)								Country mean TIMSS mathematics score	
		Below intermediate		Intermediate		High		Advanced			
		4th grade	8th grade	4th grade	8th grade	4th grade	8th grade	4th grade	8th grade	4th grade	8th grade
Chinese Taipei	2003	8	15	31	19	45	28	16	38	564 (1.8)	585 94.6)
	2011	7	12	19	15	40	34	34	49	591 (2.00	609 (3.2)
Hong Kong	2003	6	7	27	20	45	42	22	31	575 (3.2)	586 (3.3)
	2011	4	11	16	18	43	37	37	34	602 (3.4)	586 (3.8)
Japan	2003	11	12	29	26	39	38	21	24	565 (1.6)	570 (2.1)
	2011	7	13	23	26	40	34	30	27	585 (1.7)	570 (2.6)
Singapore	2003	9	7	18	16	35	33	38	44	594 (5.6)	605 (3.6)
	2011	6	8	16	14	35	30	43	48	606 (3.2)	611 (3.8)
South Korea	2003	NA	10	NA	20	NA	35	NA	35	NA	589 (2.2)
	2011	3	7	17	16	41	30	39	47	605 (1.9)	613 (2.9)

Note: NA = not applicable. Standard errors are provided in parentheses.
Sources: Mullis et al. (2004, 2012).

Table 2: The percentage of students reporting "low confidence and low enjoyment" toward learning mathematics in the five East Asian countries who participated in TIMSS 2003 and 2011

Country	Year	Students' reported attitudes toward mathematics (%)			
		Low confidence in math		Do not enjoy math	
		4th grade	8th grade	4th grade	8th grade
Chinese Taipei	2003	20	44	34	58
	2011	38	67	32	53
Hong Kong	2003	19	33	28	41
	2011	31	55	17	37
Japan	2003	21	45	35	61
	2011	48	73	23	53
Singapore	2003	16	27	15	25
	2011	38	40	19	23
South Korea	2003	NA	34	NA	68
	2011	38	63	29	56
East Asian average	2003	19	37	28	51
	2011	39	60	24	44
International average	2003	11	22	22	35
	2011	21	41	19	31

Note: NA = not applicable.
Sources: Mullis et al. (2004, 2012).

USING TIMSS DATA AS AN INDICATOR TO EVALUATE POLICY

By providing out-of-school supplementary mathematics courses to students who were struggling academically, the After Class Support program was designed to achieve two goals: (1) to reduce the percentage of low achievers in the 8th grade from 15% to 10% or lower; and (2) to increase the percentage of students who "like" mathematics to at least 60% in TIMSS 2011. By 2008, the benefits of the program were becoming apparent, as data from the MOE indicated that the majority of the program participants had developed a more positive attitude toward learning and made clear progress in school exams (Lin, 2008). Nonetheless, the TIMSS 2011 results (Mullis et al., 2012) initiated further reflection on the efficacy of the educational policy.

TIMSS 2011 demonstrated only a small decline in the percentage of the "below intermediate" group in Chinese Taipei, dropping from 8% to 7% at the 4th grade and 15% to 12% at the 8th grade, and the percentages for both grades remained higher than the other four East Asian countries (Table 1). Meanwhile, the percentage of the low achievers in the 8th grade (12%) had not met the expected target (10%), and was higher than South Korea, which had made considerable progress over the same period.

There were also changes in the attitude and confidence of students toward mathematics. A consistent rise in the percentages of students reporting "low confidence in math" was detected both among the five East Asian countries and at the international level in the TIMSS 2011 research (Table 2). For Chinese Taipei, regardless of the observed decline in the percentages of low achievers at both grades, the percentage of students who did not enjoy mathematics was still large and had not met the expected target (40%) for 8th graders. The number of students who reported low confidence in their mathematics ability was also high (at the 4th grade this percentage was 38%, and at the 8th grade 67%; Table 2).

The failure to increase students' enjoyment and confidence in learning mathematics undermined the 2006 After Class Support program and suggested a need to change policy in Chinese Taipei.

CHANGING THE POLICY: DESIGN AND OUTCOMES OF THE JUST DO MATH PROGRAM

TIMSS 2011 had revealed that the efforts to address the problems in Taiwanese mathematics education identified in TIMSS 2003 were not sufficiently effective. A year later, the Programme for International Student Assessment (PISA) 2012 showed that, among the seven top achieving systems (Shanghai, Singapore, Chinese Taipei, Hong Kong, Korea, Macao, and Japan), the variation in students' mathematics scores in Chinese Taipei was the largest and the percentage of the students who did not reach the baseline proficiency level was the highest (OECD [Organisation for Economic Cooperation and Development], 2013). The data pointed out the severe disparity in the mathematics performance of 15-year-old students in Chinese Taipei; the results showed not only that there were high percentages of high achievers but also revealed that there were high percentages of low achievers. The country was forced to reconsider the After Class Support program that had been introduced to address the problems indicated by TIMSS 2003.

To address the problems revealed by TIMSS 2011 and PISA 2012 in Chinese Taipei, the Shi-da Institute for Mathematics Education launched the 2014 project "Just Do Math" (JDM; see http://www.sdime.ntnu.edu.tw/main.php), with the support of the Ministry of Education. This project was designed to help low-achieving primary and junior high school students. JDM involved multiple mathematics activities, including the design of instructional materials (known as mathematics grounding activity [MGA] modules), mathematics camps for students (Fun-math Camps), and professional development activities for primary and junior high school teachers, designed to support the new JDM program (MGA teachers were trained to hold Fun-math Camps and MGA designers were trained to develop MGA modules). JDM aimed to help students establish the fundamental prerequisite concepts before learning a mathematics topic in regular classes, instead of providing remedial instruction after they had failed to learn that topic. In addition, to increase students' learning motivation and facilitate their understanding of mathematical concepts, manipulative concrete presentations and gamified learning activities were employed such as card games, board games, and mathematical magic tricks. By the summer vacation of 2017, more than 45,000 students had participated in the Fun-math Camps, more than 10,000 MGA teachers had received training, about 150 MGA modules had been developed, and approximately 60 MGA designers had been trained.

The JDM project's initial aim was to help low-achieving students, but it has already proved to have positive impacts on other students. Furthermore, JDM has unexpectedly influenced teachers' attitudes and the debate on curriculum reform. The TIMSS results in 2019 will be used to evaluate the success of the JDM project, but three exciting findings have already been reported.

1. Students with difficulties are returning to school, supported by their families, schools, and the new mathematics classes

In Chinese Taipei, many low-achieving students are from families of low socioeconomic status or from remote districts. Some of the parents struggle to earn a living and do not have time to supervise their children's school attendance. These students rarely go to school and often record demerits for violating school regulations, preferring to skip formal education to socialize with other absentee youths in the villages. The JDM project found that these more challenging students started attending Fun-math Camps out of curiosity, but ended up being attracted to the Camps' mathematical games or the magic tricks incorporated in the grounding activity modules (Lin, Wang, & Lin, 2016). Such students might struggle to catch up with the pace of the instruction at first, but, with the teachers' patient instruction and encouragement, they learned successfully and became more confident about their abilities. This experience often changed their attitude toward education and their interaction with their families. For example, one student stated:

> "My mother is happy that I am performing magic. Except for the activities of temple fairs, school can also allow us to learn such interesting magic and mathematics. I wish I did not have to graduate. I could possibly become better in the future to make her happier."

2. Teachers ignited their enthusiasm for teaching and kept the fire burning

The majority of teachers who participated in the JDM project reported that they were inspired by the ideas of the project during the teacher professional development training workshops and by the improved performance and positive feedback of the students after holding Fun-math Camps. These experiences were shown to have ignited the teachers' enthusiasm for teaching (Lin et al., 2016; Lin, Wang, & Yang, 2018). In some schools, the teachers wanted to help as many students as possible to learn mathematics; they thus held camps for their colleagues in advance to gain their approval and appreciation of the ideas of the project, and then to gain their additional support in encouraging students in their classes to attend Fun-math Camps. After holding the camps in their own schools, some teachers even volunteered to help hold camps in other schools. A group of teachers in one urban school volunteered to hold camps for aboriginal students in one remote district. The teachers of the rural school were also touched by the outcomes of these processes, and expressed strong willingness to learn from the teachers from the urban school. There were also teachers from the suburbs in the Eastern region of Chinese Taipei or from the outlying islands travelling to big cities at their own expense to take the opportunities to learn how to use grounding activity modules to improve teaching practice (Lin et al., 2016).

3. Grounding activity modules have already become part of the school curriculum

Aligning with Keith Devlin's idea that games are the best way to teach mathematics (Shapiro, 2014), the JDM project designed grounding activity modules to embed mathematics learning activities in games. In Chinese Taipei, the mathematics curriculum is demanding, the pace of mathematics instruction is fast and the instructional schedule is tight. Recognizing this, grounding activity modules were developed to be used as extra-curricular teaching materials. Fun-math Camps were held at the weekends, and during the summer and winter vacations. Unexpectedly, several teachers used the modules to introduce a topic in their teaching of regular mathematics classes, thus unofficially incorporating them into the school mathematics curriculum. In some cases, grounding activity modules were used across the school, and schools were warming up all students' cognitive and affective learning in mathematics by arranging for them to play the games in the grounding activity modules on the first day of a new semester. The Minister of Education in Chinese Taipei is now formally initiating discussions about the possibility of including the JDM grounding activity modules in the official mathematics curriculum as introductions to topics.

WHAT WE LEARNT FROM TIMSS FOR POLICYMAKING AND POLICY SHIFTS

The TIMSS results reminded Taiwanese policymakers and the research community to reflect on whether the appropriate efforts to improve mathematics education were being implemented. Both policymakers and researchers have to collaborate to promote policymaking and the evolution of mathematics education as solutions to educational problems, such as improving students' mathematics learning attitudes and motivation, or helping low-achieving students to understand mathematics. The TIMSS results also served as indicators, enabling Chinese Taipei to monitor whether new policies improve educational problems and to identify possible directions and topics to work on.

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SELECTED ONLINE RESOURCES FOR MATHEMATICS EDUCATION

Shi-Da Institute for Mathematics Education:
http://www.sdime.ntnu.edu.tw/en/main.php

Free Math Games:
http://www.softschools.com/math/games/

Mathletics:
http://uk.mathletics.com/

Math is fun:
https://www.mathsisfun.com/

NRICH:
https://nrich.maths.org/frontpage

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