

A New way of recognizing the spatial distribution of educational issues: regional variation of science literacy in the Finnish TIMSS 2011 data

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ABSTRACT

Socioeconomic and cultural factors play a crucial role in students' educational achievement. We tend to use statistical models that provide an overview of different underlying socioeconomic variables when explaining educational achievement, but easily forget that these models only present an average or give a cross-sectional picture of the real life situations. In this way we may get a largely simplified view on things and forget the effect of underlying cultural factors, for example.

In this paper we take a closer look at the Finnish TIMSS 2011 data and try to present a new way of analyzing the data beyond the regular models. Firstly, we outline a 2-stage linear model for science performance and its underlying socioeconomic factors. In that model, the distribution of explanatory factors and model residuals are observed. Secondly, we try to visualize the regional variation of science literacy scores and look for possible local accumulations. This variation and grouping of performance, together with relevant background factors, are studied by means of a spatial statistical method called kriging (e.g. Isaaks and Srivastava, 1989; Brimicombe, 2000). With the help of this model, contour maps are drawn in order to reveal and visualize, for example, any clear clusters of science literacy scores across Finland.

While also the explanatory factors tend to be clustered, these clusters do not necessarily follow the same pattern. Thus, regional variation in student factors does not explain the between-school variance. This can be confirmed by observing the contour map of random school intercepts, which shows clear clustering in this respect.

This knowledge is useful for local authorities and for national education policy as well. It is crucial to identify local special characteristics or cultural features for possible improvements and, on the other hand, in nationwide education policy it is important to consider whether there is a need for particular regional interventions.

Keywords: science literacy, GIS, kriging method, regional policy, social capital

INTRODUCTION

For many countries in Europe, external evaluation data is an important part of the evaluation of their schools (Eurydice 2012). Finland is slightly different in this respect, however, as here the main purpose of educational evaluation is to support the development of education and improve conditions for learning (Act on Basic Education 1988). Therefore there is no high-stake evaluation of schools in Finland, which probably also explains why local or regional variation has received relatively little attention in educational research.

Finland is also well known for its educational system that produces highly equal educational outcomes for its students. International assessments have shown that while having a reasonably large proportion of high performers, Finland has relatively few students at the low-achieving end. Despite the good overall student performance, recent research has revealed inequalities in the Finnish educational system. For example, there are statistically significant differences in educational outcomes for many core subjects between the two parallel educational systems in Finland, i.e. between the Swedish-language and the Finnish-language schools, in favor of the latter (see e.g. Harju-Luukkainen & Nissinen, 2011). These differences can be found in both national and international assessments (Harju-Luukkainen & Hellgren, 2013). There are also statistically significant differences and regional variation between different parts of Finland (Harju-Luukkainen & Vettenranta, 2013; Harju-Luukkainen & Nissinen, 2011). We have suggested (Harju-Luukkainen & Vettenranta, 2013) that this is partly due to the local cultural factors involved.

In this article we examine the Finnish TIMSS 2011 data in the light of a 2-stage linear model for science performance. The model deals with the distribution of explanatory factors and random school variables. The regional variation and grouping of performance, together with relevant background factors, are studied by means of a spatial statistical method called kriging (e.g. Isaaks and Srivastava, 1989; Brimicombe, 2000). Plausible values, background factors and their standard errors are estimated at the nodes of a square grid of 10 km x 10 km covering the whole country. The estimation is based on the 12 nearest neighbors (TIMSS schools) weighted by distance. Corresponding contour maps are produced for visual observation. As a statistical method kriging provides more precise information about the regional variation of useful indicators.

Our study focuses particularly on the influence of local culture on student achievement as examined by means of the kriging method. In this paper we take a wide meso-perspective on education and learning and address these wider social contexts in the light of kriging and resulting contour maps. We assume that young people are generally bound up with their living environment in many ways. For example, different mental functions develop in interaction in social, historical, cultural and institutional contexts. We think that this cultural interaction in different areas localizes the learning outcomes of individuals (see e.g. Bernelius, 2011).

CULTURAL APPROACH TO EDUCATIONAL OUTCOMES

In many studies educational outcomes have been associated with cultural factors (Carbonaro, 1998; Israel et al., 2001; Sun, 1999; Schlee et al., 2009; Bernelius, 2011). Quite often the focus has been on how the family or a specific community influences the individual's development in terms of social capital. Here the focus has been often on the family, but larger social settings like communities have got less attention. Especially Moss, Girard and Haniford (2006) have

pointed out that interpretations of student test performance must be made with attention to the local context. Therefore understanding the local special characteristics of the youths is of importance (see Morrow, 1999).

The term “social capital” can be traced back to John Dewey’s writings and since then it has been used in various studies in economics, sociology, political science and education (see Ferguson, 2006). Lacking a single generally agreed definition the term can nowadays have many definitions, interpretations, and uses, and is therefore applied to a broad range of outcomes to be explained. This has probably led also to its popularity in many research fields.

In this paper we see social capital as collective benefits that individuals achieve when they are interacting with each other. We think that social networks have an impact on people involved in them. On the one hand, the culture we live in is connected with our social capital. On the other hand, different networks have different cultures, which produce different types of social capital. This in turn influences, for example, students’ learning situations. It is difficult to define what culture is, how a particular culture influences individuals and how big of an impact it has on their educational outcomes. Rothan and Goodwin (2011, 698) argue that social capital is about relationships, it is best seen as a property of individuals and it can also have both positive and negative outcomes. This means that all social networks do not give individuals the same benefits. According to Plagens (2011, 40), this is the reason why we can find different school performance in different networks.

Family plays a central role in student achievement. Castillo et al. (2011) detected a strong connection between parental educational/occupational level and the cognitive performance of Spanish adolescents. Also Israel et al. (2001) found out in their longitudinal study that family’s social capital played a central role, while also community’s social capital helped youths to excel. Similar findings were reported by Sun (1999). According to Sun, the community’s social capital is consistently associated with performance, even after controlling for family’s social capital and demographic factors. Even though some contextual effects were modest in magnitude, they were highly consistent in pattern and associated to the performance of students in the community.

This is something that is also evident in the international PISA 2009 results, where the parents’ index of economic, social and cultural status (ESCS) correlates strongly with student achievement. In Finland the ESCS index explains approximately 10 percent of the variance in students’ reading literacy scores (OECD, 2010; Harju-Luukkainen & Nissinen, 2011).

DATA SOURCES AND METHODS

In this study we draw on the Finnish TIMSS 2011 science literacy data with related test scores for eighth-grade students’. The framework and detailed science results of the TIMSS study are reported in two international publications (Martin et al., 2012; Mullis et al., 2009).

The Finnish TIMSS 2011 data comprises answers from altogether 4266 students and 145 schools, of which 3890 students and 136 schools are included in the final statistical model presented in this paper. The science score points were used as an outcome variable in the model design, while student background variables, school characteristics and aggregated student background variables were used as explanatory variables. A hierarchical two –stage linear modeling was applied, due to the data structure. In this modeling, random school

intercepts were used to describe regional variation between schools and random slopes were used to describe the explanatory power of different variables on student performance. A number of student-level variables were aggregated into school-level averages, so that different level effects could be separated. Student and school weights were used in the estimation. However, plausible values were not used here, because we were not particularly interested in error rates and variation at the population level, but rather in observations about regional differences in terms of student background and performance as social indicators.

To find out possible regional or local variation in school-based observations, we applied the so-called kriging method. Kriging is a geostatistical interpolation method based on the statistical relationship among the measured points' spatial autocorrelation. Kriging weights the surrounding measured values to derive predictions for unmeasured locations according to the distance between measured points, the prediction location and the overall spatial arrangement among measurements (McCoy & Johnston, 2001). In this study, plausible values from TIMSS 2011 data for science literacy, explanatory and random factors in the model and their standard errors were estimated at the nodes of a square grid of 10 km x 10 km covering the whole country. The estimation was done by kriging based on the 12 nearest neighbors (schools that participated in the TIMSS study) weighted by distance. School averages and school-specific indices were used in that estimation. Predictions were weighted by distance only, not by any student or school weights.

On this basis, corresponding contour maps were produced for visual observation. This method allowed us to remove the effect of individual students and schools from the spatial variation analysis, and observe the pure regional variation. The final results are surfaces that indicate a predicted value for a randomly located school's randomly selected student for the observed factors. In other words, it answers the question, "If there were a school in that location, what would be the expectation value for a student in that school?"

It is also important to note that the color of the different areas or raster cells do not tell anything about the significance of difference between the areas. Statistical significance of the difference between predictions can be estimated by the prediction standard errors calculated during the kriging process. For each 10 by 10 kilometers raster cell, a prediction value and related standard error were estimated, and thus the significance of difference between two predictions can be determined.

RESULTS

In this section we present a science performance model based on the Finnish TIMSS 2011 data (Tables 1 and 2). With the help of this model we will explain which socioeconomic background variables have an effect on student achievement in science at student and at school level. Later on we will take a closer look at regional variation in Finland as displayed by contour maps based on the kriging method. The maps help visualize the varying effects of certain variables in different parts of Finland.

In order to separate possible contextual school-level effects from individual students' conditions, aggregated student background variables were added to the model. Due to the large number of missing answers in parent's educational status (range 1 thru 7), the "I don't know" responses were coded with the scale value 2.5 according to the group mean and standard deviation. The totally missing responses were coded as 1. The final science score model is presented in Table 1. Explanations for the variables and their variation are presented in Table 2.

When the variance in the data was explained by the intercept only, 15.5% (502.6) of the total variance (3226.2) was between-school variance. In the estimated full model, between-school variance is 246.0 and between-student variance 2243.7. Thus, the model explains 49.0% of the between-school variance and 31.5% of the between-student variance. Random slopes were not applied in the final model.

According to the results at the school level (Table 1), those schools that emphasize academic success can have over 20 points higher science score averages. Moreover, parents' educational status can raise the average by 25 score points, whereas the possession of a computer and television (students' own) can decrease the science score average by as much as 32 points. Students' positive attitude in school towards biology and earth science can increase average science performance by up to 20 score points.

Table 1. Fixed parameter estimates of the science performance model for the TIMSS 2011 eighth-grade data in Finland.

Fixed Effect	Coeff.	Std err.	t-ratio	Appr. d.f.	p-value
Intercept	463.12	17.67	26.20	131	<0.001
School level					
Sch_emp	3.03	0.97	3.12	131	0.002
Aggregated					
Par_ed_sch	5.69	1.70	3.33	131	0.001
Tv_and_pc_sch	-23.60	6.48	-3.64	131	<0.001
Bio_earth_sch	10.64	4.65	2.28	131	0.024
Student level					
Nbr_books	10.62	0.87	12.16	3748	<.001
Tv_and_pc	-8.13	1.06	-7.64	3748	<.001
Mus_instr	13.64	1.62	8.38	3748	<.001
Par_ed	3.39	0.24	13.66	3748	<.001
Phy_chem	16.12	1.00	16.12	3748	<.001
Bio_earth	6.12	0.93	6.57	3748	<.001

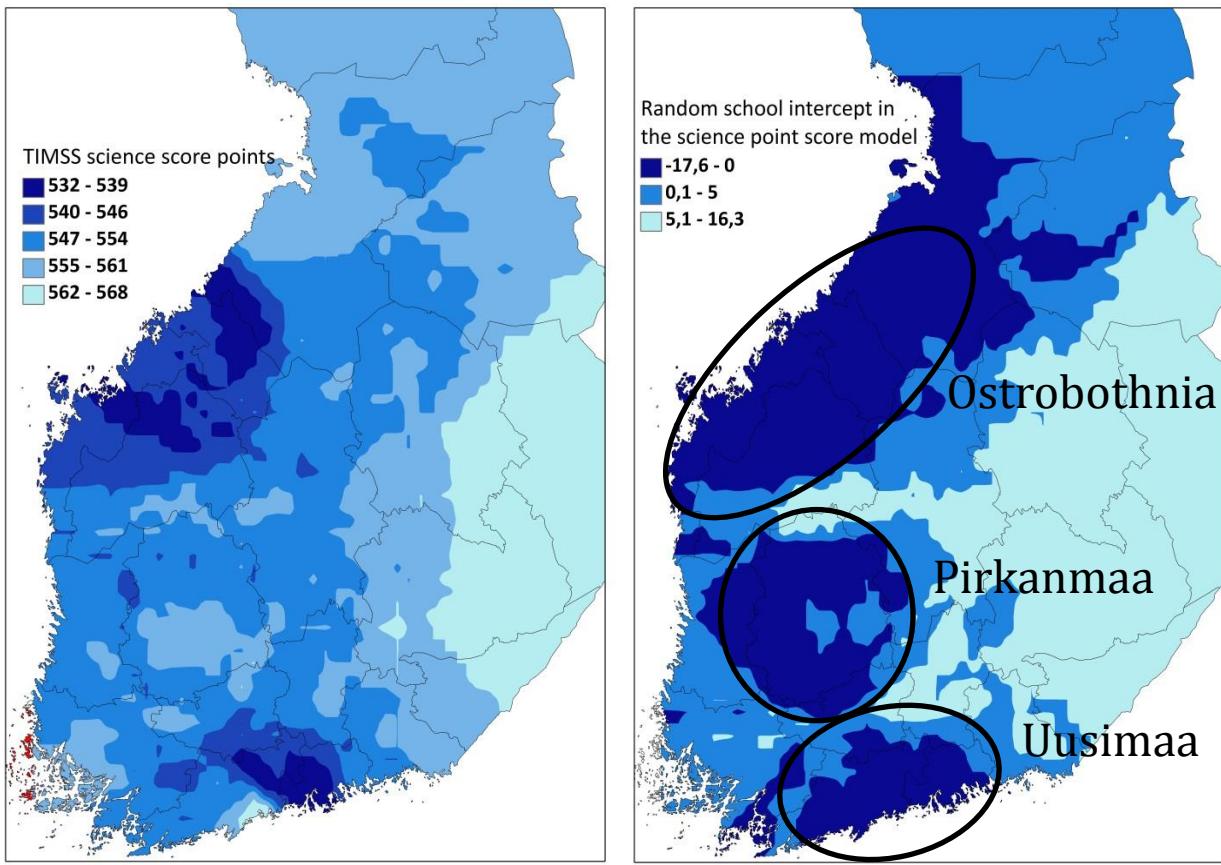
Table 2. Range, mean, and standard deviation for variables used in the science performance model.

Variable	Min	Max	Mean	Sd.
Sch_emp = School emphasis on academic success	6.59	14.16	10.42	1.36
Par_ed_sch = Parents' educational level, school mean	4.81	9.82	7.34	0.94
Tv_and_pc_sch = Possession of tv and/or pc of student 's own, school mean	0.31	1.75	1.15	0.23
Bio_earth_sch = Students engage, enjoy and have confidence in biology and earth science, index, school mean	-1.05	0.98	0.00	0.35
Nbr_books = Number of books at home, categorical variable	1.00	5.00	3.29	1.17
Tv_and_pc = Possession of tv and/or pc of std. own, (neither = 0, either = 1, both = 2), categorical variable (centered in the model)	0.00	2.00	1.15	0.79
Mus_instr = Family having musical instrument (1) else (0)	0.00	1.00	0.61	0.48
Par_ed = Parents' educational level, combined categorical variable (centered in the model)	2.00	14.00	7.34	3.00
Phy_chem = Students engage, enjoy and have confidence in physics and chemistry, index	-3.34	3.52	0.00	0.99
Bio_earth = Students engage, enjoy and have confidence in biology and earth science, index	-3.99	3.63	0.00	0.99

At student level, number of books at home, having a musical instrument at home, parents' higher educational status and positive attitude towards science increased the test scores. In turn, having own television and/or computer decreased student's science performance. A positive personal attitude towards science together with peers can increase science scores by as much as 110 points, compared to a student and a school with corresponding negative attitudes.

Regional variation

The kriging method helps illustrate the spatial distribution of student performance in the TIMSS assessment in Finland (Figure 1a) and show how the random school intercepts are distributed (Figure 1b). The model described in Tables 1 and 2 can explain 31.5% of between-student variance and 49% of between-school variance in the students' science scores. From the random school intercepts in figure 1b, we can detect effects of other underlying variables in different parts of Finland. This visualization of the distribution of TIMSS science scores, added with the random school intercepts, gives us a better understanding not only about the predictive power of the variables in the model, but also about how they affect in different parts of Finland.



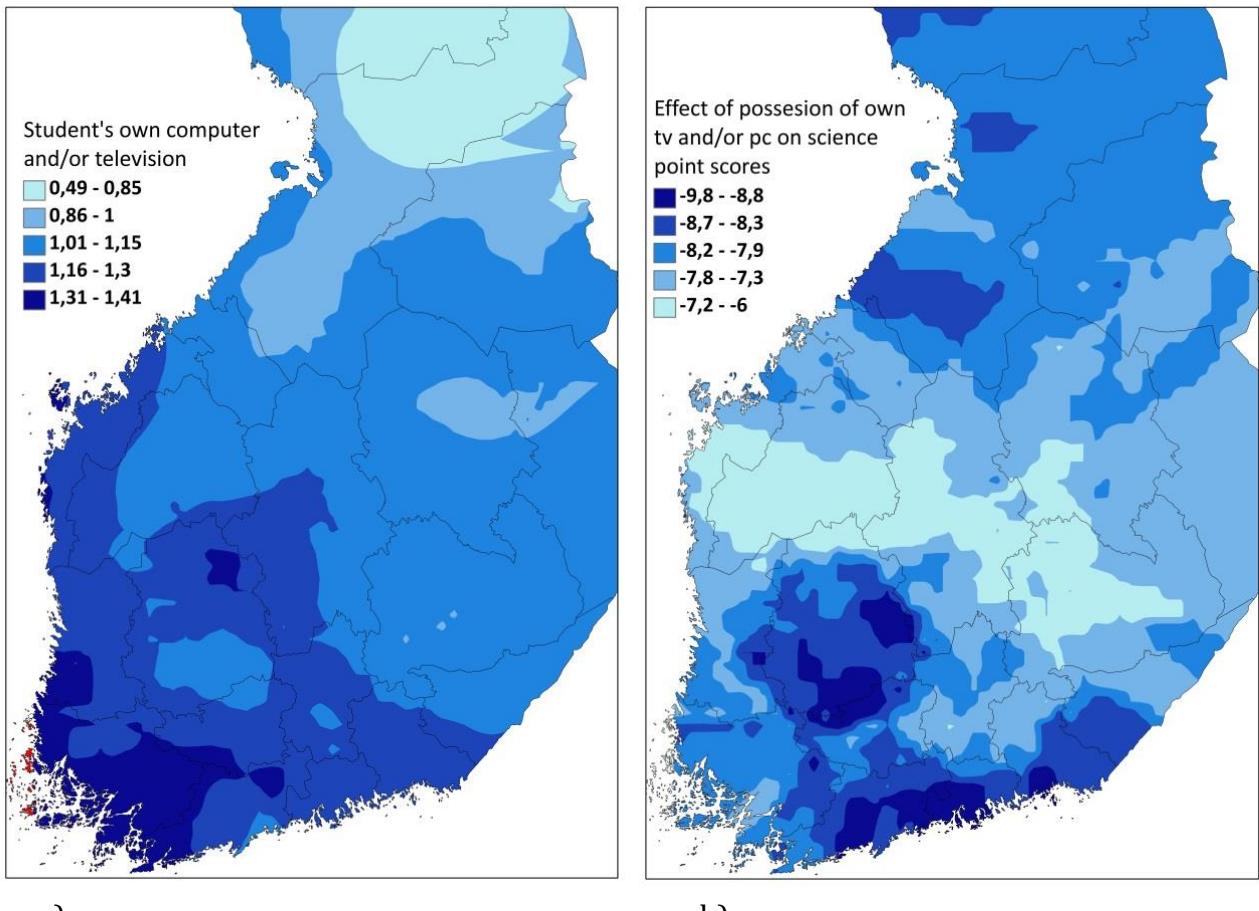
a)

b)

Figure 1. Regionally smoothed predictions (kriging) of the TIMSS science scores (a) and smoothed random school intercepts in the outlined model (b).

In Figure 1a, we can see a clear (20 – 35 points) and wide-ranging difference in science performance between Eastern Finland and Ostrobothnia. We can also see that the outlined model (in Tables 1 and 2) cannot remove the regional variation with the variables applied. In Figure 1b, random school intercepts are negative in Ostrobothnia, Pirkanmaa and Uusimaa. This means that the model, on average, overestimates the predicted science test scores in those areas, while producing underestimated results for Eastern Finland.

With the same method, we can also take a closer look at the explanatory variables in the model presented in table 1. An example of this is illustrated in Figure 2. In Figure 2a, the proportion of television and computer owning students decreases from southwest towards northeast. This trend is not manifested, however, as an effect on the science scores or the random intercept in Figure 1. Furthermore, the distributions of effects as depicted by the random slopes in Figure 2b are the strongest in Pirkanmaa and Uusimaa and the weakest in South Ostrobothnia. This indicates that for some reason the negative effect of ICT possessions varies across these areas.



a)

b)

Figure 2. Regionally smoothed predictions of the average possessions of students own television and computer in schools (a) and the strength of effect (random slope) of possessions on the science scores (b).

DISCUSSION

It is well known that family's economic, social and cultural status correlates with academic achievements to some extent. Usually we design different statistical models to present socioeconomic variables and their explanatory power on the variance at school and student level. These models, unfortunately, are not successful in explaining the whole phenomenon – due to the fact that socioeconomic factors and local cultures, for example, are intertwined in complex ways. In this paper we presented a science performance model based on the Finnish TIMSS 2011 data. Further we described a method that can help us reveal some, perhaps hitherto hidden dependencies among educational variables.

For long we have been able to find correlations between student behavior and academic achievement. We can study differences between schools, their conditions and results and we can study the common characteristics within the Finnish school system, but we have been less capable to study if there are some regional consistencies that can indicate some kind of local special characteristics affecting the educational climate and outcomes.

Two key concepts in this context are social interaction and social capital. However, we must bear in mind that social interaction takes place on different levels, and social capital can develop and appear in several stages. Students' life and degree of educational devotion are affected mostly by their own families. But as can be seen in the model in this study, also a communal attitude to the education can affect individual students' performance, or at least these things are correlated. The communal level of parental education also correlates with educational achievement at student level. These features can vary between schools and neighborhoods, but can we identify relevant local characteristics shared by schools as well?

In order to make reasonable political decisions concerning education, we should have more detailed information about the distribution of the performance and the regional variation of explanatory factors. This method can give needed new perspective for educational policymakers, decision makers and local authorities.

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