CROSS-NATIONAL PATTERNS OF GENDER DIFFERENCES IN MATHEMATICS AN ANALYSIS OF EAST-EUROPEAN AND WEST-EUROPEAN COUNTRIES.

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ABSTRACT

This study examines gender differences in math achievement across 21 countries. The main aim of the study is to analyse whether there are differences in math performance between boys and girls across time and in two groups of countries: the countries of the former East Bloc and West-European countries. Nine East-European and twelve West-European countries were analysed with regard to their math achievement measured by the Programme for International Student Assessment (PISA) in 2003 and 2012. Gender gap was analysed based on *z* score and Cohen's *d*.

Findings show a small and narrowing gender gap. A small but consistent advantage of boys over girls in math achievement has been noted in the majority of countries, although in a few countries females outperformed males. However, a substantial national variability has been noted (*d*= -.002 to *d*= -.201). Although in 2003 the effect sizes of gender gap in math achievement were similar in two blocs (*d*= -.112 in East-European countries and *d*= -.122 in Western countries), nine years later the East-European nations bridged the gap (*d*= .031**)** , whereas in the Western countries the gap remained at the similar level (*d*= -.118).

Over the course of 9 years, a significant decrease in gender gap in math performance was observed. However, more in-depth analysis of the results shows that this is not a universal trend and that the changes seem to be specific to two blocks of countries. The differences between East- and West-European countries point to socio-cultural factors (e.g. gender role perception, self-concept and stereotypes about math ability) as important variables affecting gender differences in math education. The findings are interpreted with regard to sociological theories and gender stratification hypothesis.

Keywords: culture, gender differences, mathematics achievement

INTRODUCTION

Gender gap in mathematics has been for a long time a controversial topic in educational discussions. Research shows that although the differences between boys and girls are not so visible at the early stages of education [1], they seem to be more profound at later stages [2] which may have important career consequences. Females are less likely to enroll for advanced mathematics courses in high school and college which leads to their underrepresentation in STEM disciplines such as engineering and the physical sciences [3, 4]. Research into gender gap identifies numerous factors that account for the differences in math performance between boys and girls [5]. The growing popularity of international large scale assessments such as PISA and TIMMS allows to investigate new cultural and social variables influencing math performance across time and in numerous countries, such as educational policies or political factors. Although much research has been done with regard to the differences between the East and West [e.g. 6], there is scarcity of studies analyzing whether political systems such as communism and democracy may have had effect on gender roles and gender differences in math performance. The purpose of this study is to address this research gap by comparing gender differences in the West- and East-European countries in PISA.

1.1. Gender differences in mathematics performance

Although gender gap in math performance has not been fully bridged, research shows that the differences in achievement are decreasing. Whereas studies conducted in the 1960s and 1970s on big samples of American students pointed to substantial differences favouring males [4], more recent analyses report smaller discrepancies between two genders; however, the effect depends to a large extent on student's age and sampled population [7]. A well-known meta-analysis by Hyde, Fennema and Lamon [2] showed that although girls demonstrated on average a slight superiority in elementary school and middle school (d = -.02), differences favouring men emerged at later stages (high school and college) (d = .29 and d = .32). The differences in the extent of discrepancies between boys and girls over the years as well as apparent closing of gender gap drew attention to important social and cultural factors affecting it.

In 2010, Else-Quest, Hyde and Linn [8] meta-analysed the results of TIMSS 2003 and PISA 2003 testing whether the gender gap observed 20 years earlier is still visible in mathematics performance. The international data from 69 nations were compared. The results revealed very small mean effect sizes in mathematics achievement (d < .15), however, national effect sizes showed considerable variability (d = - .42 to .40). The results of these and other studies [7] suggest that gender gap is not necessarily a direct result of biological differences between boys and girls which predispose males to achieve higher in STEM-related subjects (an extensive discussion in [5]) but points to micro-level factors such as family, peer and teachers' influences as well as macro-level variables such as political system, educational policies and cultural context [7].

1.2. Gender differences in post-Communist countries

The cold-war division into the Western world, led by the US, and the East Bloc, under the Soviet influence, was definitely one of the most important political events of the 20th century which has had a tremendous impact on the modern world. The Iron Curtain divided Europe (and the rest of the world) not only politically and economically but also ideologically and culturally, leading to significant differences in values, work organization as well as political and socioeconomic development between the blocs of countries. Whereas the Western countries enjoyed democracy, free market and civic liberties, the East Bloc countries focused on uniformity, redistribution of wealth and socialist view on equality. Ideological differences had a powerful influence on almost all life domains, including employment, education and gender roles. Due to ideological underpinnings, socialist view of gender equality and economic necessities leading to so called "work obligation", women in the Communist countries were more likely to be professionally active, study at universities and work in occupations and sectors typically perceived as masculine [9, 10].

The analysis of job market in the Soviet Empire shows that women held many professional positions, while men predominated in sectors requiring manual work (skilled and unskilled workers) [10]. The relatively high emancipation of women can be explained with gendered educational tracking after the primary school when many more boys than girls were directed to vocational schools. As a result, girls consisted two thirds of students in general secondary schools which led to universities [10]. Furthermore, due to on-going military and cosmic competition between the US and the USSR (e.g. Space Race), much attention was placed on education in such domains as engineering, mathematics and science [11, 12].

A good illustration of the differences between the East and West Bloc in female involvement in STEM sector is a high disproportion in the number of women taking part in space programmes [12] and mathematical competitions. One of such events is the International Mathematical Olympiad (IMO), an annual team competition at which representatives from more than 90 countries compete in numerous math tasks [13]. First started in 1959, the competition is one of the oldest international science Olympiads. Due to its long history and worldwide coverage, it gives opportunity to investigate temporal and cultural underpinnings of math performance across time and in numerous countries.

Although there are still many more men than women taking part in the competition, interesting differences between the countries of former East and West Bloc can be observed [4]. Firstly, there were visibly more female representatives from communist countries; secondly, at some years women constituted more than 20% of Russian and Serbian teams (compared to 12% in the UK and Canada, the countries with the highest proportion of female participation in the West). Furthermore, the results of East and West Germany are especially telling in this matter. Whereas in the German Democratic Republic women consisted 6% of IMO teams, West Germany had zero female representatives over the period of three decades.

The analysis of female participation at IMO shows also that gender proportions vary dramatically across times and countries. All these differences suggest that gender differences in math achievement are more likely to be a result of external factors rather than some biological differences. It has to be borne in mind, however, that the participants of the IMO can neither be regarded as good representatives of their countries, nor the skills manifested by these exceptionally math-skilled students can be generalized over the whole population. Be that as it may, the analysis of the percentages of female students on IMO teams gives interesting information regarding cultural differences among nations, also with regard to the differences between the nations of the former East Bloc and Western countries. The aim of our research is to investigate whether these differences are still present among general population of students. Furthermore, we will test possible changes across time. In order to do that we will look on the results of large scale assessments in two time periods (2003 and 2012).

Hypotheses:

1.a) Gender gap in mathematics performance will be still present.

b) Boys will have higher mathematics results than girls.

2. East Bloc countries will show smaller gender gap in comparison to Western countries.

3. Gender gap will be closing over the years 2003 – 2012.

METHODOLOGY

2.1. Data

The data used for this work comes from PISA 2003 and 2012 mathematics assessment. PISA, Program for International Student Assessment, is an international large scale assessment first developed by the Organization for Economic Cooperation and Development in 2000 [14]. The purpose of the programme is to evaluate education systems worldwide by testing the skills and knowledge of 15-year-old students. PISA assessments pertain to three domains: mathematics, reading and science literacy. Conducted every 3 years, each edition focuses on one of the three core subject areas in depth (a major). Two other subjects are also tested but they are considered as minor for a particular year. As mathematics has been the major element tested in 2003 and 2012, these particular years have been selected for the study. Reading and science literacy were the secondary foci.

2.2. Investigated countries

The total number of countries participating worldwide in PISA 2003 is 40 and 65 in PISA 2012. However, as the aim of the analysis is to research whether there are differences in mathematics performance between the former countries of the West and East Bloc, only a subset of all countries has been selected. The selection of countries follows the methodology adopted by Mirazchiyski, Caro and Sandoval-Hernández (2014) [15] who analysed the differences in the levels of expected civic participation in the countries of former East and West Bloc (9 post-Communist and 13 established democracies). Due to the fact that not all of these countries participated in 2003 and 2012 editions of PISA, the final analysis covered 17 countries in 2003 and 21 countries in 2012. Table 1 presents the list of countries analysed in the study along with the number of participants in each year and country.

Table 1
Number of participants in each of the countries.

		2003	2012
East countries	Bulgaria (BGR)	---	1 658
	Czech Republic (CZE)	6 159	1 697
	Estonia (EST)	---	1 585
	Latvia (LVA)	4 592	1 384
	Lithuania (LTU)	---	1 520
	Poland (POL)	4 377	1 508
	Russian Federation (RUS)	5 914	1 719
	Slovak Republic (SVK)	7 216	1 486
	Slovenia SVN	---	1 844
West Countries	Austria (AUT)	4 545	1 552
	Belgium (Flemish) (BEL)	8 552	2 661
	Denmark (DNK)	4 033	2 388
	England (GBR)	9 294	4 155
	Finland (FIN)	5 718	2 807
	Greece (GRC)	4 193	1 662
	Ireland (IRL)	3 811	1 644
	Italy (ITA)	11 484	10 224
	Norway (NOR)	3 927	1 494
	Spain (ESP)	10 697	8 229
	Sweden (SWE)	4 543	1 499
	Switzerland (CHE)	8 283	3 676
	TOTAL	**10 7338**	**56 392**

2.3. Data Analysis

The five sets of plausible values for total math score were used in order to obtain correct population parameter estimates. A SPSS *macro* program provided by the PISA 2003 data analysis manual was used to produce direct estimates of the mean gender difference and the standard error of the difference [14]. In the first step, the means for girls and boys in all countries in question were analysed. In the second step, the gender gap between boys and girls in overall math achievement was measured. A *z* statistic was used to indicate the statistical significance of the mean difference for each comparison. A *z* score was significant if it was below -1.96 or above 1.96. Cohen's *d* was used to describe the effect sizes of gender differences [16] .

RESULTS

Table 2 presents the means and standard deviations in math performance of boys and girls in 2003 and 2012 PISA assessments in the selected countries. Table 3 shows gender gap in the results (negative values show higher performance of boys over girls).

Overall, the mean math achievement in the East-European countries remained on a similar level (M = 491.287, SD = 91.685 in 2003 and M = 489.975, SD = 89.874 in 2012), whereas it showed a drop of 6.383 in the Western countries (M = 502.635, SD = 92.960 in 2003 and M = 496.252 , SD = 90.166 in 2012).

A small but consistent male advantage was noticed in all countries in 2003. Nine years later, male dominance was less visible and a few countries (Bulgaria, Latvia, Russia, Finland, Sweden) noted even a slight female advantage (*d* = .018 to .047). Overall, math achievement of girls in the East-European countries improved over the years ($\Delta M = 2.448$) and boys decreased ($\Delta M = -5.071$). In the Western countries, the results of girls and boys noted a drop of 6 points ($\Delta M_{girls} = -6.029$ and $\Delta M_{boys} = -6.736$).

Table 2
Math achievement performance in PISA 2003 and PISA 2012 (Means, SD)

		2003				2012			
		GIRLS		BOYS		GIRLS		BOYS	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD
East countries	Bulgaria (BGR)	---	---	---	---	440.013	90.091	437.551	97.318
	Czech Republic (CZE)	508.869	93.924	523.842	97.303	492.903	92.811	504.710	96.566
	Estonia (EST)	---	---	---	---	517.930	78.220	523.214	83.470
	Latvia (LVA)	482.026	84.168	484.839	91.757	492.521	78.976	488.655	84.579
	Lithuania (LTU)	---	---	---	---	478.736	85.850	478.909	92.211
	Poland (POL)	487.451	84.616	493.041	95.474	515.533	86.377	519.564	94.322
	Russian Federation (RUS)	463.382	87.804	473.499	96.284	482.944	85.606	481.394	87.118
	Slovak Republic (SVK)	488.629	90.599	507.290	94.924	476.712	97.365	486.134	103.698
	Slovenia SVN	---	---	---	---	499.387	89.938	502.748	93.217
	MEAN	**486.071**	**88.222**	**496.502**	**95.148**	**488.520**	**87.248**	**491.431**	**92.500**
West Countries	Austria (AUT)	501.816	88.721	509.390	97.097	494.462	89.114	516.682	94.437
	Belgium (Flemish) (BEL)	525.370	104.674	532.882	114.341	508.935	98.816	520.081	105.281
	Denmark (DNK)	506.150	91.129	522.728	90.748	493.029	80.772	506.953	82.813
	England (GBR)	505.140	90.911	511.803	93.645	487.815	94.096	500.295	94.536
	Finland (FIN)	540.597	79.395	548.002	87.620	520.185	80.669	517.391	89.434
	Greece (GRC)	435.551	88.634	454.952	98.107	448.984	81.636	457.039	93.473
	Ireland (IRL)	495.376	83.527	510.184	86.297	493.705	82.346	509.035	86.012
	Italy (ITA)	457.091	89.685	474.916	100.964	475.794	87.228	494.199	96.833
	Norway (NOR)	492.049	87.773	498.271	95.939	488.293	88.192	490.399	92.585
	Spain (ESP)	480.744	84.403	489.606	92.270	475.965	83.226	492.422	91.172
	Sweden (SWE)	505.778	92.484	512.308	96.838	479.629	87.599	476.916	95.630
	Switzerland (CHE)	517.951	95.442	534.578	100.387	524.473	91.736	537.369	96.344
	MEAN	**496.968**	**89.731**	**508.302**	**96.188**	**490.939**	**87.119**	**501.565**	**93.212**

East-European countries. In, 2003, the effect size of gender gap was small, between $d = -.032$ to $d = -.157$ in the East-European countries. Three countries (the Czech Republic, Russia and the Slovak Republic) showed significant differences between boys and girls in math achievement ($z_{Czech} = -2.945$, $< .005$, $z_{Russia} = -2.323$, $p < .005$ and $z_{Slovak} = -5.110$, $p < .005$). Nine years later, in all mentioned countries apart from Russia, gender gap remained significant ($z_{Czech} = -2.573$, $p<0.005$ and $z_{Slovak} = -2.098$, $p<0.005$). Russia, on the other hand, did not only bridge the differences but girls overtook boys (overall change in gender gap of 11.667 points).

Western countries. In 2003, the effect size of gender gap ranged between $d = -.068$ and $d = -.208$ for particular countries. Significant gender differences were visible in eight countries, i.e. Denmark, Finland, Greece, Ireland, Italy, Spain, Sweden and Switzerland ($z_{Denmark} = -5.172$, $z_{Finland} = -2.770$, $z_{Greece} = -5.346$, $z_{Ireland} = -3.537$, $z_{Italy} = -3.029$, $z_{Spain} = -2.970$, $z_{Sweden} = -1.997$, $z_{Switzerland} = -3.414$, $p < .005$). In all countries a small male advantage was visible. In 2012, the effect sizes ranged between $d = -.023$ and $d = -.200$. Over the period of nine years, the gap was bridged in two countries (Finland and Sweden), however, it widened in such countries as Austria, Belgium, England ($z_{Austria} = -4.517$, $p < .005$, $z_{Belgium} = -3.256$, $p < .005$, $z_{England} = -2.668$, $p < .005$). The gap remained significant also in Denmark, Greece, Ireland, Italy, Spain and Switzerland.

Table 3

Gender gap in math achievement in PISA 2003 and PISA 2012.

		2003				**2012**			
		Gender Gap	**SD**	**z**	**Cohen's d**	**Gender Gap**	**SD**	**z**	**Cohen's d**
East countries	Bulgaria (BGR)	----	----	---	---	2.461	4.099	.600	.026
	Czech Republic (CZE)	-14.974	5.085	-2.945 (*)	-.157	-11.807 ▼	4.590	-2.573 (*)	-.125
	Estonia (EST)					-5.284	2.636	-2.005 (*)	-.065
	Latvia (LVA)	-2.813	3.970	-0.709	-.032	3.866 ▲	3.626	1.066	.047
	Lithuania (LTU)					-0.174	2.416	-.072	-.002
	Poland (POL)	-5.590	3.140	-1.780	-.062	-4.031 ▼	3.419	-1.179	-.045
	Russian Federation (RUS)	-10.117	4.356	-2.323 (*)	-.110	1.550 ▼	3.019	.514	.018
	Slovak Republic (SVK)	-18.661	3.652	-5.110 (*)	-.201	-9.422 ▼	4.491	-2.098 (*)	-.094
	Slovenia SVN					-3.361	3.119	-1.077	-.037
	MEAN	**-10.431**	**4.041**	**-2.582 (*)**	**-.112**	**-2.911** ▼	**3.491**	**-.834**	**-.031**
West Countries	Austria (AUT)	-7.574	4.405	-1.720	-.082	-22.220 ▲	4.919	-4.517 (*)	-.242
	Belgium (Flemish) (BEL)	-7.511	4.811	-1.561	-.069	-11.147 ▲	3.423	-3.256 (*)	-.109
	Denmark (DNK)	-16.577	3.205	-5.172 (*)	-.182	-13.924 ▼	2.334	-5.965 (*)	-.170
	England (GBR)	-6.663	4.902	-1.359	-.072	-12.480 ▲	4.678	-2.668 (*)	-.132
	Finland (FIN)	-7.405	2.673	-2.770 (*)	-.089	2.795 ▼	2.866	.975	.033
	Greece (GRC)	-19.401	3.629	-5.346 (*)	-.208	-8.054 ▼	3.213	-2.506 (*)	-.092
	Ireland (IRL)	-14.808	4.187	-3.537 (*)	-.174	-15.330 ▲	3.792	-3.537 (*)	-.182
	Italy (ITA)	-17.825	5.886	-3.029 (*)	-.187	-18.405 ▲	2.485	-3.029 (*)	-.200
	Norway (NOR)	-6.222	3.206	-1.941	-.068	-2.106 ▼	3.026	-.696	-.023
	Spain (ESP)	-8.861	2.983	-2.970 (*)	-.100	-16.458 ▲	2.215	-7.431 (*)	-.189
	Sweden (SWE)	-6.530	3.270	-1.997 (*)	-.069	2.712 ▼	2.982	.910	.030
	Switzerland (CHE)	-16.627	4.870	-3.414 (*)	-.170	-12.896 ▼	2.709	-4.760 (*)	-.137
	MEAN	**-11.334**	**4.002**	**-2.832 (*)**	**-.122**	**-10.626** ▲	**3.220**	**-3.300 (*)**	**-.118**

* p <.005

CONCLUSION AND FUTURE WORK

The study showed a few interesting findings. Firstly, although gender gap is closing, it is still present in the majority of countries in question. Secondly, a slight male advantage is visible in mathematics achievement, however, this tendency is slowly changing. Although the magnitude of gender differences indicated by the effect sizes is fairly small (less than .2.), it is worth remembering that even slight gender differences may have some important practical consequences, for instance in female and male representation in math-related domains such as engineering and physical sciences [6].

The changes in the differences between boys and girls show relevant changes across time. In 2003, a small but consistent male advantage in mathematics achievement was noticed in all countries. Nine years later, a few countries (Bulgaria, Latvia, Russia, Finland, Sweden) noted a slight female advantage. Interestingly, whereas the math achievement of girls followed general tendency of a particular bloc of countries (i.e. it improved in the East-European countries and slightly decreased in the Western countries), the math achievement of boys followed a negative trend in both groups of countries in question.

The hypothesis about the differences between East-European and Western countries has been only partially confirmed. The first assessment of 2003 showed similar percentage of countries with the gender gap in math performance, i.e. in 3 out of 5 East-European countries (60%) and 8 out of 12 Western countries (66%), there were significant differences between boys and girls in math achievement. However, the PISA assessment of 2012 showed more substantial differences between the two blocs of countries. Firstly, whereas the average gender gap in the East-European dropped by 7.52 point, in the West it fell only by 0.708 point.

Furthermore, the differences between two blocs of countries are visible not only in reference to the magnitude of the gender gap but also with regard to the number of countries in each bloc with statistically significant gender differences. Whereas in the East-European countries, the majority of nations has bridged the gender gap by 2012 (only three out of nine Eastern countries, i.e. 33%, demonstrated significant male advantage), the number of Western countries with a significant gender difference has actually risen. In the West, nine out of twelve countries (75%) displayed significant advantage of boys over girls. Austria and Spain are the two countries, in which the gap rose particularly much, by 14.646 and 7.597 points respectively. Furthermore, although math results in the countries of the former East Bloc are on average lower than in the West, the new democracies managed to overcome gender differences in mathematics performance, whereas such an improvement has not been observed in the West (with the exception of the Scandinavian countries: Finland, Norway and Sweden).

It remains, however, unclear whether the differences between two sets of countries can be explained by ideology and differences in gender roles in both systems. Had the differences been related to ideological differences and the Soviet notion of equality, one would expect no gender gap in 2003 in the countries of the former East Bloc and possibly the results similar to those of the Western countries in 2012 (due to westernization processes). This, however, was not the case. Although the hypothesis can be only partially confirmed, the results suggest that the differences are more likely to be attributed to socio-cultural differences.

The results confirm the previous meta-analytic findings of Hyde, Fennema and Lamon [2] and Else-Quest, Hyde and Linn [8] which suggest that the gender gap in math achievement is progressively closing. However, as the analysis of the results from PISA 2012 shows, it has not been yet fully bridged and there is still a big variability between nations. The results can be interpreted in reference to gender similarities hypothesis, which assumes that males and females are similar on most, but not all, psychological variables [7, 8]. The differences between countries, however, suggest the influence of country-specific factors affecting differences in math results.

The differences in the performance may be also interpreted with gender stratification hypothesis according to which gender gap in school achievement can be attributed to gender inequities in educational and economic opportunities of a particular country or culture [8, 17, 18]. This sociological hypothesis, proposed by Baker and Jones [17] (1993), posits that in patriarchal cultures, females are less successful in math because they are given less opportunities by the society and hence they do not perceive themselves as likely to succeed. Such beliefs are said to be instilled in girls due to numerous socialization processes (teachers, parents, friends). The hypothesis is consistent with cognitive social learning theory [19] as well as studies on stereotype threat which indicate that stereotypes about gender roles and mathematics make girls feel anxious and less confident which leads to worse mathematics achievement [20, 21].

Big variability in gender gap among nations as well as significant changes over a relatively short period of time suggest that differences in math performance can be attributed to systemic and cultural reasons. The example of Russia, Latvia, Finland and Sweden are especially telling as these countries did not only eradicate gender gap but a slight female advantage has been noticed. However, as the study was exploratory in nature, it is difficult to hypothesize about possible causal relationships between socio-cultural variables and achievement in mathematics. The division in the new and old democracies seems to offer new explanations, however, more in-depth studies are needed.

In the future research, it would be interesting to extend the analyses with data from other countries and years. In order to test the possible relationship between the Communist ideology of gender equality and mathematics results, it would be advantageous to compare the gender gap in the 1990s when the possible ideological influence was probably stronger. Additionally, such variables as Gender Gap Index, Gender Inequality Index, Relative Status of Women and possibly GDP should be tested in order to analyse in more detail socio-economic factors that might explain the gender differences in math achievement between various countries.

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