Success Factors of Taiwan in TIMSS Mathematics Assessment

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Abstract: *The Trends in International Mathematics and Science Study (TIMSS) is a project of the International Association for the Evaluation of Educational Achievement (IEA). TIMSS measures trends in mathematics and science achievement at the fourth and eighth grades in participating countries around the world, while also monitoring curricular implementation and identifying promising instructional practices. TIMSS is conducted on a regular 4-year cycle and the first assessment had been carried out in 1995.Taiwan (Chinese Taipei) took part in TIMSS Mathematics Assessment since 1999. The mean score is always greater than international benchmark. Their ranking for 8th grader is always in top 5 with 3rd in 1999, 2nd in 2003, 1st in 2007 and 3rd in 2011. The achievement is awesome when compare to Malaysia. Like Taiwan, Malaysia also took part in TIMSS Mathematics Assessment since 1999 but only for 8th grader. The achievement is declining from year to year and the mean score was below the international benchmark, except for 1999. Therefore, a hypothetical study of factors that contributed to mathematics performance of Taiwanese in TIMSS Mathematics assessment had been carried out so that we can try to learn from Taiwan on how to achieve such excellent performance. In this study, the author would like to confirm the effect of the factors under learner variable, school variables and home variable on mathematics performance. Six hypotheses were created. The data used will be the secondary data obtained from TIMSS 2011. Structural Equation Modeling – Partial Least Squares method will be used to analyze the data. The smartPLS2.0 software is used for the study. As conclusion, it was found all the three variables, school variable, learner variable and home variable have direct effect on mathematics performance and home variable and school variable have indirect effect on mathematics performance.*

Keywords: *Mathematic Performance, Learner Variable, Home Variable, School Variable, Structural Equation Modeling, Partial Least Squares*

I. INTRODUCTION

Since the forming of Taiwan (Chinese Taipei), education has always been an important agenda of government. The government is committed to provide good quality education to their citizen. In recent years, the Ministry of Education of Taiwan has proposed 12 key policies to improve the quality of their education [19]. The 12 key policies are Establish White Paper on Talent Cultivation to Actively Engage in Talent Cultivation and Recruitment; Promote 12-year Basic Education to Strengthen Diverse and Appropriate Development for Students; Implement Early Childhood Education and Care Act to Create Quality Preschool Education; Shorten the Gap between School and Work and Build Quality Human Resources; Enhance and Internationalize the Quality of Higher Education; Deepen Teacher and Arts Education to Create Mentors and Citizens with Artistic Strengths; Build a Lifelong Learning Society and Promote the Year of Family Education, 2013; Integrate Assistance for Education for Disadvantaged Students and Bring about Social Justice and Care; Promote E-learning and Establish a Learning Environment High in the Clouds; Build a Friendly Campus to Promote Students' Physical and Mental Health; Cultivate Youths' Creativity and Shape Their Values; and Enhance Sports Development to Improve Citizens' Health and Obtain Results at International Competitions.

In 1968, Taiwan's government had changed the education system from 6 compulsory years to 9 compulsory years. And from 2014, the government is extending the compulsory study years to 12 years. Mathematics is one of the subjects of study for 12 years. The education system in Taiwan is shown in Figure 1.

Taiwan's government is also setting the aim of their national education. The aim is to teach students to obtain basic knowledge and to develop the capacity for lifelong learning, in order to cultivate able citizens who are mentally and physically healthy, vigorous and optimistic, gregarious and helpful to the community, intellectually curious and reflective, tolerant and with vision creative and have a positive attitude and global perspective.

Besides, general principles had been set for writing or designing the curriculum. The principles are to involve all aspects of daily life that correspond to the students' mental and physical development; to encourage the development of individuality and the exploration of one's potentials; to foster democratic literacy and respect for different cultures; and to develop scientific understanding and competencies, in order to meet the demands of modern life

With those principles and aim, the Ministry of Education of Taiwan sets to achieve 10 curriculum goals which are to enhance self-understanding and explore individual potential; to develop creativity and the ability to appreciate beauty and present one's own talents; to promote abilities related to career planning and lifelong learning; to cultivate knowledge and skills related to expression, communication, and sharing; to learn to respect others, care for the community, and facilitate team work; to further cultural learning and international understanding; to strengthen knowledge and skills related to planning, organizing, and their implementation; to acquire the ability to utilize technology and information; to encourage the attitude of active learning and studying; and to develop abilities related to independent thinking and problem solving.

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In order to achieve the goal, the learning area or curriculum of Mathematics is going to include six major contents which are acquiring the basic concepts of figures, shapes, and quantity; the ability to calculate and organize; the ability to apply such knowledge and skills in their daily life; comprehending of the principles of reasoning and problem solving; the ability to elaborate clearly on math-related concepts; and making appropriate connections among materials and contents between this and other Learning Areas.

The effort of the Taiwan has seen the success. Taiwan had shown an outstanding performance in international arena in recent years. Some of the performances of Taiwan in International Mathematics Assessments/Competition are:

a) TIMSS 2011

   i) ranked 4th(out of 52 participated countries) for 4th Grade with mean score 591

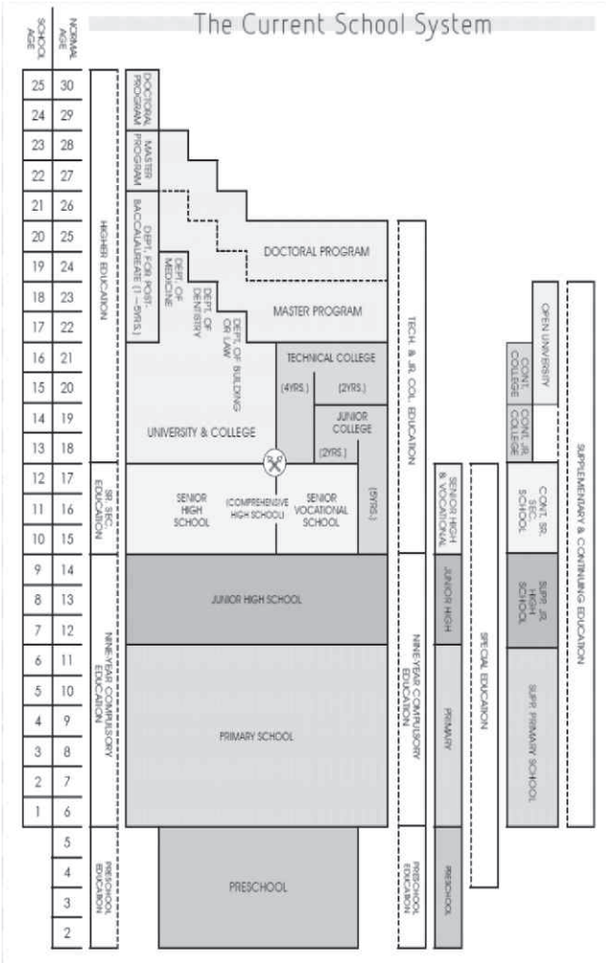
   ii) ranked 3rd (out of 45 participated countries) for 8th Grade with mean score 609

b) PISA 2012

   i) ranked 4th(out of 64 participated countries) with mean score 560

c) International Mathematical Olympiad

   i) ranked 8th(out of 97 participated countries) with 2 golds and 4 silvers



II. CONCEPTUAL FRAMEWORK

Two articles were found to have most similarity to the concept of this study. They were reviewed and summarized as follow.

Ai in [1] had suggested Individual, Home, and School Influences as factors that were affecting the mathematics performance. Though the study was done in the interest of comparison of growth rate between boys and girls, but it was confirmed at the end of the study that these factors were affecting the mathematics performance for both gender. 3,116 seventh graders randomly selected from 52 public schools. This group of students was followed through from Grade 7 to Grade 10. Item Response Theory technique scale ranging from 0 to 100 by Hambleton & Swaminathan was used to analyze the mathematics test scores. The mathematics test, consisting mainly of 60 items from the National Assessment of Educational Progress tests, covered such areas as math skill and knowledge, routine application, problem solving and understanding, and spatial visualization (reliabilities of these math scores ranged from 0.86–0.95).

In [2], Aiken pointed out that attitudinal explanations might be insufficient. The roles of other factors, such as the influence of parents, teachers, peers, and schools, must also be taken into consideration as important determinants of gender differences in attitude and ability in mathematics.

Therefore, Learner Variable, Home Variable and School Variable had been determined as the construct affecting the mathematics achievement.

Under Learner Variable, the variables/items that will be studied are related to math attitude, math anxiety and self-esteem to mathematics.

For Home Variable, the variables/items that will be studied are related to parents' attitude and encouragement towards mathematics learning by children.

As for School Variable, the variables/items that will be studied are related to the learners' peer math attitude and math mathematic encouragement.

LITERATURE REVIEW AND HYPOTHESES

Taiwan had been performing so well in TIMSS Mathematics Assessment since 1999. Their ranking for 8th grader is always in top 5. Taiwan was ranked 3rd in 1999, 2nd in 2003, 1st in 2007 and 3rd in 2011. A study is to be done to confirm the factors and determine their relations or effects of each in contributing towards the success of Taiwan in mathematics assessment [20].

Parental involvement behaviors significantly affect children's academic achievement, indirectly, through the influence of the following behaviours on children's personal variables [14]:

a) academic self-concept
b) causal attributions
c) school aptitudes

In [25], Strayhorn further confirm that family influences children's mathematics achievement by checking students' homework and actively involved in their child's education.

Besides that, parents' education and household income were also said to have effect on mathematics performance. In [29], Yavuz from Turkey had conducted a study on the factors that affect mathematics-science scores in the secondary education institutional exam. The author found that father's and mother's education has direct effect on students' mathematics score.

In [22], Savas, Tas & Duru had conducted a similar investigation on the factors affecting the mathematics achievement of 6th, 7th and 8th grade secondary school students in Van and proven that family income had significant relationship on mathematics achievement. Same go to Mullis, I. V. S., Martin, M. O., Foy, P., Arora, A. [20] and Noor [21]. Both study had confirm that students' home backgrounds is accountable for students' mathematics achievement.

Kiamaneshin [31] once again confirmed that home background such as parents' level of education and number of books at home has positive relationship with mathematics achievement. The author had conducted the study on Iranian students.In [9], Crane also supported that home environment is important for children to achieve well in mathematics. The author concluded that home environment, socio-economic status (SES) and maternal cognitive test scores each had significant effects on the mathematics scores of children.

Parent involvement in schools is essential towards their children performance. It is important to have a good relationship between parent and the schools. In [30], Zellman& Waterman found that a higher level of reported parent school involvement was associated with better test scores in reading and teacher ratings if fewer learning problem.

Strayhorn in [25] found that Black high school students earned higher mathematic achievement when their parents attended school meetings. By attending the school meetings, parents are probably more aware on the resources available in the school, what is going on in the school and how the teaching and learning too place in the school.

From those articles, three hypotheses are established. They are:

H1: Home Variable has indirect effect on Mathematics Performance via Learner Variable

H2: Home Variable has direct effect on Mathematics Performance

H3: Home Variable has indirect effect on Mathematics Performance through School Variable

Student variable is another factors considered. In [5], Asako had confirmed that students' mathematics-related self-concepts have positive connection with mathematics achievement in Japan and US when the author conducted a comparison study between American and Japanese students. In [21], Noor found out that one of the most critical factors that affecting the mathematics achievement among Malaysian students is self-confidence in learning mathematics. Students with high index on this factor will score higher marks in mathematics. Students' belief and anxiety were also had significant effect on mathematics achievement. This was proven by the studies conducted by Velo & Rohani and Siti & Rohaniin [27] and [23].

In [4], Amla et al had found out that the level of student engagement in school has correlation with their academic achievement. The students' engagement in school is important for the development and growth of the students. Student engagement is defined as "student willingness to participate in routing school activities, such as attending classes, submitting required work, and following teachers' instruction in class [7].

In [20], Mullis, I. V. S., Martin, M. O., Foy, P., Arora, A. proven that school climate (which I call as school variable in this paper) has positive relationships toward mathematics achievement. Students performed better under good and conducive study environment. Besides, teachers' perception on students was also affecting student performance in mathematics. In [11], Dodeen et al. had shown that there was statistically significant correlation between teachers' perception and student mathematics scores in Taiwan.

Two hypotheses are established based on the articles above. They are:

H4: Learner Variable has direct effect on Mathematics performance

H5: School Variable has indirect effect on Mathematics performance through Learner Variable

School buildings and grounds, school location, teachers working condition, computer and computer software for mathematics instruction are the items under investigation. There is strong association between schools' infrastructure and examination performance, according to [32]. They had conducted a study in the Gucha district of Kenya and found out that the schools with better infrastructure were performed better. In [28], Yarahad also confirmed that school variable played a part in mathematics performance. The author had carried out a study of Kenya Certificate of Secondary Education (KCSE) in Mathematics of secondary schools in Nyamaiya Division, Kenya. In [18], Kilic, Cene and Demirfrom Turkey had found that the mathematics achievement decreased when the students per teacher ratio increased. With larger students, the teachers will be overloaded and more stressful in their daily work.

Dasoin [10] had conducted a study on the students at the secondary school in Rivers State, Nigeria. The study was conducted on 4510 senior secondary II students and 151 principals. Z-test, means and simple percentages are used to analyze the data and found out that there is a significant evidence that the relationship exists in between teacher quality, school academic climate and students' performance.

H6: School Variable has direct effect on Mathematics Performance

METHODOLOGY

4.1 Source of Data

Data used in this study come from the 2011 Trends in International Mathematics and Science Study (TIMSS). TIMSS was developed by the International Association for the Evaluation of Educational Achievement (IEA). It has been more than 50 years for IEA in conducting comparative studies of educational achievement in a number of curriculum areas including mathematics and science.

TIMSS 2011 represents the fifth cycle of the Trends in International Mathematics and Science Study (TIMSS). TIMSS has been conducted every four years since 1995. Forty five countries had participated in the TIMSS 2011 eight grade assessment. Taiwan is one of them, likewise Malaysia.

4.2 Instrumentation

5042 students from 150 schools in Taiwan were chosen to sit for Mathematics assessment. They were also given a questionnaire to answer.

There were 217 items used in the 2011 grade eight mathematics assessment with half being multiple choice and half being constructed response items where students write their answers. The distribution of the questions is shown in the Figure 2.

Figure 2. Distribution of Assessment Items by Content Domain, Cognitive Domain and Item Format (Source: IEA)

Figure 2. Distribution of Assessment Items by Content Domain, Cognitive Domain and Item Format (Source: IEA)

TIMSS Assessment Items	Multiple-choice Items	Constructed-response Items	Total Items	Percentage of Score Points
Content Domain				
Number	31 (31)	30 (36)	61 (67)	29%
Algebra	37 (37)	33 (39)	70 (76)	33%
Geometry	25 (25)	18 (19)	43 (44)	19%
Data and Chance	25 (25)	18 (20)	43 (45)	19%
Total	118 (118)	99 (114)	217 (232)	100%
Percentage of Score Points	51%	49%		
Cognitive Domain				
Knowing	53 (53)	27 (30)	80 (83)	36%
Applying	47 (47)	38 (44)	85 (91)	39%
Reasoning	18 (18)	34 (40)	52 (58)	25%
Total	118 (118)	99 (114)	217 (232)	100%
Percentage of Score Points	51%	49%		

Score points are shown in parentheses.
Because of rounding some results may appear inconsistent.

As for the student questionnaire, students have to answer 21 questions. The questions were sub-divided into

a) About you – 11 questions
b) Your school – 2 questions
c) Mathematics in School – 3 questions
d) Sciences in School – 3 questions
e) Homework – 2 questions

4.3 SEM

PLS-SEM is applied to test the model and it is variance based SEM [3] [8]. Partial Least Squares (PLS) is the dominant approach to establish rigor in complex models as it can avert the limitations of covariance based Structural Equation Modeling (CBSEM) with regard to distributional properties, measurement level, sample size, model identification and factor in determinacy. The PLS approach to Structural Equation Models, also known as PLS Path Modeling (PLS-PM) is regarded as a component based SEM [26] to model multiple causes and multiple indicators of a single latent variable, and to latent path models [40].Objective of PLS-SEM is to maximize the explained variance of the endogenous latent constructs (dependent variables).

The Smart PLS 2.0 software had been chosen among the many to analyze the data. This software is developed by Ringle, Christian Marc/Wende, Sven/Will, Alexander.

IV. RESULTS AND ANALYSIS

Table 3. Measurement Model

Construct	Item	Loading	AVE	CR
Home	Home1	0.751	0.605	0.859
	Home2	0.840		
	Home3	0.798		
	Home4	0.715		
Learner	Learner1	0.825	0.544	0.929
	Learner2	0.846		
	Learner3	0.664		
	Learner4	0.821		
	Learner5	0.857		
	Learner6	0.709		
	Learner7	0.687		
	Learner8	0.773		
	Learner9	0.651		
	Learner10	0.595		
	Learner11	0.623		
Performance	Performance	1.000	1.000	1.000
School	School1	0.755	0.632	0.873
	School2	0.784		
	School3	0.848		
	School4	0.790		

Table 4.Discriminant Validity (comparing construct to construct)

Construct	Home	Learner	Performance	School
Home	**0.778**			
Learner	**0.301**	**0.738**		
Performance	**-0.275**	**-0.596**	**1.000**	
School	**0.449**	**0.725**	**-0.441**	**0.795**

Note: Values in the diagonal represent the square root of AVE and the off-diagonals represent the correlations

Table 5.Cross Loadings (comparing items to items)

	Home	Learner	Performance	School
Home1	**0.751**	0.236	-0.205	0.289
Home2	**0.840**	0.221	-0.253	0.365
Home3	**0.798**	0.302	-0.253	0.433
Home4	**0.715**	0.078	-0.088	0.256
Learner1	0.279	**0.825**	-0.426	0.627
Learner2	0.285	**0.846**	-0.450	0.637
Learner3	0.236	**0.664**	-0.368	0.522
Learner4	0.198	**0.821**	-0.619	0.542
Learner5	0.214	**0.857**	-0.589	0.596
Learner6	0.187	**0.709**	-0.509	0.456
Learner7	0.168	**0.687**	-0.360	0.445
Learner8	0.239	**0.773**	-0.446	0.469
Learner9	0.255	**0.652**	-0.398	0.572
Learner10	0.204	**0.595**	-0.366	0.459
Learner11	0.068	**0.623**	-0.289	0.414
Performance	-0.276	-0.606	**1.000**	-0.440
School1	0.420	0.554	-0.416	**0.755**
School2	0.380	0.509	-0.369	**0.784**
School3	0.290	0.681	-0.405	**0.848**
School4	0.340	0.503	-0.168	**0.790**

Table 6. Hypothesis Testing

Hypothesis	Relationship	t-value	Decision
H1	Home -> Learner	4.343**	Supported
H2	Home -> Performance	4.015**	Supported
H3	Home -> School	7.416**	Supported
H4	Learner -> Performance	7.871**	Supported
H5	School ->Learner	15.009**	Supported
H6	School -> Performance	5.729**	Supported

**p<0.01, *p<0.05

Table 7. Q^2 Values

Construct	Q^2
Home	0.605
Learner	0.275
Performance	0.339
School	0.125

Table 8.Description of each item

Construct	Item	Description
Home	Home1	How often do my parents ask me what I am learning in school?
	Home2	How often do I talk about my schoolwork with my parents?
	Home3	How often do my parents make sure that I set aside time for my homework?
	Home4	How often do my parents check if I do my homework?
Learner	Learner1	I enjoy learning mathematics
	Learner2	I like mathematics
	Learner3	It is important to do well in mathematics
	Learner4	I usually do well in mathematics
	Learner5	I learn things quickly in mathematics
	Learner6	I am good at working out difficult mathematics problems
	Learner7	My teacher this I can do well in mathematics lessons with difficult materials
	Learner8	My teacher tells me I am good at mathematics
	Learner9	I think learning mathematics will help me in my daily life
	Learner10	I need mathematics to learn other school subjects
	Learner11	I would like a job that involves using mathematics
Performance	Performance	Performance
School	School1	I know what my teacher expects me to do
	School2	My teacher is easy to understand
	School3	I am interested in what my teacher says
	School4	My teacher gives me interesting things to do

5.1 Reliability

All the loadings for indicators in table 3 are greater than 0.4, therefore, they are all reliable ([17]). Besides, internal consistency reliability was also check by using the value of composite reliability. Composite reliability is a measure of internal consistency and must be at least 0.7([6]). From table 3 also, we found out that the composite reliability score for all the constructs are above 0.7 that is

Home = 0.859
Learner = 0.929
School = 0.873
Performance = 1.000

5.2 Discriminant Validity

Two measures of discriminant validity have been introduced: The Fornell-Larcker criterion and the cross loadings [16]. The Fornell-Larcker criterion stated that a latent variable shares more variance with its assigned indicators than with any other latent variable. In statistical terms, the average variance extracted (AVE) of each latent variable should be greater than the latent variable's highest squared correlation with any other latent variable [12]. In table 4, it is clearly showing that the criterion is fulfilled whereby the AVE of each latent variable or construct is greater than the highest squared correlation with any other latent variable.

As for second criterion, the loading of each indicator is expected to be greater than all of its cross-loadings ([8], [15]). This criterion is fulfilled too by referring to table 5.

5.3 Inner model evaluation

Stone-Geisser's Q2 is used to measure the predictive relevance of the model ([24], [13]). The Stone-Geisser criterion postulates that the model must be able to provide a prediction of the endogenous latent variable's indicators. Q2 can be measured using blindfolding procedures [26]. The blindfolding procedure is only applied to endogenous latent variables that have a reflective measurement model operationalization. If the value for a certain endogenous latent variable is larger than zero, its explanatory variables provide predictive relevance [8]. Table 7 shows that all the endogenous latent variables have Q2 greater than zero.

5.4 Convergent Validity

The average variance extracted (AVE) is used to evaluate the convergent validity. All the involved AVE need to be 0.5 or higher in value ([33]). From table 3, it is clearly seen that all of the AVE values are greater that the accepted threshold of 0.5, so the convergent validity is confirmed.

VI. CONCLUSION

Home is directly affecting the mathematics performance and is also indirectly affecting the mathematics performance through Learner and School. In [34], Sheldon& Epstein also confirmed that home play an important role in helping the students to do well in Mathematics. Epstein in [35] has listed types of involvement in a comprehensive program of school and family partnerships. The involvement includes

i. Parenting: Helping all families establish supportive home environments for children
ii. Communicating: Establishing two-way exchanges about school programs and children's progress
iii. Volunteering: Recruiting and organizing parent help at school, home, or other locations
iv. Learning at home: Providing information and ideas to families about how to help students with homework and other curriculum-related materials
v. Decision making: Having parents from all backgrounds serve as representatives and leaders on school committees

School is directly affecting the mathematics performance and is also indirectly affecting the mathematics performance through Learner. In [36], Jebson said that in order for teachers to make their mathematics teaching makes meaning to the learners, teachers must explore and use the approaches that would ensure that the learners participate actively in the learning process and one of the important approaches is cooperative approach. Plass, et. al. recommended collaborative learning through game play is able to increase the mathematics performance of students [37].

Learner is also directly affecting the mathematics performance. In their study, Raccanello & De Bernardi found that student's mastery goals (strive to reach competence) plays the strongest role in relation to achievement [38]. Walsh in her study showed that students' mathematics anxiety has negative correlation with mathematics performance while mathematics self-efficacy has positive correlation with mathematics performance [39].

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