THE DYNAMIC OF GROWTH OF ACHIEVEMENT IN MATHEMATICS OF LATVIAN SCHOOL LEARNERS: ANALYSIS OF INTERNATIONAL RESEARCH

ABSTRACT

Mathematics takes a specific place in the education of any country because the opportunities and success of youth in contemporary society are often dependent on their knowledge and skills exactly in the sphere of mathematics. Information about the status quo of mathematics education in the country is gained in international comparative research on education. The goal of the present research is to reflect the outcomes of the international project “Non-cognitive skills and Singapore learners – international comparison” organized by Singapore National Education Institute about the achievement of 2828 Latvian school learners of grade 9 in doing 12 mathematical sums. These outcomes were compared with Programme for International Student Assessment (PISA) 2003 research outcomes that, in turn, made it possible to predict the outcomes of PISA 2012 research in mathematics education as well as evaluate the efficiency of the new standard of education in Latvia in the first six years. The article will also regard the causes of the low achievement of Latvian learners in doing sums in mathematics.

Keywords: *learners’ achievement, mathematics education, international comparative research*

INTRODUCTION

Comparative research in education constitutes an important group of education indicators that may be used to compare the systems of education in world countries that are so very different (Broks, Geske, Grīnfelds, Kangro & Valbis, 1998), to assess the degree to which learners who are to leave primary school have mastered knowledge and skills that are needed for participation in the life of the society as well as formulate requirements for the improvement of the system of education in each country.

Two major international comparative studies may be distinguished in mathematics education: the International Association for Evaluation of Educational Achievement (IEA), international study Trends in International Mathematics and Science Study (TIMSS) and Organization for Economic Cooperation and Development (OECD) Programme for International Student Assessment (PISA). The major difference of OECD programme from research organized by IEA is found in its conceptual approach, choice of the means and methodology of research, and the age of the surveyed learners. OECD PISA research is focused on 15 years old learners and assesses the mathematical competence of learners instead of checking what learners have learned in mathematics. It must be noted that in PISA research mathematics competence is defined as individual’s ability to formulate, use, interpret mathematical problems in various real life contexts. Mathematics competence includes the ability to reveal regularities by means of mathematics, use the notions, actions, and facts of mathematics to describe, explain, and predict the phenomena and their procedure (Geske, Grīnfelds, Kangro & Kiseļova, 2010).

In 2003 mathematics competence of school learners in Latvia was in average slightly

lower than that of OECD countries. In the table of mean evaluations Latvia was listed as number 27. The differences of Latvian school learners' achievement were not statistically significant from that of learners in Norway, Luxemburg, Poland, Hungary, Spain, USA, and Russia.

Competence levels are another important indicator of learners' achievement: from 1 (learners who can answer only clearly formulated questions about a familiar context that includes the respective information, can complete routine activities following clearly expressed indications in precisely formulated situations) up to 6 (learners can conceptualize, generalize, and use the information proceeding from their own investigations and complex problem situation modeling, can relate different sources of information and explanations and flexibly operate with them) (for more information see for example Geske, Grīnfelds, Kangro & Kiseļova, 2010).

27 per cent of Latvian school learners could not do the sums that were more difficult than competence level 1. No more than 3 per cent of learners reached the result that corresponds to the highest competence level 6 (Geske, Grīnfelds, Kangro & Kiseļova, 2004). However, the analysis of the mean results of PISA 2000 and PISA 2003 showed a radical improvement of the competence quality of Latvian school learners in such spheres of mathematics as space and form (geometry) and variables and functional correlations (algebra). The next PISA research took place in 2006 that showed that in the time period from 2003 to 2006 further improvement of Latvian school learners' achievement was not observed, the changes of achievement were not statistically significant (Kiseļova, 2011).

The results of TIMSS and PISA international research became the basis of the dialogue in the sphere of education policy in Latvia to define and implement education goals in an innovative way, to evaluate and reflect competences that learners will need in their adult life. As a result, in 2006 in basic education and in 2008 in secondary education in Latvia a new education standard was introduced including mathematics as well. The reform of the content of education marked transition from acquisition of large amount of information to competences of working with information; inclusion of contemporary topics in the content of education and emphasis on practically applicable ideas and skills; integration of the content of learning and its adjustment across academic subjects; inclusion of topics adapted to the age group of learners in the content of learning (Latvian National Standard, 2006). The new standard of mathematics of Latvia fully corresponds to the content of the mathematics link items used in PISA tests up to now; approximately a half of the standard themes are included in the PISA mathematics link items (Kiseļova, 2011).

Despite the fact that for several years Latvian national standard of mathematics has fully matched the content of mathematical sums used in PISA tests until now, the analysis of the results of PISA 2009 showed that the average achievement of Latvian school learners in this period were considerably lower than those of OECD countries. Only in some European countries the achievements were worse (Greece, Romania, Bulgaria, Azerbaijan, the Balkan countries). Among all 65 member countries Latvia ranged no higher than 32–37. Comparison of competence groups revealed that there are still very few learners in Latvia whose knowledge of mathematics would correspond to the highest level of achievement (level 6 has been reached by just 1%, while 5 – only by 5% learners) (Geske, Grīnfelds, Kangro & Kiseļova, 2010).

OECD PISA research takes place every three years and assesses learners not only in mathematics but also science, reading and problem solving, but one of the above mentioned subjects is evaluated deeper. Mathematics was in the focus of OECD research attention last time in 2003 and will be in nearest future in 2012. Therefore the evaluation of learners' achievement in

mathematics in 2012 will yield more precise results that will also give an opportunity to evaluate the efficiency of the new education standard of Latvia after its introduction in the time of the first six years (not three as it was in PISA 2009). Yet analyzing also other comparative international studies with Latvian school learners involved, the correspondence of trends noticed by PISA 2009 to the actual situation may be tested already now.

The present research is a part of Singapore National Education Institute *international study „Non-cognitive skills and Singapore learners – international comparison”* that entailed also checking learners’ ability of doing mathematical sums. These outcomes were compared with Programme for International Student Assessment (PISA) 2003 and 2009 research outcomes that, in turn, made it possible to predict the outcomes of PISA 2012 research in mathematics education.

THE AIM OF THE STUDY

The following research questions were set:

1. What are the achievements of Latvian school learners in doing mathematical sums in this international study in comparison to the achievements of the learners of other countries?
2. What and how many Latvian school learner groups that cover the achievements of doing mathematical sums of similar level and structure may be distinguished according to the data acquired in the study?
3. What socio-demographical differences are there among Latvian school learners in relation to their achievements in doing mathematical sums?

MATERIALS AND METHODS

Instrument

As was stated above, the present research is a part of Singapore National Education Institute international study *„Non-cognitive skills and Singapore learners – international comparison”* that entailed an internet survey for learners with the aim of revealing the similar and different personality traits of learners from various countries, their attitude to mathematics, and their ability to do mathematical sums.

The present research is based just on 12 mathematical sums of the survey. All mathematical sums were multiple choice or short reply tasks and were taken from PISA or TIMSS tasks of the previous years (for more information see Table 2 in subchapter “Main results”). In their mathematical content they were from four spheres: 1) space and form, 2) variables and functional correlations, 3) numbers and measures, 4) probability, combinatorics, statistics. The sums were of different degree of complexity: *tasks of reproducing* (I, 5 tasks) (actions that are relatively known and that make use of the acquired knowledge and skills in practice), *tasks of generalization* (II, 5 tasks) (require skill of interpreting, searching for and forming a bond between different manifestations of the situation), *tasks of mathematical thinking and generalization* (III, 2 tasks) (require understanding of a situation and ability to generalize as well as creative approach to successful use of respective mathematical actions and knowledge) (OECD, 2004).

According to the situation and context, all tasks were distinguished into four groups: *tasks of everyday life situations* (entailing the context directly related to the routine actions of learners), *tasks of education and vocational situations* (entailing the context related to learners’ life in school or at work), *social context tasks* (entailing situations that make learners observe some wider environment context), and *science related situation tasks* (entailing a more abstract context that may be related to a theoretical situation or a precisely formulated mathematical problem that has no wider context).

For each correctly done sum learner received 1 point. If the sum had not been completed or was wrong, the learner's achievement was evaluated as 0. Exceptions are tasks 2, 7, 11. Each of those tasks contained four subtasks, therefore for doing each of these tasks learner could receive from 0 to 4 points. Hence, for a correctly done mathematical test learner could maximally score 21 points.

To assess the reliability of scale, Cronbach's Alpha coefficient was calculated for this part of survey. The value of Cronbach's Alpha was 0.582. Thus it may be concluded that reliability level of this part of survey is average and may be used in the research, though the results will not have the highest degree of probability yet. One reason for the lower reliabilities for the mathematics test is the small number of items relative to the breadth of the construct – by contrast, PISA 2003 had 85 mathematics items.

However, it was observed that if items 2 and 11 are deleted, Cronbach's Alpha grows and will reach the value 0.615. Thus for cluster analysis only 10 items described below were used (from 1 to 12, except for 2 and 11).

Sample and procedure

From 3083 learners who participated in the research, 2828 grade 9 learners were selected from different regions in Latvia: Latgale (17 per cent), Vidzeme (13 per cent), Kurzeme (12 per cent), Zemgale (12 per cent) and Riga (46 per cent). From all participants 51.8 per cent were female and 48.2 per cent were male. 79.2 per cent studied in schools of general education, and 20.8 per cent studied in school of ethnic minorities. 43.3 per cent of all participants lived in big towns, and 56.7 per cent lived in small town or countryside (see Table 1). The learners were not selected for further research if there were mistaken data indicated, e.g., the ID number of their teacher.

Table 1. Learner sampling and researched population distribution into socio-demographical groups

Socio-demographical indicators		Sampling frequency N (%)	Investigated population frequency (%)	p value comparing the investigated sampling to the investigated population sampling*
Region of Latvia	Riga and region	1304 (46%)	9606 (43.6%)	0.000
	Latgale	482 (17%)	3368 (15.3%)	
	Vidzeme	369 (13%)	2777 (12.6%)	
	Kurzeme	327 (12%)	3382 (15.4%)	
	Zemgale	346 (12%)	2879 (13.0%)	
Sex	Female	1464(51.8%)	No data	0.060
	Male	1364(48.2%)		
Education programme	General	2241 (79.2%)	16450 (74.7%)	0.000
	Ethnic minority	587 (20.8%)	5562 (25.3%)	
Urbanization	Urban	1225 (43.3%)	10038 (45.6%)	0.000
	Rural/small town	1603 (56.7%)	11974 (54.4%)	
Birth year	1993 or earlier	99 (3.1%)	No data	
	1994	392(13.9%)		
	1995	2248 (79.5%)		
	1996 or later	97 (3.4%)		

* Group differences were assessed with Chi-square test

By means of Chi-square test it was stated that there are statistically significant differences between the sample and the investigated population. Indeed, in the surveyed population there are fewer learners from Riga region and Latgale but more from Kurzeme, and more learners live in bigger towns. To state that there are statistically significant differences between the sample and the investigated population according to sex, it was assumed that the number of boys and girls must be equal.

The data collecting process took place in November – December, 2010. Mathematics teachers who worked at that time in grade 9 were sent invitations to organize the investigation in their grade 9. Those teachers who agreed to organize the investigation were given ID number and they received instructions by e-mail.

Each learner had to fill in the questionnaire electronically either in Russian or Latvian by opening a specially created for this purpose Internet address. Therefore each learner needed a computer with Internet connection as well as some sheets of paper for draft calculations of mathematical sums. Doing the sums they were allowed to use the calculator. If learners could not cope with any of the tasks they were allowed to skip it.

Thus basically the survey was organized in computer labs and it was conducted by teacher of mathematics who gave learners instructions how to fill in the questionnaire. Each learner had to do it independently without consulting teacher or classmates, only according to one's own experience and knowledge. Though whole classes were invited to participate in the survey, it was not demanded that absolutely all learners from the particular class take part. Participation in this investigation was voluntary.

MAIN RESULTS

The following methods of statistical analysis were used for data processing: Kolmogorov-Smirnov test to assess the distribution of data, Descriptive Statistics, Frequencies, two step cluster analyze, hi-quadrangle criterion as well as Cronbach's Alpha to assess the reliability.

According to Kolmogorov-Smirnov criterion, the data on all items significantly differed from normal distribution, therefore the statistical analysis of differences in items was conducted using non-parametrical criterions of data analysis.

Achievement of Latvian school learners and their international status

First let us analyze the academic achievement of Latvian school learners in doing 12 mathematical sums. Tables 2 and 3 reflect the characteristic features of the mathematical sums (mathematical content, competence group, context), the source of the task and the number of learners who did/failed to do each task. Table 2 contains tasks without subtasks while table 3 includes 3 tasks with subtasks.

Summarizing the results according to the task competence content, it appeared that in average 73.5 per cent of learners failed to do tasks of competence group 1 and 47.6 per cent and 34.7 per cent from all learners scored 0 points respectively for doing tasks of competence groups 2 and 3.

For all correctly done tasks altogether each learner who did the mathematical test could score maximally 21 points. Distributing learners' possible achievement in 7 equal intervals, the number of learners (per cent) who reached the appropriate level may be determined (see Table 4).

Table 2. Characteristics of tasks (without subtasks) and the rate of success

Task number	Task content	Task mathematical content	Task competence group	Task situation and context	Task survey, source, item code	Number of learners (%) who did the task correctly	Number of learners (%) who failed to do the task
1.	Coloured Candies	Probability	I	Educational and vocational situation	PISA, 2003, M467Q01	34.2	65.8
3.	Bookshelves	Numbers and measures	II	Educational and vocational situation	PISA, 2003, M484Q01	49.9	50.1
4.	Choices	Combinatorics	I	Everyday life situation	PISA, 2003, M510Q01	28.5	71.5
5.	Science Tests	Statistics	II	Educational and vocational situation	PISA, 2003, M468Q01	28.9	71.1
6.	Patio	Numbers and measures	I	Educational and vocational situation	PISA, field trial, M267Q01	16.8	83.2
8.	Space Flight	Numbers and measures	II	Social context	PISA, field trial, M543Q01	45.5	54.5
9.	Earthquake	Probability	III	Social context	PISA, 2003, M509Q01	41.3	58.7
10.	Zedland	Variables and functional correlations	I	Science related situation	TIMSS, 2006, pg. 106	48.6	51.4
12.	Skateboard	Combinatorics	I	Everyday life situation	PISA, 2003, M520Q02	23.0	77.0
Average						35.2	64.8

Table 3. Characteristics of tasks (with subtasks) and the rate of success

Task number	Task content	Task mathematical content	Task competence group	Task situation and context	Task survey, source, item code	Number of learners who scored points (%)				
						Points				
						0	1	2	3	4
2.	Carpenter	Space and form	II	Educational and vocational situation	PISA, 2000, M266Q01	1.30	27.4	19.0	35.7	16.6
7.	Drug Concentrations	Variables and functional correlations	II	Science related situation	PISA, field trial, M307Q01	60.9	16.1	4.60	17.6	0.80
11.	Payment by Area	Numbers and measures	III	Educational and vocational situation	PISA, 2003, M480Q01	10.7	21.1	36.7	23.6	8.00
Average						24.3	21.5	20.1	25.6	8.5

Table 4. The number of learners corresponding with the achievement levels of the mathematical test (%)

Quantitative indicators	Levels of achievement						
	0.	1.	2.	3.	4.	5.	6.
Mean coefficient of acquisition (%) and scored points	0-14 (0-3)	15-29 (4-6)	30-43 (7-9)	44-57 (10-12)	58-71 (13-15)	72-86 (16-18)	87-100 (19-21)
Number of learners who reached the appropriate level (%)	4.7	29.3	34.6	18.1	8.9	3.7	0.7

Judging from the learners' achievement in doing 10 mathematical sums (excluding 2 and 11), raw scale mean was calculated for each country of participants in Singapore study (Morony, Kleitman & Stankov, 2012). Unfortunately, according to these results Latvian school learners score the lowest place among learners from all other countries, though according to PISA 2009 results the lowest achievements were demonstrated by learners from Serbia (see Table 5).

Table 5. Raw scale mean for students' achievements in Singapore Project mathematics test and PISA 2009

	Singapore	Korea	Hong Kong	Taiwan	Netherlands	Denmark	Finland	Serbia	Latvia
Singapore study (Raw scale mean)	53.91	50.82	55.87	50.00	53.12	47.77	37.55	37.00	35.02
PISA 2009 (Mathematics Scores)	562	546	555	543	526	503	541	442	462

Groups of learners

To answer the research question about groups of learners that are equal according to the level and structure of doing mathematical sums, cluster analysis was produced. As mentioned before, only 10 items (from 1 to 12, excluding 2 and 11) were used for cluster analysis. Using two step cluster analysis, all learners, according to their results in doing 10 sums, were divided into four clusters (see Table 6).

Table 6. The number of learners (%) who did the particular sum correctly in each cluster

Task No. (predictor importance)	Number of learners (%) in each cluster who did the sum correctly										
	1. (0.64)	3. (1.00)	4. (0.18)	5. (0.30)	6. (0.34)	7.* (0.57)	8. (0.23)	9. (0.14)	10. (0.47)	12. (0.41)	Total
Cluster 1 (N ₁ =957, 33.8%)	30.1	00.0	30.8	20.1	8.5	10.4	39.7	37.8	49.6	18.8	1-8
Cluster 2 (N ₂ =386, 13.6%)	00.0	00.0	00.0	12.7	0.00	0.00	38.1	31.9	0.00	0.00	0-3
Cluster 3 (N ₃ =553, 19.6%)	35.2	86.6	47.9	64.4	46.7	55.9	79.9	68.0	85.7	60.0	5-12
Cluster 4 (N ₄ =932, 33.0%)	22.1	100.0	26.4	23.7	14.6	12.2	34.2	32.9	45.7	14.8	1-8

* For Task 7 the number of learners was indicated (%) who scored 3 or 4 points for the task.

Comparing four clusters, cluster 2 may be considered the one that unites learners with the lowest achievements because none of these learners did sums 1–4 as well as 6, 7 and 10, and 12, except for 5, 8, and 9. Hence, the common achievements of learners of cluster 2 will be between 0 and 3 points.

The highest achievement in doing 10 sums was demonstrated by learners of cluster 3: this cluster contains the greatest number of learners (in per cent) who did all the sums correctly (except for sum 3). The number of points scored by learners for 10 sums ranges between 5 and 12.

The major differences between cluster 1 and 4 learners lie in the results of doing sum 3: none of the learners from cluster 1 did this sum correctly, whereas all learners of cluster 4 managed to do it (see Table 6). Besides, 67.5 per cent learners in cluster 1 scored up to 3 points for all 10 sums, while in cluster 4 the number of such learners was much smaller – 45.8 per cent. The number of points scored by learners for 10 tasks in both clusters lies in the range between 1 and 8.

Socio-demographical differences of Latvian school learners in their achievement in doing mathematical sums

By means of hi-quadrangle criterion it was made out that there are statistically significant differences ($p < 0.01$) among four clusters of learners over the regions: in cluster 3 the ratio of learners from Kurzeme and Vidzeme is much smaller and that of learners from Riga and Riga region is bigger. There are also differences according to the place of residence: in cluster 3 the majority of learners live in bigger towns (55.2 per cent), in other clusters the majority of learners live in the countryside and small towns. Especially big ratio of learners from the countryside and small towns is in cluster 2 (62 per cent).

Statistically significant differences between four clusters of learners according to the program of education and sex of learners were not located, though it must be noted that in cluster 3 the number of boys was biggest (51.5 per cent).

These results match those of the prior research on learners' achievement in mathematics in Latvia. For instance, it was stated in OECD 2003 study that school learners from Latvia living in Riga had the highest achievement as compared to learners from other regions of Latvia. The highest achievement was also registered with learners from Riga and bigger towns as compared to learners from the countryside and small towns. Achievement of girls and boys in mathematics were very similar (Geske, Grīnfelds, Kangro & Kiseļova, 2004).

CONCLUSIONS

According to the analysis of learners' academic achievement in Singapore study, Latvian school learners' achievement in mathematics has not improved since 2003. For instance, in 2003 sum 12 was done by 32 per cent of all Latvian learners who participated in PISA research but the same sum in 2010 was done correctly only by 23 per cent of learners. 21 per cent of Latvian school learners in 2003 did sum 2 correctly but in 2010 it was done only by 17 per cent of learners. No doubt, there are statistically significant differences among the samplings that took part in studies in 2003 and 2010 but yet there are negative trends apparent in the dynamics of growth of Latvian school learners' achievement in mathematics (Geske, Grīnfelds, Kangro & Kiseļova, 2004).

The fact that Latvian school learners' achievement has not improved since 2003 is testified to also by comparison of Latvian learners' achievement to that of other countries in Singapore study in 2010. Again it must be noted that according to these results Latvian school learners score the lowest place among all participating countries of Asia and Europe. This result matches that of PISA 2009 study, except for the fact that in 2009 the achievements of Serbian school learners were lower than those of Latvian learners (OECD, 2010).

The number of learners who have low achievement in Singapore project test in mathematics (34 per cent having levels 0 and 1) greatly exceeds the number of learners who have high achievements in this test (4.4 per cent having levels 5 and 6). It must also be noted that in this research none of Latvian school learners scored the maximum number of points that, in turn, matches the trend revealed in PISA 2009 indicating the decrease of the number of outstanding learners in Latvia. For Latvia it is an important problem (Geske, Grīnfelds, Kangro & Kiseļova, 2010).

It may be observed that Latvian school learners surveyed within Singapore project have not mastered some topics from education standard in mathematics. This is proved by the fact that the level of doing sums is low even for competence 1 level sums. This may be accounted for by the fact that many teachers teach topics recently added to the standard (e.g. combinatorics) only at the end of grade 9. It is possible that if this study had been produced at the end of the academic year, not in the middle, learners' achievement in it would have been much better.

Proceeding from the stated above, it may be stated that there is a high degree probability that PISA 2012 learners' achievements in mathematics will not improve and like in PISA 2009 will remain lower than the average level of OECD countries. Latvian education politicians consider that PISA 2009 results bring out a serious need to analyze basic education standard in Latvia and methods of learning. However, this problem may be regarded also from other aspect. For instance, Norwegian parliament report (Norwegian Parliament, 2009) describes *the teacher* as the most important single factor influencing students' learning. In a review of research on teacher competence, the importance of *teachers' informal competence* is underlined (Nordenbo, Larsen, Tiftikci, Wendt & Østergaard, 2008). In turn, according to many studies the process of raising teacher's competence is closely related not only to acquiring knowledge but also the formation of teacher's beliefs (Shulman, 1987; Ball, Thames & Phelps, 2008). From various predictors who may predict learners' achievement in mathematics, the impact of teacher's beliefs on learners' achievement has been little studied so far. Clarifying this correlation between teacher's beliefs and learners' achievement may become the goal of further research.

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