# Why has average achievement in mathematics in the Czech Republic decreased since 1995 according to TIMSS results?

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## Abstract

In TIMSS 1995, students from the Czech Republic showed very good achievement in both fields tested. During the following cycles, however, a significant decrease in average achievement occurred. This text aims at identifying causes that are likely to have contributed to the decrease in students' average achievement in mathematics ascertained for the Czech Republic on the basis of the international TIMSS survey. The purpose of this paper is to give an outline of factors which may have influenced the decline in average achievement in mathematics among Czech eighth-grade students since 1995. Our work has been based on a presumption that besides factors that can be expressed by standard variables (school type, gender, etc.), the achievement has also been influenced by less easily operationalizable factors which, in addition, reflect a certain development over time.

On the whole, it can be stated that while the influence of school type and the "I like math" variable on mathematics achievement does not decline in the course of individual TIMSS cycles, the impact of parents' education did decrease. This finding unfortunately confirms the fact that various types of schools and various schools in the Czech Republic show a relatively high degree of homogeneity in terms of students' socioeconomic background. In terms of average achievement, scores of boys and girls have converged significantly, which has also been confirmed by our models. As for the less easily operationalizable aspects, we focused on the analysis of the changes to the mathematics curriculum of basic education between 1995 and 1999. We found out that the decline in Czech students' rate of success in trend items from 1995 to 1999 can, to a certain extent, be explained by the shift of the curriculum. Attention was also given to the reduction in the amount of time allocated to the teaching of mathematics. Although we cannot assume a direct dependence relation between average achievement and the amount of time allocated, there undoubtedly are certain indirect impacts.

**Keywords:** *achievement, mathematics, TIMSS, Czech Republic*

## Introduction

In 2007, the Czech Republic took part in the international TIMSS survey after eight years (previous participation in TIMSS 1995 and TIMSS 1999). By international comparison, students from the Czech Republic reached above-average achievement in science at both (fourth and eighth) grades tested (Martin et al. 2008), but in mathematics their achievement was below the average at the fourth grade and only average at the eighth grade (Mullis et al. 2008).

The development of Czech students' average achievement over time is of particular concern. While in 1995 the average achievement of Czech students at both grades was statistically significantly above the average in both subject areas (mathematics, science) by international comparison, in 2007 this level was only maintained by eighth grade students in science (Tomášek et al. 2008). In comparison with other European or OECD countries, the Czech Republic experienced, between 1995 and 2007, one of the most pronounced declines in average achievement. The decline in average achievement of eighth-grade students is illustrated by Figures 1 and 2.

[Take in Figure 1 and Figure 2 about here]

This paper focuses on mathematics achievement of eighth-grade students. Firstly with regard to the fact that testing of eighth-grade students in the Czech Republic has already taken place in three TIMSS cycles (testing of fourth-grade students in two cycles only), and secondly because in mathematics a significant decrease in average achievement was observed compared to science. Table 1 shows the declining trend in math achievement of Czech students, moving from above-average values in 1995 to merely average values in 2007.

[Take in Table 1 about here]

## Methodology

Our analysis stems from previous studies examining the influence of various education tracks on the differences in achievement (Horn et al. 2006; Straková et al. 2006), the influence of gender differences (Potužníková, Straková 2006) or also the influence of other factors such as the amount of time allocated to mathematics lessons (Baumert et al. 1999).

Our main research objective is to identify factors that may have influenced the decrease in Czech students' average achievement in mathematics at the eighth grade since 1995. We have presumed that besides influences that can be expressed by standard variables (school type, gender, etc.), the achievement has also been influenced by less easily operationalizable factors which, in addition, reflect a certain development over time. We believe that these potential factors include a certain alteration in the TIMSS testing design as well as factors specific for the Czech Republic – change in the curriculum, adjusted time allotment.

Accordingly, our paper consists of two main parts. The first part analyzes which independent variables tested within TIMSS influence the changes in the dependent variable – average achievement in mathematics of students in the Czech Republic. The second part then examines the abovementioned “less easily operationalizable” factors which are not represented by any variables in the data but which, in our view, do constitute important aspects.

Data sets for the Czech Republic from three cycles of the international TIMSS survey (1995, 1999 and 2007) were used for this paper. In order to trace the main factors influencing the students’ math achievement, the linear regression modelling method was applied. The best model was determined using the forward method. The dependent variable is mathematics achievement. On the basis of correlation analysis and tests to exclude collinearity, we were able to work with the following independent variables (2007 data).

- Gender
- School type (0 – basic school, 1 – multi-year grammar school[1])
- Parents’ highest education
- Parents’ highest ISEI (occupational status)
- the “I like math” variable

The analysis of curricular changes was performed using expert assessment – analysis of changes in the mathematics curriculum of basic education between 1995 and 1999. As a basis of structuring of the mathematical content examined in the TIMSS survey, the mathematical framework used in the 1995 TIMSS investigation was chosen. By means of expert assessment, the curriculum guide in force in the Czech Republic for the teaching of mathematics at basic schools in 1995 and 1999 were compared. Our actual analysis of the curriculum guide was based on the topic trace mapping methodology used in document analysis during the first TIMSS cycle (Schmidt et al. 1997).

[1] In the Czech Republic, the population of eighth-grade students tested in the TIMSS survey can be found at basic schools (approximately 90%) and at multi-year grammar schools.

## Findings and Discussion

We aimed at analyzing factors which may have influenced the decline in average mathematics achievement of students in the Czech Republic on the basis of the TIMSS testing. As has been indicated in the methodological part, we are first of all going to focus on factors that have a measurable impact on average mathematics achievement.

Using linear regression modelling, a model was drawn up which (the 2007 TIMSS cycle) accounts for the total of 36% of the dependent variable variance. Based on the forward method it can be stated that the strongest (greatest) proportion of explained variance pertains to the variable representing the type of school being studied (school type). This is model No. 1 (Table 2) which accounts for 22% of the variance. Regrettably for the educational system of the Czech Republic this confirms the fact that there are considerable differences between students of individual school types and that the multi-year grammar schools' function in the educational system is rather selective, contributing to educational disparities (Straková et al. 2006). The second strongest influence was identified with the "I like math" variable (model 2 containing both variables accounts for 30%). It is therefore true that the more the students like math, the higher is their average mathematics achievement.

Even though it was found that a higher parents' ISEI as well as higher parents' education correspond to higher mathematical literacy scores, while the ISEI still contributes a relatively strong proportion to the variance explanation (model 3 extended by adding the given variable accounts for 35.2 %), other variables entering the model contribute only a negligible proportion to the variance explanation. Model 4 extended by adding parents' education accounts for 35.7% and model 5 extended by gender explains 35.8%. Although it is accepted that girls achieve lower average scores in mathematics, as illustrated by Table 2, the variable representing gender has only a very small impact in terms of the proportion of explained variance.

[Take in Table 2 about here]

As evidenced by the above regression models, school type represents, in our analysis, the strongest independent variable influencing the students' mathematics achievement. On average, students of multi-year grammar schools have significantly higher average achievement when compared to basic school students.

We were therefore further interested in how would the linear regression models look like if we focused only on the subgroup of basic school students. Excluding school type, we worked with the same variables as in the previous case. It was confirmed (Table 3) that besides school type, the influence of the “I like math” variable proves to be the strongest (this variable in itself accounts for 10% of the dependent variable variance). Then it is the influence of the parents’ ISEI, the addition of which increases the proportion of explained variance to 17.1%. Also in this case, when focusing only on basic school students, very weak influence of other variables was ascertained – parents’ education and gender (adding education to the model accounts for 17.8% and additional extension by the variable representing gender then explains 17.9% of the variance).

[Take in Table 3 about here]

Even though for earlier cycles (TIMSS 1999 and TIMSS 1995) the analysis cannot be performed with entirely identical variables (data on parents’ ISEI are not available), certain diversities and differences can be pointed out. As illustrated in Table 4, the model for TIMSS 1999 data (accounting for 29.5% of the variance in total), as well as in the case of TIMSS 2007, attributes the greatest influence on mathematics achievement to school type (this variable in itself accounts for 16%) and to the “I like math” variable (by adding it to the model, 26.6% of explained variance is reached). The variable representing parents’ education extends the model to 28.6% of explained variance and the smallest influence was ascertained for the gender variable.

When looking at basic school students only, the strength of influence of individual variables (excluding the variable concerning school type) does not change (Table 5). The “I like math” variable in itself accounts for 13%, the addition of parents’ education to the model accounts for 15.4% and further addition of gender explains the total of 16.3% of the variance.

In comparison with the 2007 and 1999 cycles, it was found for the 1995 cycle (Table 6) that the independent variable representing parents’ education (in itself accounting for 10% of the variance) has the strongest influence on the dependent variable. It is followed by the “I like math” variable (its addition to the model gives 17% of explained variance) and the third place is occupied by school type (by adding it we obtain the explained variance value of 21.9%). The influence of gender was, in this case as well, found to be relatively weak (increase only to 22.8%).

The model for basic school students (Table 7) contains the above variables in the same order of strength of influence. Parents’ education in itself explains 9.5% of the variance, the addition of the “I like math” variable increases the value to 16.5% and the extension of the model by gender raises the value to 17.4%.

Although in all the models described above the variable representing gender contributes a relatively small proportion of explained variance to the model, it is important to draw attention to the development over time. While in the 1995 and 1999 cycles the mathematics achievement of girls was 13 points below that of boys on average, in the 2007 cycle the average difference amounted to only about 3 points.

While so far we have analyzed factors influencing mathematics achievement in terms of standardly observed variables, the second part of our analysis is going to look at factors which may have caused the decline in Czech students' mathematics achievement, but the influence of which cannot be directly operationalized and measured. In spite of this we have dealt with these factors, since we believe them to represent key aspects.

The first question that arises is whether the methodology of the research has not changed. The TIMSS survey is conceived so that the development of the results over time can be traced. Based on the results of the first cycle in 1995 a scale was created to serve as a basis for the presentation of the results of all the following investigations. A portion of items used in a cycle is also used in the next cycle and, eventually, in yet another one. The second cycle in 1999 was conducted according to the same methodology as the first one. Then, however, changes were made. The main part of the methodology was preserved, but a new framework for the investigation in 2003 was developed and further adjusted for 2007. This is also connected with changes in the design of the tests. What we can consider a major change is a marked decrease in the proportion of multiple-choice items with traditionally highest success rates. In 1995 they represented 83% of all test items, in 1999 it was 77%, in 2003 66% and in 2007 approximately 54%. The significant reduction in this type of items certainly did contribute to a higher quality of the testing itself, but the question remains to what extent it has contributed to the decline in the students' average mathematics achievement. The Czech Republic did not participate in the investigation in 2003, and in 2007 only a few items from 1999 were used, therefore it is not able to trace possible influence of the changes introduced on the students' achievement.

As at 1 September 1995, the education system of the Czech Republic was changed so that the number of years at the basic school was increased from eight to nine. Since the 1995/96 school year, basic school is divided into the first stage which has five grades (up until then it had four grades) and the second stage with four grades. The change introduced relates to the modification of the curriculum of basic education, but also to the alteration in the transition of students to upper-secondary schools. Before the change took place, eighth-grade students left for upper-secondary schools, whereas now it is ninth-graders. Since most upper-secondary schools required entrance examinations in Czech language and mathematics, the targeted

revision of the mathematics subject matter at school and the individual student's preparation was moved from the eighth to the ninth grade. This fact also contributed to the decline in average mathematics achievement of Czech eighth-graders in the TIMSS survey.
As far as the teaching of mathematics is concerned, with the change in intended curriculum the volume of the subject matter and time allotment were more or less retained for basic school as a whole. This means that students are now taught the same subject matter in nine years which was previously taught in eight years. As part of the change in the mathematics curriculum, some thematic units (or their parts) were moved to a higher grade. Eighth-grade students tested in the TIMSS survey had not been taught certain subject matter, or they had not practised it as extensively as students of the same age before 1995.
In this phase we focused on the analysis of changes in the mathematics curriculum of basic education between 1995 and 1999. The mathematical framework used for the TIMSS 1995 investigation was chosen as a basis for the structuring of mathematical content examined by the TIMSS survey. As has already been mentioned in the methodological part, by means of expert assessment the curriculum guide in force for the teaching of mathematics at basic schools in 1995 and 1999 were compared. Our analysis of the curriculum guide itself was based on the topic trace mapping methodology used for the analysis of documents during the first TIMSS cycle. The degree of shift of individual topics of the framework is described by the following categories:

- 0 – no shift,
- 1 – beginning shifted, but taught by the eighth grade,
- 2 – shifted, and taught at the ninth grade as well,
- 3 – taught only at the ninth grade, or not taught at basic school.

What followed was a comparison of success rates for all trend items assigned in both years, which represented about 30% of score points in 1999. The difference in success rates was expressed for individual items as a percentage of the success rate reached in 1995. Figure 3 suggests that this relative decline in success rates (expressed by a positive value on the y axis) of Czech students from 1995 to 1999 in common items can, to a certain degree, be explained by the shift in the curriculum. None of the items is from a topic characterized by the 3$^{rd}$ category of shifts.

At the eight-year basic school (until 1995), a minimum weekly time allotment of 39 lessons altogether was established for mathematics instruction. Now, when the number of years has been increased to nine, the total weekly time allotment amounts to 40 lessons, four lessons being established for the ninth grade. This means that for eight years of school attendance the total weekly time allotment decreased by three lessons (by 135 minutes).

Although the intended curriculum did not undergo further modification, a moderate decrease in mathematics instructional time at the eighth grade was observed even after 1999. Figure 4 demonstrates average achievement in mathematics and average weekly instructional time for all the three investigations. These data are taken from questionnaires for math teachers. Table 8 captures the trend in the number of math lessons per week at the eighth grade of basic school. Even though a direct dependence of average achievement on the established instructional time cannot be assumed, certain indirect impacts undoubtedly do exist here. With reduced instructional time and the same manner of teaching, the students do not master the same volume of subject matter, or they are not able to practise it to a sufficient extent. The marked decrease in the number of students with the highest number of lessons is related with the decrease in the number of schools specialising in mathematics. This occurred due to the introduction of multi-year grammar schools which talented students proceed to and which saw expansion in the late 1990s. The decrease in the number of math lessons or the volume of subject matter taught may also signify that less emphasis is placed on this subject nowadays than earlier. This may result in declining interest in mathematics and, consequently, a negative impact on Czech students' achievement.

## Conclusion and Implications

On the whole, it can be stated that while the influence of school type and the "I like math" variable on mathematics achievement during individual TIMSS cycles does not decline, the influence of parents' education did decrease. This finding unfortunately confirms the fact that various types of schools and various schools in the Czech Republic show a relatively high degree of homogeneity in terms of students' socioeconomic background. In terms of average achievement, scores of boys and girls have converged significantly, which has also been confirmed by our models.

As for the less easily operationalizable aspects, we focused on the analysis of the changes to the mathematics curriculum of basic education between 1995 and 1999. We found out that the decline in Czech students' success in trend items from 1995 to 1999 can, to a certain extent, be explained by the shift of the curriculum. Attention was also given to the reduction in the amount of time allocated to the teaching of mathematics. Although we cannot assume a direct dependence relation between average achievement and the amount of time allocated, there undoubtedly are certain indirect impacts. The decrease in the number of math lessons or the volume of subject matter taught may also signify that less emphasis is placed on this subject nowadays than earlier. This may result in declining interest in mathematics and, consequently, a negative impact on Czech students' achievement.

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# Basl, Tomasek - Tables and Figures

Figure 1: Changes in average mathematics achievement of eighth-grade students (1995 – 2007; European or OECD states)

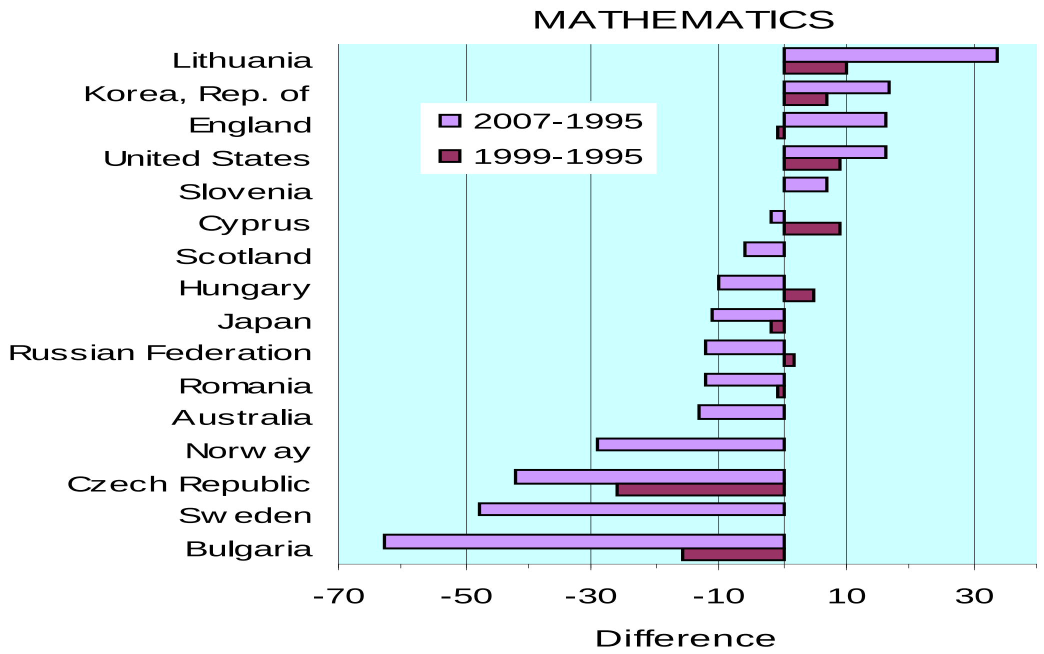


Figure 2: Changes in average science achievement of eighth-grade students (1995 – 2007; European or OECD states)

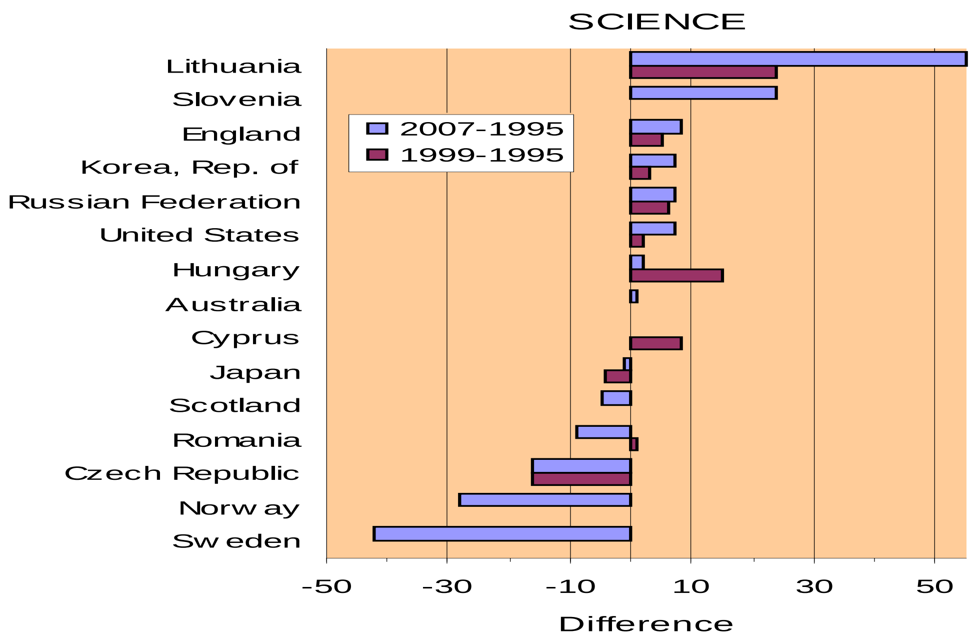

Table 1: Average mathematics achievement of eighth-grade students (1995, 1999, 2007; states participating in all three cycles)

| 1995 | | 1999 | | 2007 | |
|---|---|---|---|---|---|
| Singapore | 609 | Singapore | 604 | Korea, Rep. of | 597 |
| Korea, Rep. of | 581 | Korea, Rep. of | 587 | Singapore | 593 |
| Japan | 581 | Hong Kong SAR | 582 | Hong Kong SAR | 572 |
| Hong Kong SAR | 569 | Japan | 579 | Japan | 570 |
| **Czech Republic** | **546** | Hungary | 532 | Hungary | 517 |
| Hungary | 527 | Russian Federation | 526 | England | 513 |
| Bulgaria | 527 | **Czech Republic** | **520** | Russian Federation | 512 |
| Russian Federation | 524 | Bulgaria | 511 | USA | 508 |
| England | 498 | USA | 502 | Lithuania | 506 |
| USA | 492 | England | 496 | **Czech Republic** | **504** |
| Romania | 474 | Lithuania | 482 | Cyprus | 465 |
| Lithuania | 472 | Cyprus | 476 | Bulgaria | 464 |
| Cyprus | 468 | Romania | 472 | Romania | 461 |
| Iran, Islamic Rep. of | 418 | Iran, Islamic Rep. of | 422 | Iran, Islamic Rep. of | 403 |
| | | | | | |
| **Average** | **520** | **Average** | **521** | **Average** | **513** |
| | | | | | |

Note:
Country average achievement significantly higher than average
Country average achievement not significantly different from average
Country average achievement significantly lower than average

Table 2: Resultant models – linear regression modelling outputs (Czech Republic, TIMSS 2007)

| Model | | Unstandardized Coefficients | | Standardized Coefficients | t | Sig. | Collinearity Statistics | |
|---|---|---|---|---|---|---|---|---|
| | | B | Std. Error | Beta | Tolerance | VIF | B | Std. Error |
| 1 | (Constant) | 493.036 | .212 | | 2328.640 | .000 | | |
| | School type | 115.239 | .693 | .472 | 166.401 | .000 | 1.000 | 1.000 |
| 2 | (Constant) | 447.303 | .483 | | 926.204 | .000 | | |
| | School type | 111.273 | .658 | .456 | 169.165 | .000 | .997 | 1.003 |
| | I like math | 19.881 | .191 | .281 | 104.119 | .000 | .997 | 1.003 |
| 3 | (Constant) | 393.614 | .774 | | 508.475 | .000 | | |
| | School type | 97.497 | .653 | .399 | 149.274 | .000 | .938 | 1.066 |
| | I like math | 18.923 | .184 | .267 | 102.710 | .000 | .993 | 1.007 |
| | Parents highest ISEI | 1.190 | .014 | .232 | 86.767 | .000 | .936 | 1.068 |
| 4 | (Constant) | 388.372 | .793 | | 489.786 | .000 | | |
| | School type | 94.565 | .659 | .387 | 143.565 | .000 | .914 | 1.094 |
| | I like math | 18.817 | .184 | .266 | 102.533 | .000 | .993 | 1.007 |
| | Parents highest ISEI | .953 | .016 | .186 | 59.363 | .000 | .679 | 1.474 |
| | Parents highest edu | 3.671 | .130 | .089 | 28.256 | .000 | .673 | 1.487 |
| 5 | (Constant) | 389.964 | .809 | | 482.001 | .000 | | |
| | School type | 95.087 | .661 | .389 | 143.957 | .000 | .909 | 1.101 |
| | I like math | 18.920 | .184 | .267 | 102.976 | .000 | .989 | 1.011 |
| | Parents highest ISEI | .956 | .016 | .187 | 59.583 | .000 | .678 | 1.474 |
| | Parents highest edu | 3.591 | .130 | .087 | 27.599 | .000 | .670 | 1.493 |
| | Gender | -3.412 | .348 | -.025 | -9.793 | .000 | .987 | 1.013 |

Dependent Variable: Math achievement

Table 3: Linear regression model – basic school students only (Czech Republic, TIMSS 2007)

| | Unstandardized Coefficients | | Standardized Coefficients | t | Sig. | Collinearity Statistics | |
|---|---|---|---|---|---|---|---|
| | B | Std. Error | Beta | Tolerance | VIF | B | Std. Error |
| (Constant) | 384.932 | .873 | | 440.903 | .000 | | |
| I like math | 19.304 | .196 | .304 | 98.240 | .000 | .992 | 1.008 |
| Parents highest ISEI | 1.000 | .017 | .209 | 57.851 | .000 | .728 | 1.374 |
| Parents highest edu | 3.922 | .142 | .100 | 27.643 | .000 | .727 | 1.376 |
| Gender | -2.071 | .388 | -.017 | -5.342 | .000 | .992 | 1.008 |

Dependent Variable: Math achievement

Table 4: Linear regression model (Czech Republic, TIMSS 1999)

| | Unstandardized Coefficients | | Standardized Coefficients | t | Sig. | Collinearity Statistics | |
|---|---|---|---|---|---|---|---|
| | B | Std. Error | Beta | Tolerance | VIF | B | Std. Error |
| (Constant) | 413.665 | .929 | | 445.118 | .000 | | |
| School type | 94.816 | .733 | .361 | 129.275 | .000 | .940 | 1.064 |
| I like math | 28.576 | .246 | .315 | 116.150 | .000 | .994 | 1.006 |
| Parents highest edu | 6.884 | .136 | .142 | 50.691 | .000 | .935 | 1.069 |
| Gender | -14.014 | .408 | -.093 | -34.348 | .000 | .991 | 1.010 |

Dependent Variable: Math achievement

Table 5: Linear regression model – basic school students only (Czech Republic, TIMSS 1999)

| | Unstandardized Coefficients | | Standardized Coefficients | t | Sig. | Collinearity Statistics | |
|---|---|---|---|---|---|---|---|
| | B | Std. Error | Beta | Tolerance | VIF | B | Std. Error |
| (Constant) | 410.575 | .994 | | 413.090 | .000 | | |
| I like math | 29.278 | .264 | .346 | 110.820 | .000 | .995 | 1.005 |
| Parents highest edu | 7.130 | .146 | .153 | 48.963 | .000 | .994 | 1.006 |
| Gender | -13.501 | .437 | -.097 | -30.904 | .000 | .992 | 1.008 |

Dependent Variable: Math achievement

Table 6: Linear regression model (Czech Republic, TIMSS 1995)

| | Unstandardized Coefficients | | Standardized Coefficients | t | Sig. | Collinearity Statistics | |
|---|---|---|---|---|---|---|---|
| | B | Std. Error | Beta | Tolerance | VIF | B | Std. Error |
| (Constant) | 439.570 | .717 | | 612.914 | .000 | | |
| Parents highest edu | 15.770 | .137 | .275 | 115.246 | .000 | .978 | 1.023 |
| I like math | 22.036 | .205 | .254 | 107.347 | .000 | .998 | 1.002 |
| School type | 79.756 | .823 | .231 | 96.939 | .000 | .980 | 1.021 |
| Gender | -13.437 | .342 | -.093 | -39.239 | .000 | 1.000 | 1.000 |

Dependent Variable: Math achievement

Table 7: Linear regression model – basic school students only (Czech Republic, TIMSS 1995)

| | Unstandardized Coefficients | | Standardized Coefficients | t | Sig. | Collinearity Statistics | |
|---|---|---|---|---|---|---|---|
| | B | Std. Error | Beta | Tolerance | VIF | B | Std. Error |
| (Constant) | 435.533 | .737 | | 590.709 | .000 | | |
| Parents highest edu | 16.709 | .141 | .296 | 118.323 | .000 | .998 | 1.002 |
| I like math | 22.278 | .212 | .264 | 105.304 | .000 | .998 | 1.002 |
| Gender | -13.011 | .353 | -.092 | -36.888 | .000 | 1.000 | 1.000 |

Dependent Variable: Math achievement

Figure 3: Difference in students' success in trend items TIMSS 1995 and TIMSS 1999

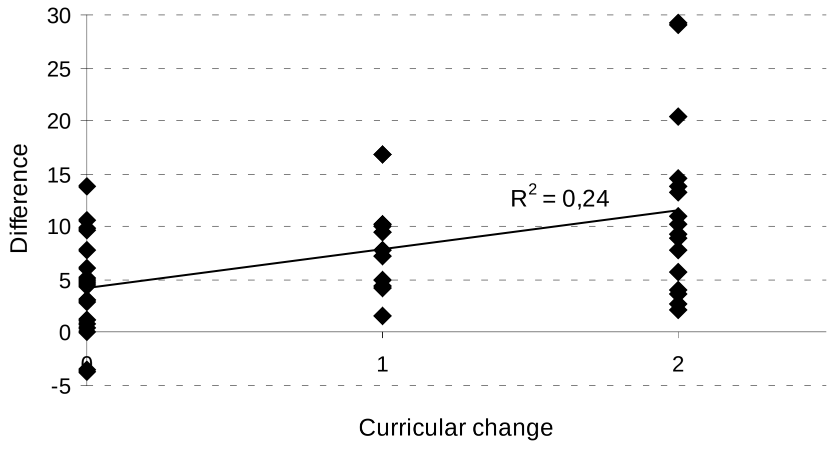


Figure 4: Average achievement and average weekly allotment of math instructional time, eighth grade

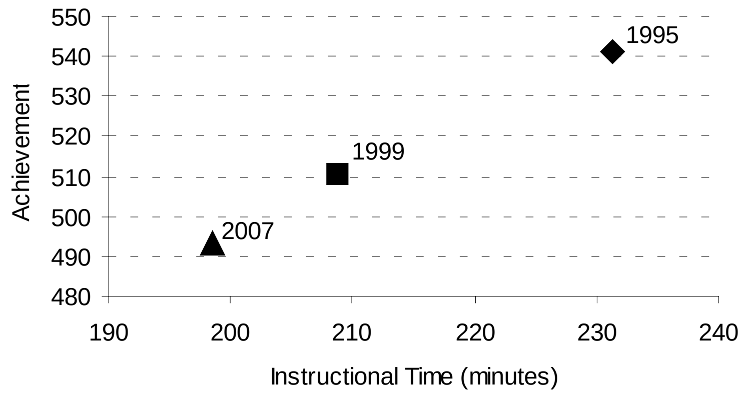


Table 8: Trend in mathematics instructional time, eighth grade

| **Time** | **Distribution of Instructional Time (%)** | | |
|---|---|---|---|
| | **1995** | **1999** | **2007** |
| **4 lessons** | 6.6 | 43.2 | 60.9 |
| **5 lessons** | 74.1 | 52.0 | 34.7 |
| **6 or 7 lessons** | 19.3 | 4.8 | 4.3 |