NINTH-GRADE STUDENTS' MATHEMATICAL-SELF CONCEPT: An international study

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ABSTRACT

An international study of 682 ninth-grade students from Finland, Poland, Yugoslavia and Israel confirmed that, despite diversity, affective variables regarding mathematics and its learning converge to an underlying construct called mathematical self-concept, the chosen indicators of which yielded an internationally-relevant math-self scale with good metric features. Gender differences in the measured construct and its indicators were mainly negligible.

INTRODUCTION

Research on affect in mathematics education has revealed that affective variables are mutually dependent, e.g., attitudes seem to develop out of emotional responses; emotions usually occur when beliefs contradict the encountered situation; and attitudes are based upon beliefs (McLeod, 1992). A recent study (Opachich & Kadijevich, 1997; see also http://www.mi.sanu.ac.yu/~djkadij/rad_ok.htm), which developed and validated an affective domain scale in the Serbian language, evidenced that, despite diversity, affective variables regarding mathematics and its learning converge to an underlying construct called ***Mathematical Self-Concept*** (M.S.C.).

Most researchers view mathematical self-concept as a generalization of confidence in learning mathematics (McLeod, 1992), which can be included in a hierarchical model of self-concept (Shavelson, Hubner and Stanton, 1976). We perceived M.S.C. 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.

According to Amit (1988, 2000), students' M.S.C. is an important predictor of success in learning mathematics and math-related career choice. Byrne & Worth Gavin (1996) found, for example, a high correlation (.73) between math self-concept and math achievement[1]. The construct under discussion may even be a better predictor of success in learning mathematics than non-verbal intelligence (Opachich & Kadijevich, 1997)[2], meaning that the correlation between M.S.C and this success may be higher than the correlation between non-verbal IQ and the success.

In order to examine whether affective variables regarding mathematics and its learning indeed converge to M.S.C for students from different countries, the present study validated the convergence of Opachich's & Kadijevich's (1997) math-self indicators. These indicators were used not only because of their good psychometric features, but also because Opachich & Kadijevich, contrary to most researchers proposing novel constructs, justified, to some extent, an independent status of such operationalized M.S.C in psychological conceptual network[3]. The study also assessed the representativity, reliability, homogeneity and validity of the applied math-self scale to test its credibility at an international research level. Finally, it determined gender differences in the examined construct and its indicators since several studies including Skaalvik & Rankin (1994), Tiedemann & Faber (1995) and Manger & Eikeland (1998) found that males have higher mathematical self-concept than females.

METHOD

Subjects

The study used a sample of 682 ninth-grade students (373 female and 309 male) described in Table 1. For fuller detail on the sample, see http://www.mi.sanu.ac.yu/~djkadij/ms4c.pdf.

Table 1: Sample

	Females	Males	All
Finland	92	89	181
Poland	93	51	144
Yugoslavia	58	67	125
Israel	130	102	232
All	373	309	682

[1] Measured by standardized tests, grades, self-ratings and teacher ratings.
[2] The correlation between the math-self and non-verbal IQ was not significant.
[3] Many constructs have been introduced without any justification. This attitude may have negative consequences for the development of psychology as well as mathematics education, since introducing new unjustified constructs may increase the number of redundant constructs. A construct justification procedure is described in Opachich & Kadijevich (1997).

Design

The study primarily had a correlative design. The variables were: Opachich's & Kadijevich's (1997) math-self indicators, mathematical self-concept, gender, and mark (grade) in mathematics for the fall semester[4] (hereafter denoted by mark). The collected data were examined by scale metric feature analysis (Knezevic & Momirovic, 1996), correlation analysis and factor analysis.

Instrument

M.S.C was measured by Opachich's & Kadijevich's (1997) math-self scale, the items of which were given in four languages (Finnish, Polish, Serbian and Hebrew), by using suitable translations from the English version of the instrument[5] into Finnish, Polish and Hebrew by the authors of this study.[6]

RESULTS

While the results of a one factor model applied to the retained 15 items[7] are reported in Table 2, the metric features of such 15-item scale are summarised in Table 3.

Table 2. Factor loading for four sub-samples and the total sample

ITEM	FI	PL	YU	IL	ALL
1. I enjoy solving mathematical problems.	.84	.76	.69	.64	.74
2. When I meet an interesting mathematical problem, I cannot calm down until I have solved it.	.63	.54	.62	.49	.58
3. I am not at all interested in mathematics.*	.78	.77	.68	.65	.74
4. These days, learning mathematics is a complete waste of time.*	.70	.72	.62	.63	.69
5. I simply cannot do mathematics.*	.76	.75	.76	.74	.75
6. A knowledge of mathematics gives a base for sound thinking in everyday life.	.70	.47	.49	.58	.61

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[4] In Finland the marks in mathematics increase from 5 (lowest) to 10 (highest). Because only one pupil in the whole sample had mark 5, the marks from 1 (5 and 6) to 5 (10) were only used. In Poland the marks in mathematics increase from 1 (unsatisfactory, very bad) to 5 (very well). Although few students had mark 6 (the pedagogical council of a school may give such a mark to students with outstanding achievements), mark from 1 (1) to 5 (5 and 6) were just used. In Yugoslavia marks increase from 1 to 5. In Israel marks increase from 40 to 100.

[5] The scale developed in Serbian was translated into English. Its re-translation into Serbian evidenced an accurate English translation.

[6] For fuller detail on the 29-item instrument and the applied procedure (the instrument administration, the construction of a 15-item math-self subscale and the authors' cooperation), see http://www.mi.sanu.ac.yu/~djkadij/ms4c.pdf.

[7] For a comparison, Marsh & Yeung (1997, p. 44) measured M.S.C. by using the following statements: "Compared to others my age I am good at math", "I get good marks in math classes", "Work in math classes is easy for me", "I'm hopeless when it comes to math", "I learn things quickly in math", "I have always done well in math".

7.	A solid mathematical knowledge opens more possibilities when selecting a future profession.	.65	.29	.34	.47	.50
8.	I am more successful than most students of my age at solving mathematical problems.	.69	.69	.64	.51	.63
9.	Sometimes, even after a class, I think about a mathematical problem that I could not solve in it.	.67	.46	.56	.52	.58
10.	I do not try to solve a task if it appears too difficult.*	.71	.59	.59	.36	.59
11.	When I begin solving a mathematical problem, I suspect in advance that I will not finish it successfully.*	.46	.45	.52	.46	.46
12.	No matter how much I try, I cannot essentially influence my success in mathematics.*	.55	.47	.44	.57	.49
13.	If I cannot solve a mathematical problem in 10-15 minutes, I cannot solve it at all.*	.44	.23	.33	.40	.40
14.	Success in mathematics depends on good or bad luck to a great extent.*	.40	.21	.40	.40	.38
15.	For success in life today, it is sufficient to know four basic arithmetic operations.*	.40	.27	.49	.52	.44

* Items for which scoring is reversed

Table 3. Representativity, reliability, homogeneity and validity of the 15-item instrument for four sub-samples and the total sample

METRIC FEATURE	FI	PL	YU	IL	ALL
Representativity: Kaiser-Meyer-Olkin Kaiser, Rice	.97 .89	.91 .75	.92 .79	.90 .78	.95 .88
Reliability: alpha reliability (Cronbach) factor reliability (Lord-Kaiser-Caffrey)	.89 .90	.81 .83	.83 .84	.82 .83	.85 .86
Homogeneity: mean correlation $1-(\theta^2-\lambda^2)*(m-\lambda^2)^{-1}$ [8]	.35 .85	.22 .60	.25 .61	.23 .64	.28 .74
Validity (Pearson's correlation between mathematical self-concept and mark)	.68*	.39*	.49*	.26*	.32* .47*[9]

* $p < .01$

Table 4 presents Pearson's correlation between gender and mathematical self-concept, whereas Table 5 reports such correlations between gender and the retained 15 items.

Table 4. Pearson's correlation between gender and mathematical self-concept for four sub-samples and the total sample

[8] λ^2 - the first eigenvalue of the correlation matrix; θ^2 - the sum of all eigenvalues greater than 1, m - the number of indicators.

[9] If all marks are expressed on the scale 1-5. For the Israeli sub-sample, 1 stands for 40-51, 2 for 52-63, 3 for 64-75, 4 for 76-87, and 5 for 88-100

SAMPLE	CORRELATION
FI	.11
PL	-.07
YU	.03
IL	.19**
ALL	.08*

* $p < .05$ ** $p < .01$

Table 5. Pearson's correlation between gender and the retained 15 items for four sub-samples and the total sample

ITEM	FI	PL	YU	IL	ALL
1. I enjoy solving mathematical problems. *	.11	-.08	.05	.17* M	.08* M
2. When I meet an interesting mathematical problem, I cannot calm down until I have solved it.	.05	.00	-.03	.17* M	.06
3. I am not at all interested in mathematics.*	.09	-.02	-.05	.09	.04
4. These days, learning mathematics is a complete waste of time.*	.00	-.15	-.04	.04	-.04
5. I simply cannot do mathematics.	.16* F	.04	.04	.19** F	.11** F
6. A knowledge of mathematics gives a base for sound thinking in everyday life.*	-.06	-.06	.15	.03	.01
7. A solid mathematical knowledge opens more possibilities when selecting a future profession.*	.05	.03	.14	.03	.06
8. I am more successful than most students of my age at solving mathematical problems.	.27** M	.15	.07	.29** M	.21** M
9. Sometimes, even after a class, I think about a mathematical problem that I could not solve in it.*	.05	-.11	.02	.09	.04
10. I do not try to solve a task if it appears too difficult.	.10	-.05	.02	-.06	.00
11. When I begin solving a mathematical problem, I suspect in advance that I will not finish it successfully.	.13	.06	.07	.16* F	.11** F
12. No matter how much I try, I cannot essentially influence my success in mathematics.	-.05	.04	-.01	.15* F	.03

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13. If I cannot solve a mathematical problem in 10-15 minutes, I cannot solve it at all.	.09	-.20* M	-.05	-.02	-.02
14. Success in mathematics depends on good or bad luck to a great extent.*	-.00	-.16* M	-.02	.05	-.02
15. For success in life today, it is sufficient to know four basic arithmetic operations.*	.01	.03	-.03	.12	.04

* $p < .05$ ** $p < .01$ M - males score higher than females F - females score higher than males

DISCUSSION

Two important findings emerged from this study. First, the retained 15 items indeed converged to an underlying construct called mathematical self-concept, yielding an internationally-relevant math-self scale with good psychometric features. Second, gender differences in mathematical self-concept and its 15 indicators were mostly minor.

The applied factor model evidenced that the retained items except for one have high factor loading (.40 or greater). Despite somewhat lower factor loading for Polish and Yugoslav students comparing to Finnish and Israeli ones - this was probably caused by more selective sub-samples in the former case - the 15 items converged to the construct of question. These items comprised a math-self scale with good representativity, reliability, homogeneity and validity, which may confidently be used in further studies on M.S.C. at an international level.

Apart from the Yugoslav sample, mark might (and probably did) differ among teachers (as well as countries). However, the students' math-self positively correlated with their marks in mathematics, which is in accord with a number of studies evidencing that mathematical self-concept is closely related to mathematical achievement (a summary may be found, for example, in Opachich & Kadijevich (1997)).[10] While for the Israeli sub-sample the former variable could explain only 6.8%[11] of variance of the latter one, this explanation was even 46.2% for the Finnish sub-sample. This suggests that M.S.C. and success in mathematics learning may be related more closely in Finland than in the other examined countries.

Some gender differences in mathematical self-concept and some of its 15 indicators were indeed found, especially for the Israeli sub-sample. Gender differences were particularly found in three items referring to confidence (items 5,

[10] According to a meta-analysis done by Hembree (1992), the mean correlation between self-confidence in mathematics and problem-solving performance regarding grades 6-8 and 10-12 was .35 ($p < .01$).

[11] .26 * .26 * 100%

8 and 11), where male expressed more confidence in their mathematical ability than female. Despite significance, the observed differences were mainly less than 4% (e.g., males had 3.6 %[12] higher math-self than females for the Israeli sub-sample) and may therefore be considered as minor. 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 (items 4, 6, 7 and 15). The same pattern emerged for items 3 and 9 relating to internal motivation and 10 regarding confidence.

Are the findings of our study in accord with the outcome of other studies?

- *The total sample*. A high correlation (.73) between math self-concept and math achievement[13] was found for 321 eleventh-grade students in Canada (Byrne & Worth Gavin, 1996), suggesting that the outcome like those for the Finnish and Yugoslav sub-samples may not be surprising. The finding regarding the item "I am more successful than most students of my age at solving mathematical problems" was evidenced in Amit & Movshovits-Hadar (1989), Sax (1994) and Tiedemann & Faber (1995), who found that girls reported lower self-evaluations of their perceived competencies in mathematics than boys.
- *The Finnish sub-sample*. The outcome is partly in accord with Kupari (1999). He found that students' mathematical achievement and math-self are related (instead of their correlation, the means of math-self for the four achievement groups were given, clearly evidencing an increasing pattern), which was found in this study. He also found that girls had a lower math self-concept than boys, which is not obtained in this study. Note that Kupari's math-self concept dealt with two issues: (a) how difficult mathematics is, and (b) how much self-confidence a particular pupil has when learning mathematics, i.e., how much pupil thinks that he/she can learn mathematics.[14] Although a Norwegian study[15] (Manger & Eikeland; 1998) did not find any relation between students' mathematical achievement and math-self, it evidenced that boys had significantly higher math-self than girls even though their achievement in third-

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[12] .19 * .19 * 100%

[13] Measured by standardized tests, grades, self-ratings and teacher ratings.

[14] Despite perceiving mathematics as a difficult school subject, almost 70% of the subjects stressed its importance to their future life almost as much as information technology and English language. This explains students' motivation to do their homework:. In 1990, for example, they used for mathematics about one third of their entire homework time. However, this particular time was only about one eighth of the time they used for watching TV (Kupari, 1999). It seems that despite an external motivation to learn mathematics, Finnish students still have very poor internal motivation and self-confidence in doing mathematics.

[15] It is interesting to compare the Finnish results with the Norwegian ones because of many similar cultural variables. In both countries, for example, pupils have usually only the teachers' every day comments as a source of evaluation.

and sixth-grade mathematics equalled that of girls. Hence in countries like Finland, where the information technology is particularly worried about female expertise, the following question "Do girls, having significantly lower math-self, feel a greater risk than boys to fail in mathematical courses and professions?" indeed causes a big educational challenge.

- *The Yugoslav sub-sample*. They are in accord with Opachich & Kadijevich (1997) and their data, which were additionally analyzed for the purpose of this study. However, the Yugoslav sub-sample may only be considered representative as regard ninth-grade Gymnasium students in this country.
- *The Israeli sub-sample*. The results obtained in this study are in accordance with former research conducted in the state (Amit & Movshovitz-Hadar, 1989, Amit 2000), the outcome of which indicates that, amongst 10^{th} graders females and males, there is a significant gap in self-confidence, favouring male. This gap, as shown, exists among male and female high achievements.

CLOSING REMARKS

The present study used a sample of 682 ninth-grade students (373 females and 309 males) from four countries: Finland (92 females and 89 males), Poland (93 females and 51 males), Yugoslavia (58 females and 67 males) and Israel (130 females and 102 males). A 29-item math-self scale was administered to all subjects and a 15-item math-self sub-scale was developed through applying an one-factor model to the collected data. The sub-scale data were then analyzed in terms of psychometric features (representativity, reliability, homogeneity and validity) and gender differences. The results showed that the 15-item math-self scale has good psychometric features, evidencing mostly minor gender differences in the measured construct and its indicators.

Further research may examine the relations among mathematical self-concept (measured, for example, by the developed scale, the indicators of which are sorted according to their factor loading obtained for the whole sample), non-verbal IQ (measured by an internationally recognised instrument being standardised in countries of interest) and mathematical achievement (measured by a standardised test) to find out whether mathematical self-concept is a better predictor of mathematical achievement than non-verbal IQ.[16] Further research may also deal with curricular changes in mathematics education addressing the student's self-concepts (e.g., Davis, 1994), which is indeed a relevant issue since mathematics instruction may (unintentionally) contribute to a decline in mathematical self-concept (e.g., Sax, 1994) that may in turn cause an unwanted decrease in learning

[16] An additional study regarding 33 randomly chosen subjects from the Finnish sub-sample and 31 randomly chosen subjects from the Yugoslav sub-sample evidenced that math-self may still be a better predictor of mathematical achievement than IQ (the Finnish IQ measure and math-self almost correlated at a .1 significance level, whereas the Yugoslav IQ measure and math-self did correlate at a .05 level).

outcome. Such changes may be, among others, based upon building self-confidence in mathematics (Eisenberg, 1991) and promoting the human face of mathematics (Kadijevich, 1998).

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