Study on Mathematical Literacy in the Context of the Household Welfare

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Abstract: The aim of this article is to investigate the extent to which poverty and inequality indicators as well as household income and consumption expenditure (from the EUROSTAT database) correlate with mathematical literacy indicators (from the OECD PISA 2012) in European countries. Using correlation analysis, there was analyzed the relationship between socio-economical indicators (Gini coefficient, people at risk of poverty or social exclusion, S80/S20 income quintile share ratio, unemployment rate, household median equivalised net income, household mean consumption expenditure per adult equivalent, household consumption expenditure for food and non-alcoholic beverages in percent from all consumption expenditure) and mathematical literacy indicators (mean score in mathematics, share of low achievers in mathematics, share of top achievers in mathematics). Using the cluster analysis there was carried out the European countries classification. The results show that the mathematical literacy and household poverty has a close relationship.

Keywords: education, mathematical literacy, poverty, household, income, consumption expenditure.

Introduction

It is generally accepted that learning and studies of mathematics is significant, first of all, in the formation of a personality and, secondly, in the acquisition of the language and the tools of mathematics which are necessary in the studies of many other professions, e.g. engineering sciences. The mathematical skills of the person are dominant in order to succeed in scientific field in exact sciences.

Mathematical literacy is defined as a bundle of knowledge, skills and values that transcend the difficulties arising from cultural differences and economic inequalities because mathematics and mathematics education themselves are not seen as culture-bound and value-driven. Mathematical literacy is connected to learning how to think, but not to learning what to think about (Jablonka, 2003, 81).

The aim of this paper was to study how the mathematical literacy influences the households' welfare. The authors see an opportunity to link mathematical literacy assessment and households' risk of poverty.

Mathematical literacy can be defined as an individual's capacity to formulate, employ, and interpret mathematics in a variety of contexts. It includes reasoning mathematically and using mathematical concepts, procedures, facts and tools to describe, explain and predict phenomena. It assists individuals to recognise the role that mathematics plays in the world and to make the well-founded judgements and decisions needed by constructive, engaged and reflective citizens (PISA 2012 Assessment…, 2013, 17).

The role of mathematical knowledge, skills and efficiency should be understood in a wider sense: not only as the theoretical knowledge of very specific issues, for example, compact topological space, but also as mathematical thinking as perfect critical thinking in a wider meaning of the term.

To function effectively in today's global society all students need to be taught to think mathematically. Mathematical modelling encourages these thinking skills through what it are very much a literacy-based process. Mathematical modelling is a problem-solving process that requires students to interpret information from a variety of narrative, expository and graphic texts that reflect authentic real-life situations (Doyle, 2005, 1).

Outstanding mathematical ability, an important societal resource, is needed to maintain leadership in today's technological world. In order to function at the optimal level people must be math literate -

able to model and understand real-world phenomena using quantitative tools, analyse and understand complex logical arguments, and use technological tools appropriately and effectively (Edge, 2009, 18).

Mathematics is the key to opportunity. No longer just the language of science, mathematics now contributes in direct and fundamental ways to business, finance, health, and defence. For students it opens doors to careers. For citizens it enables informed decisions. For nations it provides the knowledge to compete in a technological community (Gainsburg, 2005, 2).

Because mathematics literacy plays an important role in the modern world, it could as well be used to make learners become acquainted with how they can use it to develop entrepreneurial skills so that they may be at parallel with poverty. Through mathematics literacy, they would be made to understand and acquire commercial skills, bargaining power, exchange rates and so on, failure of which their ability to carry out these enterprises may be delusional (Tsafe, 2013, 52).

The European Union’s Social Inclusion Process uses a relative definition of poverty: “People are said to be living in poverty if their income and resources are so inadequate as to preclude them from having a standard of living considered acceptable in the society in which they live. Because of their poverty they may experience multiple disadvantages through unemployment, low income, poor housing, inadequate health care and barriers to lifelong learning, culture, sport and recreation. They are often excluded and marginalised from participating in activities (economic, social and cultural) that are the norm for other people and their access to fundamental rights may be restricted” (Poverty and Inequality…, 2009, 3).

Methodology

The problem has been approached by analysing and evaluating the scientific literature for the development of the methodological basis of research. Several public databases are used to analyse mathematical literacy in the context of the household welfare.

Database of OECD (Organisation for Economic Cooperation and Development) PISA (Programme for International Student Assessment) 2012 is chosen for this research. PISA aims at testing literacy in three competence fields: reading, mathematics, and science.

PISA 2012 provides an overall mathematics scale, which draws on all of the mathematics questions in the assessment, as well as scales for the three mathematical processes and the four mathematical content categories defined above. The metric for the overall mathematics scale is based on a mean for OECD countries of 500 points and a standard deviation of 100 points that were set in PISA 2003 when the first PISA mathematics scale was first developed. The items that were common to both the 2003 and 2012 test instruments enable a link to be made with the earlier scale (PISA 2012 Results:…, 2014, 46)

The results of PISA 2012 used:

a) mean score in mathematics,

b) share of low achievers in mathematics (Below Level 2),

c) share of top achievers in mathematics (Level 5 or 6).

Database of EUROSTAT (The Statistical Office of the European Communities and part of the European Commission) also is chosen. In this research there are used welfare indicators of 27 European countries in 2010 and 2012 by EUROSTAT data basis.

1. Gini coefficient (2012). The Gini coefficient measures the extent to which the distribution of income within a country deviates from a perfectly equal distribution. A coefficient of 0 expresses perfect equality where everyone has the same income, while a coefficient of 100 expresses full inequality where only one person has all the income. (EUROSTAT, 2014).
2. People at risk of poverty or social exclusion (2012). At-risk-of-poverty or social exclusion, refers to the situation of people either at risk of poverty, or severely materially deprived or living in a household with a very low work intensity. The at-risk-of-poverty rate is the share of people with an equivalised disposable income (after social transfer) below the at-risk-of-

poverty threshold, which is set at 60 % of the national median equivalised disposable income after social transfers (EUROSTAT, 2014).

3. S80/S20 income quintile share ratio (2012). S80/S20 income quintile share ratio: refers to the ratio of total equalized disposable income received by the 20% of the country's population with the highest equivalised disposable income (top quintile) to that received by the 20% of the country's population with the lowest equivalised disposable income (lowest quintile), in the relevant dimensions (EUROSTAT, 2014).
4. Unemployment rate (2012).
5. Household median equivalised net income in PPS (Purchasing Power Standards) (2012).
6. Household mean consumption expenditure per adult equivalent in PPS (2010).
7. Household consumption expenditure for food and non-alcoholic beverages in percent from all consumption expenditure (2010).

Information on household consumption expenditure in European countries is derived from the Household Budget Survey (HBS), which is carried out once every five years and the last survey was in 2010.

The Household Budget Survey is a national survey focusing on households' expenditure on goods and services, giving a picture of living conditions in the European Union (EU) (EUROSTAT, 2014).

Information on households Income and Living Conditions Survey is obtained from European Statistics on Income and Living Conditions (EU-SILC). EU Statistics on Income and Living Conditions are the reference source for comparative statistics on income distribution and social inclusion in the European Union (EU) (EUROSTAT, 2014).

A household, in the context of surveys on social conditions or income such as EU-SILC or the Household Budget Survey (HBS), is defined as a housekeeping unit or, operationally, as a social unit having common arrangements, sharing household expenses or daily needs, and in a shared common residence.

A household includes either one person living alone or a group of people, not necessarily related, living at the same address with common housekeeping, i.e. sharing at least one meal per day or sharing a living or sitting room (EUROSTAT, 2014).

Correlation analysis, cluster analysis, and discriminant analysis are used for the statistical analysis of the indicators.

The article analysed data on 27 European countries: Austria, Belgium, Bulgaria, Croatia, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Netherlands, Norway, Poland, Portugal, Romania, Slovak Republic, Slovenia, Spain, Sweden, United Kingdom.

Results and discussion

To analyse the mathematical literacy in the context of the household welfare in this article there are studied the household poverty and inequality indicators, as well as households' income and consumption expenditure correlation with students' mathematical literacy indicators**.** The obtained correlation analysis results show that there is a close correlation between mathematical literacy and poverty (Table 1, Table 2).

Table 1

Indicators of Welfare of European Countries and Students' Mathematical Literacy

Country	Mean score in mathematics*	Share of low achievers in mathematics (Below Level 2)*	Share of top achievers in mathematics (Level 5 or 6)*	Gini coefficient**	People at risk of poverty or social exclusion**	S80/S20 income quintile share ratio**	Unemployment rate %**	Median equivalised net income in PPS**	Mean consumption expenditure per adult equivalent in PPS**	Consumption of food and non-alcoholic beverages %**
Austria	506	18.7	14.3	27.6	18.5	4.2	4.3	20634	21509	12.1
Belgium	515	19	19.5	26.6	21.6	3.9	7.6	18505	20139	13.2
Bulgaria	439	43.8	4.1	33.6	49.3	6.1	12.3	5859	5644	29.3
Croatia	471	29.9	7	30.5	32.3	5.4	16.1	7362	9605	25.6
Czech Republic	499	21	12.9	24.9	15.4	3.5	7.0	10313	8328	20.3
Denmark	500	16.8	10	28.1	19.0	4.5	7.5	18638	19204	11.8
Estonia	521	10.5	14.6	32.5	23.4	5.4	10.0	7887	6755	23.3
Finland	519	12.3	15.3	25.9	17.2	3.7	7.7	18576	18097	13
France	495	22.4	12.9	30.5	19.1	4.5	9.8	18786	18085	15.8
Germany	514	17.7	17.5	28.3	19.6	4.3	5.5	19204	19234	11.6
Greece	453	35.7	3.9	34.3	34.6	6.6	24.5	10007	17036	16
Hungary	477	28.1	9.3	26.9	32.4	4.0	10.9	7725	6827	23
Ireland	501	16.9	10.7	29.9	30.0	4.7	14.7	16188	18950	12.2
Italy	485	24.7	9.9	31.9	29.9	5.5	10.7	15575	17950	18.6
Latvia	491	19.9	8	35.7	36.2	6.5	15.0	6202	6863	26.1
Lithuania	479	26	8.1	32.0	32.5	5.3	13.4	6724	8668	28.5
Luxembourg	490	24.3	11.2	28.0	18.4	4.1	5.1	26579	28621	8.8
Netherlands	523	14.8	19.3	25.4	15.0	3.6	5.3	18978	20016	10
Norway	489	22.3	9.4	22.6	13.8	3.2	3.2	25607	22820	11.8
Poland	518	14.4	16.7	30.9	26.7	4.9	10.1	8630	8801	22.7
Portugal	487	24.9	10.6	34.5	25.3	5.8	15.8	9484	13566	13.3
Romania	445	40.8	3.2	33.2	41.7	6.3	7.0	3595	5385	31.5
Slovak Republic	482	27.5	11	25.3	20.5	3.7	14.0	9799	8315	22
Slovenia	501	20.1	13.7	23.7	19.6	3.4	8.9	14271	15273	14.5
Spain	484	23.6	8	35.0	28.2	7.2	24.8	12359	17858	14.4
Sweden	478	27.1	8	24.8	15.6	3.7	8.0	19601	17436	12.7
United Kingdom	494	21.8	11.8	32.8	24.1	5.4	7.9	16449	14779	12.6

*Source: OECD (PISA 2012 Results:…, 2014, 48, 49, 299).

** Source: EUROSTAT http://epp.eurostat.ec.europa.eu/portal/page/portal/statistics/search_database

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Table 2

The matrix of Correlation between the Indicators of Welfare of European Countries and Students' Mathematical Literacy

	Mean score in mathematics	Share of low achievers in mathematics (Below Level 2)	Share of top achievers in mathematics (Level 5 or 6)	Gini coefficient	People at risk of poverty or social exclusion	S80/S20 income quintile share ratio	Unemployment rate by %	Median equivalised net income in PPS	Mean consumption expenditure per adult equivalent in PPS	Consumption of food and non-alcoholic beverages i%
Mean score in math	1									
Share of low achievers in mathematics (Below Level 2)	-0.97	1								
Share of top achievers in mathematics (Level 5 or 6)	0.92	-0.81	1							
Gini coefficient	-0.39	0.32	-0.47	1						
People at risk of poverty or social exclusion	-0.72	0.68	-0.67	0.73	1					
S80/S20 income quintile share ratio	-0.51	0.43	-0.59	0.96	0.76	1				
Unemployment rate %	-0.42	0.33	-0.50	0.63	0.52	0.71	1			
Median equivalised net income in PPS	0.46	-0.43	0.45	-0.57	-0.75	-0.59	-0.54	1		
Mean consumption expenditure per adult equivalent in PPS	0.37	-0.35	0.35	-0.37	-0.60	-0.37	-0.28	0.93	1	
Consumption of food and non-alcoholic beverages %	-0.53	0.51	-0.50	0.43	0.74	0.45	0.26	-0.87	-0.90	1

Source: Authors' calculations, using EUROSTAT data and OECD PISA 2012 data.

In correlation matrix (Table 2) it is shown that between indicators "People at risk of poverty or social exclusion" and "Mean score in mathematics" exist perceptible negative correlation (-0.72). Also between the indicators "People at risk of poverty or social exclusion" and "Share of top achievers in mathematics (Level 5 or 6)" exist negative correlation (-0.67). While between the indicators "People at risk of poverty or social exclusion" and "Share of low achievers in mathematics (Below Level 2)" exists positive correlation (0.68).

In correlation matrix (Table 2) it is shown that between households' "Median equivalised net income in PPS" and "Mean score in mathematics" exist positive correlation (0.46). Also between the household's "Median equivalised net income" and "Share of low achievers in mathematics (Below Level 2)" exist negative correlation (-0.43).

The same correlation coefficients' signs are also between the household consumption expenditure and mathematical skills. One of the indicators of household wealth is food consumption expenditure proportion of total consumption expenditure. Between “Consumption of food and non-alcoholic beverages in percent” and “Mean score in mathematics” is a negative correlation (-0.53).

It can be concluded that the lower is the level of mathematical background of the society the more there are people at risk of poverty or social exclusion in the given society.

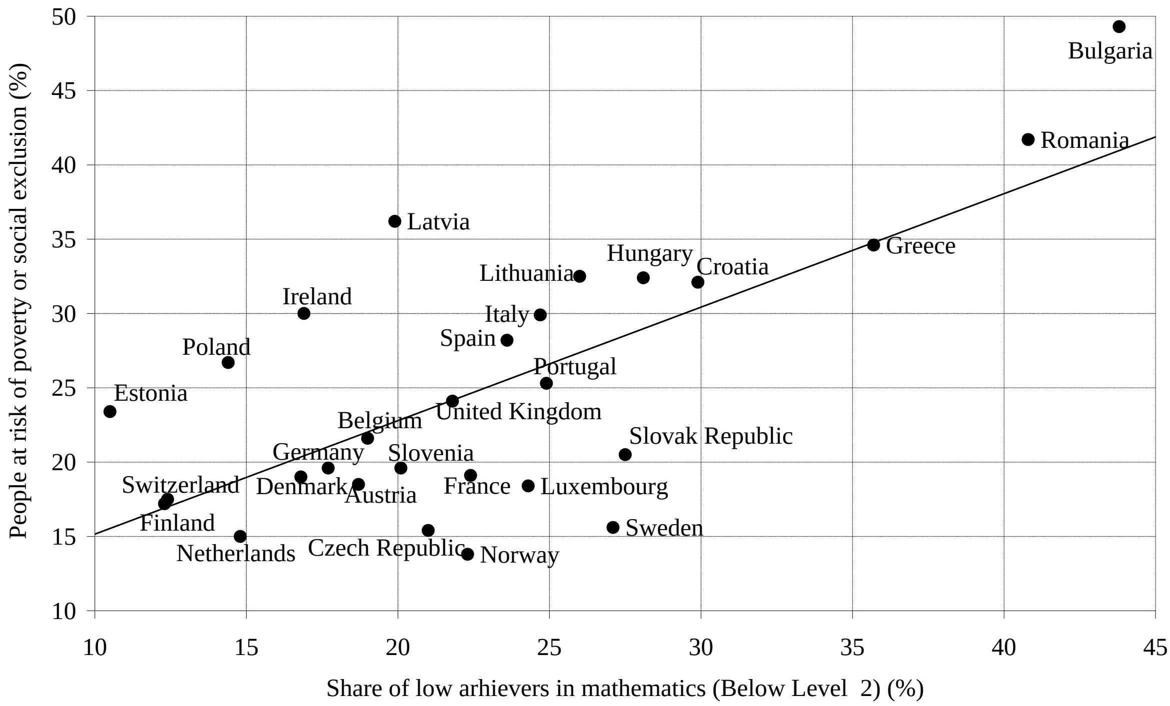

Figure 1. People at risk of poverty or social exclusion and share of low achievers in mathematics (Below Level 2).
Source: Authors’ calculations, using EUROSTAT data and OECD PISA 2012 data.

The greatest value of "People at risk of Poverty or Social Exclusion" in 2012 is in Bulgaria (49.3), followed by Romania (41.7) and Latvia (36.2), while the lowest value of the "People at risk of Poverty or social Exclusion" is in Norway (13.8), Netherlands (15) and Czech Republic (15.4). Bulgaria (43.8), Romania (40.8) and Greece (35.7) are the countries with the highest index value by the indicator "Share of Low Achievers in mathematics (Below Level 2)", while Estonia (10.5), Finland (12.3) and Poland (14.4) are three countries with the lowest index value (Figure 1).

Using cluster analysis there are identified six groups of countries with similar poverty, inequality, income and consumption expenditure and mathematical skills indicators. Six groups of countries are resulting from the application of k-average method. In all six groups of countries all mean value showings differ significantly. Values in the cluster centres are shown in Table 3.

The first cluster countries (Austria, Belgium, Denmark, Finland, France, Germany, Ireland, Italy, Netherlands, Sweden, and United Kingdom) are characterized by the highest level of mathematical skills, and relatively high rates of income and consumption expenditure figures, as well as the relatively low inequality.

The second cluster countries (Croatia, Estonia, Czech Republic, Hungary, Lithuania, Poland, Slovak Republic) are characterized by a high level of mathematical skills, and relatively low levels of income inequality. Compared to the first cluster of countries they have lower incomes and consumer spending, as well as a greater share of expenditures for food.

The third cluster countries (Greece, Portugal, Slovenia, and Spain) are characterized by the highest unemployment rate.

The fourth cluster countries (Bulgaria, Latvia, and Romania) are characterized by the lowest level of mathematical skills, the greatest income inequality, and the greatest value of the parameter “People at risk of Poverty or Social Exclusion”, the lowest income and consumer spending, as well as the highest proportion of food expenditure.

The fifth cluster country (Norway) is characterized by the lowest income inequality and the lowest value of the characteristic "People at risk of Poverty or Social Exclusion" and "Unemployment rate".

The sixth cluster country (Luxembourg) is characterized by the highest income and consumption, as well as the smallest food consumption specific weight.

Table 3

Final Cluster Centres

	Clusters					
	1	2	3	4	5	6
Mean score in mathematics	502.73	492.43	481.25	458.33	489.00	490.00
Share of low achievers in mathematics (Below Level 2)	19.29	22.49	26.08	34.83	22.30	24.30
Share of top achievers in mathematics (Level 5 or 6)	13.56	11.37	9.05	5.10	9.40	11.20
Gini coefficient	28.35	29.00	31.88	34.17	22.60	28.00
People at risk of poverty or social exclusion	20.87	26.17	26.93	42.40	13.80	18.40
S80/S20 income quintile share ratio	4.36	4.60	5.75	6.30	3.20	4.10
Unemployment rate %	8.09	11.64	18.50	11.43	3.20	5.10
Median equivalised net income in PPS	18284.91	8348.57	11530.25	5218.67	25607.00	26579.00
Mean consumption expenditure per adult equivalent in PPS	18672.64	8185.57	15933.25	5964.00	22820.00	28621.00
Consumption of food and non-alcoholic beverages %	13.05	23.63	14.55	28.97	11.80	8.80

Source: Authors’ calculations, using EUROSTAT data and OECD PISA 2012 data.

Hereafter there was used discriminant analysis to determine discriminant functions that separate the definite groups of countries and to ascertain that the determined clusters of countries were classified properly. Out of 27 countries dealt with, 21 countries are classified properly but 6 countries can be referred to the cluster of other countries. Thus 78% of all countries are classified in six clusters. The first cluster includes 11 countries out of which Denmark and Sweden can be referred to the countries of the fifth cluster, in its turn Italy and United Kingdom – to the countries of the third cluster. The second cluster includes 7 countries, one country – Croatia – can be attributed to the fourth cluster. The third cluster includes 4 countries, and one country – Slovenia – can be attributed to the first cluster.

Conclusions

The research has revealed that there exists correlative coherence between “Share of Low Achievers in mathematics (Below Level 2)” and “People at Risk of Poverty or Social Exclusion”, but our thesis is that any of these indicators is neither regressor nor regressand. These are indicators which complement each other and mutually interact. Generally speaking the children in households which are under the risk of poverty get poorer mathematical education and vice versa – if children have problems with acquisition of mathematics then probably they are from the households under the risk of poverty. When elaborating the socioeconomic policy for poverty decrease, these both factors should be taken into account.

When classifying the European countries according to socio-economic indicators and mathematical literacy indicators with the help of the method of cluster analysis, it was stated that there were formed six clusters. The interpretation of the clusters of countries requires further investigation.

However this study proved that the households' welfare is related to the mathematical literacy of the population.

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