PISA 2012 mathematics achievement: Interpreting the results in the context of individual and contextual predictors

Isidora Micić (isidora.jazz@gmail.com)
Laboratory of developmental psychology, University of Belgrade

Jasmina Šljivić (jasmina.sljivic97ca@gmail.com)
Laboratory of developmental psychology, University of Belgrade

Lea Gorišek (leag98@gmail.com)
Laboratory of developmental psychology, University of Belgrade

Ljubica Conić (ljubica1719@gmail.com)
Laboratory of developmental psychology, University of Belgrade

Svetlana Pavlović (pavlovic.sc@gmail.com)
Laboratory of developmental psychology, University of Belgrade

Abstract

The achievement of Serbian students in PISA 2012 assessment of mathematical literacy is statistically significantly below the OECD average. The aim of this research was to reveal the complex relations between the individual characteristics of students, the dimensions of teacher-student interaction, the socio-demographic context and achievement. In order to examine the relations between those dimensions, a path model was constructed, based on the secondary analysis of 2012 PISA data. The path model parameters were acceptable (*CFI* = .92; *RMSEA* = .049; *TLI* = .88), indicating that the model fits the existing data. Self-efficacy has been singled out as the best predictor of students' achievement.

Keywords: achievement, mathematics, PISA, path model, self-efficacy

Introduction

The primary aim of the Programme for International Student Assessment (PISA) is to assess the degree to which the students who are nearing the end of their general education have mastered the competences relevant for continuing their education and participating in social life (Pavlović Babić & Baucal, 2013). The central concept of PISA testing is literacy, which is assessed in three key domains: mathematics, reading and science. The "central" domain in the 2012 cycle was mathematical literacy, defined as *an individual's capacity to formulate, implement and interpret mathematics in different contexts* (OECD, 2013; Pavlović Babić & Baucal, 2013). Mathematical literacy entails mathematical reasoning and the use of mathematical concepts, procedures, facts, and "tools" in order to describe, explain and predict a certain phenomenon. It serves to help people recognize the role of mathematics in the world and make well-based judgements and decisions that are necessary to constructive, interested and reflexive citizens (OECD, 2013).

In 2012, mathematical literacy achievement of Serbian students was 449 points on average. This is significantly below the OECD average, i.e. approximately one-half of a standard deviation lower than the average international achievement (OECD, 2013).

Besides student achievement on knowledge tests, PISA also provides data on the way students perceive and assess their own motivation for learning, learning strategies, success in fulfilling school requirements, their attitudes towards school and future education. The relations between these variables and mathematics achievement have been the subject of many studies and primary PISA results (Pavlović Babić & Baucal, 2013). It has been shown that intrinsic motivation for mathematics is the key factor to success in this field, along with the factors such as ability, understanding the instructions and school and home climate (Walberg & Uguroglu, 1980, in Gottfried, 1985). A meta-analysis of 26 studies has found that very frequently there is a negative correlation between anxiety and achievement, which is consistent across genders, grades and ethnic groups (Ma, 1999, in Radišić & Videnović, 2016). However, there are also some results indicating that certain students can profit from their own anxiety because it encourages motivation and achievement (Pekrun et al., 2007, in Radišić & Videnović, 2015).

Aim of the study

The studies so far have mainly focused on analysing the isolated effects of a small number of variables, while in this research we tried to analyse multiple interactions between the variables that both influence one another and the achievement. The aim of the research was to investigate the relations between the individual and socio-demographic characteristics of students, their experience with mathematics and teacher-student interaction and mathematics achievement in PISA testing.

Method

The sample included 4684 students from Serbia who participated in PISA testing in 2012. A secondary analysis of PISA data was performed and the Path model was constructed. The model consisted of four groups of variables – 1. Individual (mathematics anxiety, mathematics intentions, mathematics self-efficacy, intrinsic motivation, instrumental motivation, attributions of failure); and 2. Socio-demographic characteristics of students (ESCS, ICT resources, use of ICT in mathematics lessons, home possessions, highest parental occupational status); 3. Teacher-student interaction (disciplinary climate, teacher behavior: formative assessment, teacher behavior: student orientation, teacher behavior: teacher-directed instruction, teacher support, cognitive activation in mathematics lessons, mathematic teachers support, teacher student relations); and 4. Experience with mathematics (perseverance, openness for problem solving, experience with pure mathematics tasks in school, familiarity with mathematical concepts).

Results

The path model parameters were satisfactory (*CFI* = .92; *RMSEA* = .049; *TLI* = .88), which indicates that the model fits the existing data. Model is presented in Appendix 1.

Mathematics self-efficacy (as an individual characteristic) was singled out as the best predictor of student achievement (Table 1). The model shows that *Motivation* does not have a direct effect on achievement, but rather that it exerts influence via *Self-efficacy*. The variable *Cognitive activation of students*, belonging to the domain of teacher-student interaction, influences achievement in the same way, while *Teacher behaviour: Student orientation* had a negative effect on achievement. In addition to these, *Familiarity with mathematical concepts* (domain of experience) and the *Highest level of parental occupation* (domain of socio-demographic characteristics) had a positive effect on achievement via *Self-efficacy*.

Besides Self-efficacy, *Mathematics anxiety* (as an individual characteristic) was another variable which had a direct (but negative) influence on achievement. Students' anxiety was higher if they had lower *Mathematics intentions and* external attribution to failure and were less familiar with math concepts.

In addition to an indirect effect, F*amiliarity with mathematical concepts* also has a direct positive effect on achievement, and hence the students who are more familiar with mathematics concepts have a better achievement in PISA testing.

When it comes to socio-demographic characteristics, the variables *Highest level of parental occupation* and *ICT resources* exert a direct positive effect on achievement.

Discussion and Conclusion

The aim of the current analysis of the PISA data was to obtain insight into the complex relations between numerous individual and contextual factors and mathematics achievement. *Self-efficacy* was singled out as the key dimension, while *Motivation* did not have a direct effect on achievement. Self-efficacy was assessed via student responses on how much they felt they were capable of solving various mathematics problems, and, in practice, the obtained link indicates that the more students believe in their abilities to solve mathematics tasks, the better will their mathematics achievement be. The absence of a direct link between motivation and achievement can be explained by the decline in intrinsic motivation for doing mathematics with age, as has been shown in previous studies (Wigfield& Eccles, 2000). We can assume that at this age motivation has already become an integral part of the experience of students' self-efficacy, so it consequently influences self-efficacy, but not achievement.

It has also been shown that the more anxious students are about mathematics, the lower their achievement. This result is in line with previous findings that anxiety negatively affects achievement in situations which demand a deeper cognitive processing of content, such as PISA tasks (Ahmed et al., 2013; Pekrun, 2006; Radišić, Videnović, &Baucal, 2015).

Mathematics anxiety is influenced by *Students' attribution to failure*, but also by their intentions for further engagement with mathematics. The attribution to failure refers to the extent to which students attribute internal responsibility for achievement to themselves, while the intention to pursue mathematics implies students' desire to deal with something that is related to mathematics in the future. The direction of these influences is clear – the more students attribute failure to themselves, the more anxious they will be, while, on the other hand, the higher their intentions to pursue mathematics, the less prominent mathematics anxiety will be.

When it comes to the domain of teacher-student interaction, the results show that cognitive engagement is the most important for students' achievement, i.e. the extent to which the teacher encourages deeper information processing and independent solving of complex problems. The studies that emphasize pedagogical support as one of the most important dimensions of interaction (Pianta et al., 2008) additionally confirm this finding.

The negative direction of the relationship between *Self-efficacy* and *Teacher behaviour: Student orientation* implies teachers' orientation towards individualized forms of work, non-typical for our education (e.g. Differentiates between students when giving tasks).

The impact of *Familiarity with mathematics concepts* on *Self-efficacy* indicates that the students who are more familiar with math concepts assess that they feel more capable of solving mathematical tasks. This is in line with Bandura's theory of self-efficacy, which argues that one of the main sources is precisely previous experience with mathematics (Schunk&Pajares, 2002). *Familiarity with mathematics concepts* also has a direct effect on achievement, which means that, besides self-efficacy, knowledge plays an important role as well. The children who do not have the level of knowledge of the concepts demanded by PISA tasks spend more resources on recalling, which affects their achievement.

The results also indicate that children of parents with higher occupations demonstrate higher self-efficacy in solving mathematical tasks. The parents with higher occupations have more knowledge, as well as all other resources to support the learning of mathematics and their children's education, which in turn contributes to the development of positive attitudes towards mathematics and the feeling of self-efficacy (Baucal, 2012; Chiu &Xihua, 2008; Baucal&PavlovićBabić, 2010).

The constructed model shows that "individual characteristics", which include self-efficacy, attribution to failure, anxiety, intentions related to mathematics and intrinsic and extrinsic motivation, contribute most to explaining the achievement on PISA tests. Self-efficacy proved to be the best predictor of achievement on PISA tests.

These results indicate that student achievement rely largely on their socioemocional skills, like self-efficacy, motivation, attribution of failure, anxiety. Since anxiety is a significant part of everyday school life and our study showed negative impact on achievement, it is necessary to put more attention on students academic emotions. Having in mind that development of socioemotional skills and emotional wellbeing of students are one of the key educational goals in the 21st century, teacher roll should not be just in transferring math knowledge, but also to support students' socioemotional learning. Besides an appropriation of math knowledge, math class should be also an opportunity for teachers to help improve students' self-awareness, self-regulation and learning strategies in order to have higher self-efficacy, be more motivated and engaged in learning math, and to better regulate negative emotions toward math. Organising interesting, pragmatic and engaging class activities would enable both teachers and students to be active participants in the teaching/learning. Furthermore, familiarity with mathematical concepts is a strong predictor of mathematical achievement which indicated that teachers should make an additional effort to enable students to better understand the relationship between math knowledge they learn in school and everyday life and how math knowledge could empower students to cope with everyday challenges.

References

Ahmed, W., van der Werf, G., Kuyper, H. & Minnaert, A. (2013). Emotions, Self-Regulated Learning, and Achievement in Mathematics: A Growth Curve Analysis. J*ournal of Educational Psychology 2013,* Vol. 105(1), 150–161.

Baucal, A. (2012). Uticaj socio-ekonomskog statusa učenika na obrazovna postignuća: direktni i indirektniuticaji. Psihološka istraživanja, 5 (1), 5-24.

Baucal, A. & Pavlović Babić, D. (2010). Kvalitet i pravednost obrazovanja u Srbiji: obrazovne šanse siromašnih: analiza podataka PISA 2003 i 2006. Ministarstvo prosvete Republike Srbijei Institut za psihologiju, Beograd.

Chiu, M. M., & Xihua, Z. (2008). Family and motivation effects on mathematics achievement: Analyses of students in 41 countries. Learning and Instruction, 18(4), 321-336.

Gottfried, A. E. (1985). Academic intrinsic motivation in elementary and junior high school students. *Journal of Educational Psychology*, *77*(6), 631-645. DOI:10.1037/0022-0663.77.6.631

Norwich, B. (1987). Self-efficacy and mathematics achievement: A study of their relation. *Journal of Educational Psychology, 79*(4), 384-387.http://dx.doi.org/10.1037/0022-0663.79.4.384

OECD (2013). *PISA 2012 Results: Ready to Learn: Students' Engagement, Drive and Self Beliefs (Volume III),* PISA, OECD Publishing. Preuzetosa: http://dx.doi.org/10.1787/9789264201170-en

Pajares, F. & Graham, L. (1999). Self-Efficacy, Motivation Constructs, and Mathematics Performance of Entering Middle School Students, *Contemporary Educational Psychology 24*, 124–139.

Pianta, R. C., La Paro, K. M. & Hamre, B. K. (2008). *Classroom Assessment Scoring System (CLASS) Manual*, Pre-K. Baltimore, MD: Brookes Publishing.

Pavlović Babić, D., & Baucal, A. (2013). Inspiriši me, podrži me, PISA 2012 u Srbiji: prvi rezultati [Inspire me, support me, PISA 2012 in Serbia: first results]. Beograd: Institut za psihologiju Filozofskog fakulteta u Beogradu, Centar za primenjenu psihologiju.

Pekrun, R. (2006) The Control-Value Theory of Achievement Emotions: assumptions, corollaries, and implications for educational research and practice. *Educational Psychology Review,* Vol. 18, 315-341. http://dx.doi.org/10.1007/s10648-006-9029-9 Retrieved March 18. 2012.

Radišić, J. & Videnović, M. (2015). Matematička anksioznost učenika u Srbiji u svetlu rezultata PISA 2003 i 2012. U Radišić, J. &Buđevac, N. Sekundarne analize istraživačkih nalaza u svetlu novih politika u obrazovanju, 159-172. Beograd: Ministarstvo prosvete, nauke i tehnološkog razvoja.

Radišić, J., Videnović, M. & Baucal, A. (2015). Math Anxiety - Contributing School and Individual Level Factors. *European Journal of Psychology of Education,* Vol. 30, No. 1, 1–20.

Schunk, D. H., & Pajares, F. (2002). The development of academic self-efficacy. U *Development of achievement motivation* (pp. 15-31). Academic Press.

Wigfield, A., & Eccles, J. S. (2000). Expectancy–value theory of achievement motivation. *Contemporary educational psychology*, *25*(1), 68-81.

Appendix 1: The full path model