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EXAMINING MATHEMATICS ATTITUDE IN A TIMSS 2003 PILOT RESEARCH

Abstract. Apart from the data on test reliability, the psychometric features of the TIMSS variables are not officially available. It is therefore not clear whether the TIMSS findings capture real educational trends. Being concerned with mathematics attitude, the aim of this research was to determine the psychometric values of a mathematics attitude scale derived from a student questionnaire, and, if these are appropriate, to examine the relation of mathematics attitude to gender and mathematics achievement, and search for gender differences in the applied mathematics attitude indicators. By using a sample of 89 seventh-grade students involved in a TIMSS 2003 pilot research, it revealed the following findings: (a) the representativity, reliability, homogeneity and validity of the applied attitude scale were acceptable, (b) attitude to mathematics was related to mathematics achievement, (c) gender differences in mathematics attitude were not found; and (d) gender differences in the applied indicators were only present for the statement »I need to do well in mathematics to get into the faculty of my choice« where males expressed a higher agreement than females.

Keywords: TIMSS, attitude to mathematics, mathematics achievement, gender differences.

TIMSS 2003 (Trends in International Mathematics and Science Study in 2003; see *http://timss.bc.edu/*) is an IEA (International Association for the Evaluation of Educational Achievement; see *http://www.iea.nl/*) project measuring trends in students performance in mathematics and science. This project started in 1995 with the original TIMSS (Third International Mathematics and Science Study), followed by TIMSS-Repeat conducted in 1999.

The TIMSS projects have so far been realized in some 50 countries around the world. As it may be expected, the outcomes of these projects have influenced the development and (re)design of mathematics and science education curricula in a number of countries (see Robitaille, Beaton & Plomp, 2000).

Research context

Although a positive relation between mathematics attitude and mathematics achievement has been evidenced in a number of studies (see, for example, Hembree, 1992), the TIMSS 1995 eighth-grade data rise some doubts to this finding since attitude to mathematics was a significant predictor of mathematics achievement in just 4 of 18 examined countries (Martin *et al.*, 2000). As such an outcome is not supported by tables of correlation coefficients but multiple regression model results – a significant correlation, as well as an insignificant one, may or may not result in a significant predictor within a multiple regression model – it is still unclear whether the relation mentioned above applies in the TIMSS context. It is true that a 1999 report states that

> *there was a clear positive association between attitudes towards mathematics and mathematics achievement on average across all the TIMSS 1999 countries and in many of the Benchmarking entities*[1]

but no numeric data are given. Furthermore, like in the case of other TIMSS utilized variables, no data are given concerning the psychometric features of the applied math attitude scale.[2] In fact, the 1999 findings resulted from a somewhat cumbersome procedure quoted below.[3]

> *Students were asked to state their agreement with the following five statements:*
> - *I like mathematics*
> - *I enjoy learning mathematics*
> - *Mathematics is boring*
> - *Mathematics is important to everyone's life*
> - *I would like a job that involved using mathematics.*
>
> *For each statement, students responded on a four-point scale indicating whether their feelings about mathematics were strongly positive, positive, negative, or strongly negative. The responses were averaged, with students being placed in the high category if their average indicated a positive or strongly positive attitude. Students with a negative or strongly negative attitude on average were placed in the low category. The students between these extremes were placed in the medium category.*

Can one precisely repeat this procedure? Why not simply enter in statistical analyses with the total score of these five indicators provided that this measure is an appropriate one? Why not search for gender differences in each of the applied five indicators provided that their psychometric features are acceptable?

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[1] see *http://timss.bc.edu/timss1999b/mathbench_report/t99bmath_chap_4_4.html*

[2] A search for relevant data at *http://timss.bc.edu/* only revealed the test reliability information. In the 1999 study, Cronbach's Alpha Reliability Coefficient was around .90 for most countries see *http://isc.bc.edu/timss1999b/mathbench_report/t99bmath_A.html#s10*). The face validity of the instrument *should* be supported/strengthen by appropriate psychometric data.

[3] see *http://timss.bc.edu/timss1999b/mathbench_report/t99bmath_chap_4_4.html*

Gender differences in mathematics attitude have also been examined in the TIMSS context. In the 1999 study, concerning the international average, males had a more positive attitude than females in the high attitude group, whereas the opposite was the case in the medium and low attitude groups (recall the procedure quoted at the previous page)[4]. However, in 5 out of 13 countries and in 27 states, districts and consortia, gender differences were not present in these three groups[5]. An open question is whether the findings are real, or artificial resulted from an inadequate instrument and procedure.

Except for the index of overall attitudes towards mathematics, gender differences were also examined in some Likertianly-operationalized indicators concerning the importance of doing well in mathematics, doing well in mathematics to please parents, and doing well in mathematics to get desired job (see Mullis *et al.*, 2000). When Likert introduced his instrument in 1932, he was concerned with the total score on those items that positively correlate with the calculated total, not considering the possibility of individual item analysis (Clason & Dormody, 1994). Thus, no matter now useful and valuable it may be, an outcome generated by a single indicator may be open to doubt when its psychometric features are not reported or are nevertheless questionable.

Research questions

On the basis of the research context presented above, this study dealt with the following questions:

- Can a psychometrically indisputable (representative, reliable, valid and homogenous) TIMSS measure of mathematics attitude be applied?
- Provided that the applied mathematics attitude measure is appropriate, are attitude to mathematics and mathematics achievement related?[6]
- Provided that the applied mathematics attitude measure is appropriate, are there gender differences in attitude to mathematics and their indicators?

These questions were answered by using some of the Serbian official data provided by the IEA Data Processing Center, Hamburg, Germany. The data were collected in the TIMSS field study realized in Serbia in June 2002 by the Institute for Educational Research of Belgrade. The results of this study, as in other pilot studies conducted in some 50 countries around the world, were used to design the final TIMSS study. This final study, TIMSS

[4] see exibit 4.11 at *http://timss.bc.edu/timss1999b/mathbench_report/t99bmath_chap_4_4.html*

[5] except for one medium attitude group in states

[6] What we assume here is that the TIMSS measure of mathematics achievement is not open to doubt, which, because of a high test reliability, may be the case.

2003, was realized in spring 2003 (for the north hemisphere) according to internationally agreed frameworks and specifications
(see *http://timss.bc.edu/*).

Method

The study used a sample of 89 seventh-grade students (51 males and 38 females) who came from two schools selected by Statistics Canada. One school was urban, whereas the other was sub-urban. Two classes were randomly chosen in each of the schools.[7]

The study had a correlative design. The variables were: gender (1-male, 2-female), mathematics attitude and its indicators, and mathematics achievement.

The values of the applied variables were obtained from the above-mentioned Serbian official data.

- The values of mathematics attitude were obtained from the TIMSS 2003 field study student questionnaire (questions 9 and 10 except for 10d; see Appendix I) by using the first principal component factor scores whose reliability (Lord-Kaiser-Caffrey)[8] was .80.
- The values of mathematics attitude indicators were examined for the subjects' individual-item scores transformed into the Guttman space (done by the author of this report).[9]
- The values of mathematics achievement were obtained from the IEA standardization of the subjects' raw test scores submitted by the Institute.

The collected data were examined by correlative analysis, factor analysis, and scale metric feature analysis (Knežević & Momirović, 1996).

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[7] The sample comprised 112 students, but only 89 fully completed the part of the questionnaire used in this study.

[8] Lord-Kaiser-Caffrey's coefficient α is defined by the formula

$$(m / (m - 1)) * (1 - 1 / \lambda)$$

where m and λ are respectively the number of variables (12 in our case) and the maximal eigenvalue of the correlation matrix of the variables (Kaiser & Caffrey, 1965). By taking the factor score, we are in fact taking a linear combination of the variables that has the greatest reliability under the classical model of measurement.

[9] This transformation, which eliminates noise from the initial data, is defined by

$$T = Z(I - R^{-1}U^2),$$

where T, Z, I, R and U^2 are, respectively, the matrix of true results, the matrix of the standardized (and perhaps normalized) initial data, the identity matrix, the matrix of the intercorrelation among the measured variables, and the matrix of an variance measurement error estimate given by $(\text{diag}R^{-1})^{-1}$. The transformation can, for example, be realized by utilizing a SPSS syntax file written in the SPSS's macro language (see Appendix II).

Results

The representativity, reliability and homogeneity of the mathematics attitude scale and its indicators are presented in Tables 1-4.

Table 1: The representativity of the mathematics attitude scale

Kaiser, Mayer, Olkin measure of sampling adequacy	psi 1	.90
Kaiser, Rice	psi 2	.62[10]
Kaiser	psi 3	.80

Table 2: The reliability of the mathematics attitude scale

Reliability Under the Classical Measurement Model		
Guttman	lambda 1	.71
Guttman, Cronbach α	lambda 3	.78
Guttman	lambda 6	.85
Reliability Measures of the First Principal Component		
Lord-Kaiser-Caffrey	beta 3	.80
Measures of Reliability Under Guttman's Measurement Model		
Guttman-Nicewander	rho	.88

Table 3: The homogeneity of the mathematics attitude scale

Mean correlation	h 1	.22
Participation of the first Guttman's factor in the total predictable (image) variance	h 2	.52
$1- (\theta^2 -\lambda^2) * (m-\lambda^2)^{-1}$	h 5[11]	.44

[10] Kaiser-Miller's measure indicates that there might be some items with a very similar content, i.e. items characterized by very high mutual correlations and relatively low correlations with other items.

[11] λ^2 - the first eigenvalue of the correlation matrix; θ^2 - the sum of all eigenvalues greater than 1.

Table 4: The representativity, reliability, homogeneity and internal validity of the mathematics attitude scale indicators

ITEM	REP	REL	HOM	H	B[12]
I usually do well in mathematics*	.95	.59	.69	.78	.72
I would like to take more mathematics in school*	.83	.40	.33	.38	.41
I would like mathematics much more if it were not so difficult	.84	.28	.34	.42	.45
Mathematics is more difficult for me than for many of my classmates	.88	.46	.40	.46	.47
I enjoy learning mathematics*	.92	.60	.61	.68	.65
Sometimes, when I do not initially understand a new topic in mathematics, I know that I will never really understand it	.76	.36	.25	.32	.39
Mathematics is not one of my strengths	.96	.61	.72	.80	.75
I learn things quickly in mathematics*	.95	.51	.66	.76	.72
I think it is important to do well in mathematics at school*	.82	.21	.28	.35	.40
I would like a job that involved using mathematics*	.94	.52	.63	.71	.67
I need to do well in mathematics to get the job I want*	.73	.49	.23	.29	.40
I need to do well in mathematics to get into the faculty of my choice*	.84	.50	.41	.46	.51

* items for which scoring is reversed

The correlations among gender, mathematics attitude and mathematics achievement are presented in Table 5. Only the relation of mathematics attitude to mathematics achievement was found (.35, $p < .01$).

Table 5: Correlations among gender, mathematics attitude and mathematics achievement

VARIABLE	2	3
1. gender	-.03	-.05
2. mathematics attitude		-35*
3. mathematics achievement		

* $p < .01$

[12] REP = $(\Sigma_{j=1}^{n} a_j^2) / (\Sigma_{j=1}^{n} r_j^2)$ where a_j and r_j are respectively the column elements of matrix $A = UR^{-1}U$ $U^2 = (\text{diag}(R^{-1}))^{-1}$ and correlation matrix R. / REL - the item variance explained by other items. / HOM - the proportion of the first image factor in the total image variance of the item. / H - the correlation with the first principal component. / B - the correlation with the total score.

The correlations between the mathematics attitude indicators and gender are reported in Table 6. Since the psychometric features of these indicators were low for most of them, the relation between indicator score and gender was determined by using the Guttmanized indicator data. Gender differences were only obtained for indicator »I need to do well in mathematics to get into the faculty of my choice« where males expressed a higher agreement than females.

Table 6: Correlations between the mathematics, attitude indicators and gender

INDICATOR	CORR
I usually do well in mathematics	-.02
I would like to take more mathematics in school	-.05
I would like mathematics much more if it were not so difficult	.06
Mathematics is more difficult for me than for many of my classmates	.15
I enjoy learning mathematics	-.07
Sometimes, when I do not initially understand a new topic in mathematics, I know that I will never really understand it	.07
Mathematics is not one of my strengths	.07
I learn things quickly in mathematics	.04
I think it is important to do well in mathematics at school	.01
I would like a job that involved using mathematics	-.14
I need to do well in mathematics to get the job I want	-.10
I need to do well in mathematics to get into the faculty of my choice	-.24*

$^{*}p < .05$

Discussion

Four important findings emerged from this study. First, a TIMSS measure of mathematics attitude chosen by the author of this study showed acceptable representativity, reliability and homogeneity. Second, attitude to mathematics was related to mathematics achievement, proving some sort of the validity of the applied 12-indicator scale. Third, no gender differences were found in mathematics attitude. Fourth, except for the indicator »I need to do well in mathematics to get into the faculty of my choice«, no gender differences were found in the applied mathematics attitude indicators.

The first two findings evidenced that a psychometrically indisputable TIMSS measure of mathematics attitude can be applied. Although the psychometric features of the attitude scale were acceptable, its refinement may be needed to achieve better representativity (psi2 and psi3 were low for our sample), reliability (Cronbach α should be around .85 or so) and homogeneity (closer to 1, say .7, evidencing that just one subject is measured by the applied instrument). Again, the TIMSS measure of the examined variables should be psychometrically indisputable (representative, reliable, homogenous and valid) and the relevant psychometric data listed in the TIMSS official reports. Of course, any variable is to be operationalized according to a sound theoretical framework, which in our case (mathematics attitude) should include three attitude domains: cognitive, affective and behavioural[13] (see Kay, 1993).

Attitude to mathematics was related to mathematics achievement, which is in accord with Hembree (1992). As already mentioned, the nature of this relation in the TIMSS context is not clear and should be clarified. A recent ninth-grade international study on mathematical-self concept[14], undertaken in Israel, Finland, Poland and Yugoslavia, evidenced low to medium correlations between this construct and the mark (grade) in mathematics for the fall semester (Kadijevich *et al*., 2003). Such an outcome is relevant here since several items of the math-self scale (see items 1, 5, 7, 8 and 13 in Appendix III) capture data identical/similar to these obtained by the mathematics attitude scale (see items 9d-g and 10c in Appendix I).

Apart from the indicator »I need to do well in mathematics to get into the faculty of my choice« where males expressed a higher agreement than females, no gender differences were found in other mathematics attitude indicators nor in the construct as a whole. This difference may reflect an expected pattern: while males usually study technically-oriented areas, females do so for hymanistically-oriented ones. The above cited study on mathematical-self concept revealed that, despite significance, gender differences in the measured construct and its 15 indicators were mainly negligible (less than 4%). The only exception was indicator »I am more successful than most students of my age at solving mathematical problems«, where males scored 4.4 % higher than females for the whole sample, 7.3% higher for the Finnish sub-sample and 8.4% higher for the Israeli one. Note that no gender differences were found in any sub-sample relating to the subjects' perception of the value and importance of mathematics (»These

[13] Although the chosen indicators deal with these domains (9g - cognitive, 9e - affective, and 9b - behavioral), there is no evidence that their selection has been done on explicit grounds.

[14] Mathematical-self concept is viewed as an organised system of beliefs about mathematics, supplemented by behavioural and emotional reactions regarding the value of mathematics and mathematical way of thinking as well as confidence in and motives for learning mathematics. Such a view of the construct clearly includes attitudes toward the subject.

days, learning mathematics is a complete waste of time«, »A knowledge of mathematics gives a base for sound thinking in everyday life«, »A solid mathematical knowledge opens more possibilities when selecting a future profession« and »For success in life today, it is sufficient to know four basic arithmetic operations«), and that the same pattern emerged for two items regarding internal motivation (»I am not at all interested in mathematics« and »Sometimes, even after a class, I think about a mathematical problem that I could not solve in it«) and one regarding confidence (»I do not try to solve a task if it appears too difficult«). In her review paper Fennema (2000) emphasizes the following:

> *Research into gender and mathematics must continue. We should continue to monitor the best we can learning, attitudes, and participation in mathematics. In addition, we need to develop new paradigms of research that will provide insight into why gender differences occur. In other words, gender as a critical variable must enter the mainstream of mathematics education research.*

Having in mind that the size of gender differences determined may depend on the facet of attitude measured (see Whitley, 1996), we may first find out critical cognitive, affective and behavioural indicators of mathematics attitude or a related construct that appropriately measure the size of the examined gender differences.

* * *

To summarize: like the relation between mathematics attitude and mathematics achievement, gender differences in mathematics attitude and its indicators need to be clarified in the TIMSS context. To achieve this end, a skilful construct operationalization (both theoretically and empirically grounded)[15] is to be done, which should, with a greater confidence, enable us to grasp the underlying patterns, find out their behaviour over time, and uncover possible causes for such findings.

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[15] What is rarely reported in a research paper is a justification that the operationalized construct has an independent status in psychological conceptual network.

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Appendix I – The mathematics attitude indicators

9

What do you think about learning mathematics? Tell how much you agree with these statements.

*Fill in **one** circle for each line*

	Agree a lot	Agree a little	Disagree a little	Disagree a lot
a) I usually do well in mathematics	1	2	3	4
b) I would like to take more mathematics in school	1	2	3	4
c) I would like mathematics much more if it were not so difficult	1	2	3	4
d) Mathematics is more difficult for me than for many of my classmates	1	2	3	4
e) I enjoy learning mathematics	1	2	3	4
f) Sometimes, when I do not initially understand a new topic in mathematics, I know that I will never really understand it	1	2	3	4
g) Mathematics is not one of my strengths	1	2	3	4
h) I learn things quickly in mathematics	1	2	3	4

10

Indicate how much you agree with these statements about mathematics.

*Fill in **one** circle for each line*

	Agree a lot	Agree a little	Disagree a little	Disagree a lot
a) I think it is important to do well in mathematics at school	1	2	3	4
b) I would like a job that involved using mathematics	1	2	3	4
c) I need to do well in mathematics to get the job I want	1	2	3	4
d) I need to do well in mathematics because it is important to please my parents	1	2	3	4
e) I need to do well in mathematics to get into the <university> of my choice	1	2	3	4

omitted because of an inappropriate factor loading

Note: scoring was reversed for items: 9a, 9b, 9e, 9h, 10a, 10b, 10c, and 10e.
Source: the TIMSS 2003 field study student questionnaire (pp. 8 and 9).

Appendix II - The content of the Guttman space SPSS macro

```
define gutspace ()
matrix
get dataraw/file='d:\timss03\rawdata.sav'
compute r = t(dataraw)*dataraw/89
compute rinv=inv(r)
compute drinv=diag(rinv)
compute u2=mdiag(drinv)
compute u2=inv(u2)
compute u=rinv*u2
compute datagut=dataraw-dataraw*u
save datagut/outfile='d:\timss03\gutdata.sav'
end matrix
!enddefine.
```

Suppose that these instructions were saved in folder *timss03* just below harddisk partition *d* under name *guttman.sps* (the raw data were to be saved in the same folder under name *rawdata.sav*). The macro is made available in the SPSS program by executing

```
include "c:\timss03\guttman.sps".
```

typed in the Syntax window. The macro can then be utilized by executing

```
gutspace().
```

again typed in the Syntax window. Note that the transformed data are memorized in file *gutdata.sav* saved in folder *timss03* mentioned above.

Appendix III – The mathematics self-concept indicators

1. I enjoy solving mathematical problems.
2. When I meet an interesting mathematical problem, I cannot calm down until I have solved it.
3. I am not at all interested in mathematics.
4. These days, learning mathematics is a complete waste of time.
5. I simply cannot do mathematics.
6. A knowledge of mathematics gives a base for sound thinking in everyday life.
7. A solid mathematical knowledge opens more possibilities when selecting a future profession.
8. I am more successful than most students of my age at solving mathematical problems.
9. Sometimes, even after a class, I think about a mathematical problem that I could not solve in it.
10. I do not try to solve a task if it appears too difficult.
11. When I begin solving a mathematical problem, I suspect in advance that I will not finish it successfully.
12. No matter how much I try, I cannot essentially influence my success in mathematics.
13. If I cannot solve a mathematical problem in 10-15 minutes, I cannot solve it at all.
14. Success in mathematics depends on good or bad luck to a great extent.
15. For success in life today, it is sufficient to know four basic arithmetic operations.

The scoring was reversed for indicators 3-5 and 10-15. The psychometric features of the 15-item instrument were good (see below).

FEATURE	VALUE (N = 682)
Representativity: Kaiser-Meyer-Olkin	.95
Reliability: alpha reliability (Cronbach)	.85
Homogeneity: $1- (\theta^2 -\lambda^2) * (m-\lambda^2)^{-1}$	.74
Validity: Pearson's correlation between mathematical self-concept and mark	.32*

* $p < .01$

Note that when all marks were expressed on the scale 1-5 (for the Israeli sub-sample, 1 was taken for 40-51, 2 for 52-63, 3 for 64-75, 4 for 76-87, and 5 for 88-100), the validity measure was .47, $p < .01$ (see Kadijevich *et al.*, 2003).