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Mathematics, Gender and the Meaning in Life: The Results of PISA testing in Bosnia and Herzegovina

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Abstract: The Program for International Student Assessment (PISA) was developed by the Organization for Economic Cooperation and Development to measure students' knowledge and skills needed for today's society. PISA is a large-scale assessment of 15-year-old students in reading, mathematics, and science. In this analysis of PISA data from Bosnia and Herzegovina (BIH), we examined the relationship between gender, mathematics achievement, and perceived meaning in life in BIH students. The sample for this analysis comprised 6480 students (3148 females and 3332 males). The results of the analysis revealed a small but statistically significant, negative relationship between mathematics and the student's perception of the meaning in life. Boys achieved higher scores in mathematics than girls, but the difference was relatively small. In addition, boys' rating of meaning in life was higher than that of girls. Knowing what factors influence mathematical achievement might help educators create better intervention programs. In conclusion, we provided some possible explanations for these data.

Keywords: *Adolescents, Bosnia and Herzegovina, mathematics, meaning in life, PISA testing.*

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Introduction

The Organisation for Economic Co-operation and Development (OECD) created the Program for International Student Assessment (PISA) to measure the 15-year-old achievements of students in three broad areas: reading, science, and mathematics. In addition to assessing educational attainments in these three core subjects, PISA includes detailed questionnaires related to students' backgrounds, attitudes, teacher perceptions, school characteristics, and many other factors that might affect students' achievement. These questionnaires are completed by students and school principals. The age of 15 years was determined as the age at which children finish their compulsory education in most countries.

In 2018, students from 79 countries (37 OECD countries and 42 partner countries) participated in PISA testing. For the first time since the PISA testing began, Bosnia and Herzegovina (BIH) participated in this large-scale assessment. This is very important as PISA results can serve as a rationale for governments worldwide to initiate various educational reforms and thus improve their educational system (Keita Takayama, 2010; Tan, 2019). PISA testing is regarded as a reliable instrument for benchmarking student performance across the world, and PISA results influenced policy reform in the majority of participating countries/economies (Breakspear, 2012). Besides having a large effect on governments, PISA also greatly impacts the media and the general public (Feniger & Lefstein, 2014). Improving PISA ranking has become an educational priority in many countries as the stakes are high for governments. They are to be blamed for low scores and take credit when results improve (Sjøberg, 2015). Given such importance of PISA testing, its results must be carefully and meaningfully interpreted. Some cautionary notes are related to sampling procedures and exclusion rates (Sjøberg & Jenkins, 2022); thus, the educational comparison between the countries might not provide accurate insight into educational accomplishments. These are not the only complaints regarding PISA testing. Some authors have cautioned against the OECD system as not being transparent and have instead advocated for an alternative mode of social inquiry (Araujo et al., 2017).

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As stated above, the PISA assessment focuses on three broad subjects: reading, mathematics, and science. Each circle of testing has one subject as a major focus; in 2018 the major focus was on reading. Unfortunately, there are not many studies and analysis conducted on the topic of PISA 2018 results in BIH. One exception is the study conducted in relation to reading achievement and its predictors in students from BIH. The results of that study showed that metacognition has a substantial and statistically significant effect on reading in BIH students (Memisevic & Cehic, 2022). However, to date, no such studies have been published in BIH in relation to PISA mathematics achievement.

Finding out which factors best predict educational attainment is one of the most important segments of PISA testing. Knowing these factors might help in improving educational outcomes and fostering positive educational reforms throughout the world. Thus, it is not surprising that a plethora of studies aimed at discovering what factors (cognitive and non-cognitive) lead to better educational outcomes. Self-beliefs were the best predictors of individual student achievement, even better than socioeconomic status (Lee & Stankov, 2018). On the other hand, socioeconomic status was the strongest predictor of country-level student achievement. Additionally, factors such as teacher quality, and (de)centralization of the educational system were also found to impact PISA results (Argina et al., 2017). Many factors were found to affect reading achievement. For example, a sense of enjoyment in reading is correlated with reading achievement (Cheema, 2018). Attitudes towards reading and meta-cognitive strategies also significantly affect PISA reading results (Keskin, 2014).

A plethora of international studies was published in relation to factors leading to mathematical achievement. In the PISA framework, mathematics is defined as “the capacity to identify and understand the role that mathematics plays in the real world, to make well-founded judgments, and to use and engage with mathematics in ways that meet the needs of that individual’s life as a constructive, concerned and reflective citizen” (OECD, 2004, p.26). Mathematics skills rely on mastery and integration of many simpler numerical processes and concepts (Lyons et al., 2014).

Studies have found that personality, attitudes, and well-being matter more for mathematical achievement than background variables (Pipere & Mieriņa, 2017). Gender, self-confidence, and socio-economic status are some of the factors affecting mathematics scores (Demir et al., 2010). In addition, math self-efficacy was found to be the best predictor of mathematics performance in the USA and Hong Kong (Liu, 2009). Studies have also shown that attitudes towards math are related to math abilities (Fisher et al., 2012).

Much research has been directed at examining gender differences in mathematics achievement. It seems that differences vary across mathematics domains. Liu and Wilson (2009b) have found that the largest difference and male advantage was for complex multichoice items. However, even in that area, the effect size of difference was rather small with Cohen’s d = 0.19. Another study analyzed PISA math achievement in Ireland, and the results indicated males outperformed females on all mathematics subscales. Again, the difference, although statistically significant, was rather small in terms of the effect size, that is 1/6 of the standard deviation (Close & Shiel, 2009). A male advantage in math scores was also found in the USA and Hong Kong (Liu & Wilson, 2009a). Contrary to most examined countries, there are some exceptions to these results indicating male advantage in mathematics. An analysis of Iceland PISA results has shown that female students achieved higher mathematics results than male students (Halldórsson & Ólafsson, 2009). Thus, differences between male and female students obviously depend on cultural contexts, which warrants further scientific investigation.

Thus far, we have mentioned several factors that have an impact on PISA mathematical achievement. Nevertheless, some of the factors for which data were collected in PISA testing were not sufficiently examined in relation to mathematical achievement. One of these factors or constructs is the meaning of life. PISA defines meaning in life as the extent to which 15-year-old students comprehend, make sense of, or find significance in their lives (Steger, 2009). Research has shown a small negative correlation between the construct “meaning in life” and reading achievement (OECD, 2019). meaning in life has been shown to be a protective factor against health risk behaviors and poor psychological health (Brassai et al., 2011). Meaning in life has also been found to be important in the formation of adolescent well-being (Krok, 2018). Well-being is one of the components of mental health, which, in turn, is related to better academic outcomes (Murphy et al., 2015). However, the construct of meaning in life has not been explored in relation to mathematics achievement. Thus, this is the first study to explore PISA mathematics achievement in relation to meaning in life and gender. In addition, this study is aimed to explore whether there are differences in mathematics achievement in 15-year-old students from BIH.

More specifically, in the present study, we set the following research questions:

1. What is the relationship between meaning in life and mathematics achievement in BIH students?

2. Are there significant differences in math achievement between male and female students?

3. Is there a moderating effect of gender on the relationship between meaning in life and mathematics achievement?

4. Are there significant differences in the reported meaning in life scores between male and female students?

Methodology

Procedure

PISA testing in BIH took place from 2nd April to 25th May 2018. As in other countries, OECD was responsible for the sampling procedure. The sample included public and private schools from all Cantons in Federation BIH, Brčko District, and the Republic of Srpska (Džumhur, 2019). The testing length is 2 hours for mathematics, science, and reading tasks. After these tasks are finished, students have 30 minutes to complete a questionnaire about themselves, their homes, schools, and learning experiences. The total time for PISA administration is 3–3.5 hours, with instructions and breaks.

Participants

The entire sample of 15-year-old students from BIH who participated in the PISA testing was 6240 students (3,148 girls and 3,332 boys) from 213 elementary and high schools in BIH. These students attended different grades, and their distribution is shown in Figure 1.

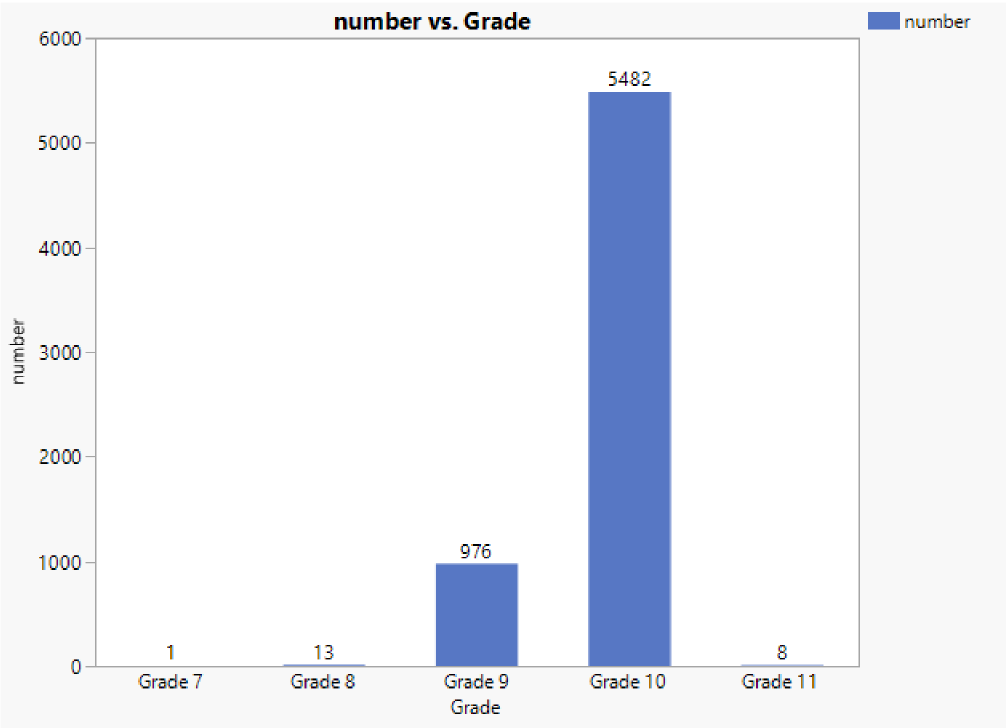

Figure 1. Number of Students by Grade who Participated in PISA Testing

It is important to note that students in Grades 7, 8, and 9 attended elementary school, while the students in Grades 10 and 11 attended high school according to the BIH educational system.

Instruments/Assessments

Mathematics achievement: Mathematics outcomes were assessed in four broad areas: Geometry,

Algebra, Arithmetic, and Probability. PISA employs a system of plausible values that can represent the range of abilities a student might have in mathematics. Plausible values have several methodological advantages compared to classical Item Response Theory as they provide unbiased estimates of population performance parameters (OECD, 2009).

meaning in life was assessed through the following questions:

1. My life has a clear meaning or purpose;

2. I have discovered a satisfactory meaning in life; and

3. I have a clear sense of what gives meaning to my life.

Students were asked to answer whether they agree or disagree with these statements on a 4-point Likert scale (“strongly disagree”, “disagree”, “agree”, “strongly agree”).

These items were combined to create the index of meaning in life whose average value is 0 and standard deviation is 1. Higher positive values in this index mean that the student has a greater sense of meaning in life.

Statistical Analysis

For the first research question, we calculated a Pearson Correlation Coefficient. We next performed an independent t-test on mean score differences in math achievement between male and female students. We conducted regression analysis for the third research question with variables "meaning in life" and "gender" predicting mathematics scores. Lastly, we conducted an independent t-test between male and female students on the meaning of life scores. All tests used an alpha level of .05 as a benchmark for statistical significance. Statistical analyses were performed with the computer program SPSS v.27 for Windows (IBM, 2020).

Results

The results of this analysis revealed a small negative, statistically significant relationship between the meaning of life and mathematics scores. The relationship is shown in Figure 1.

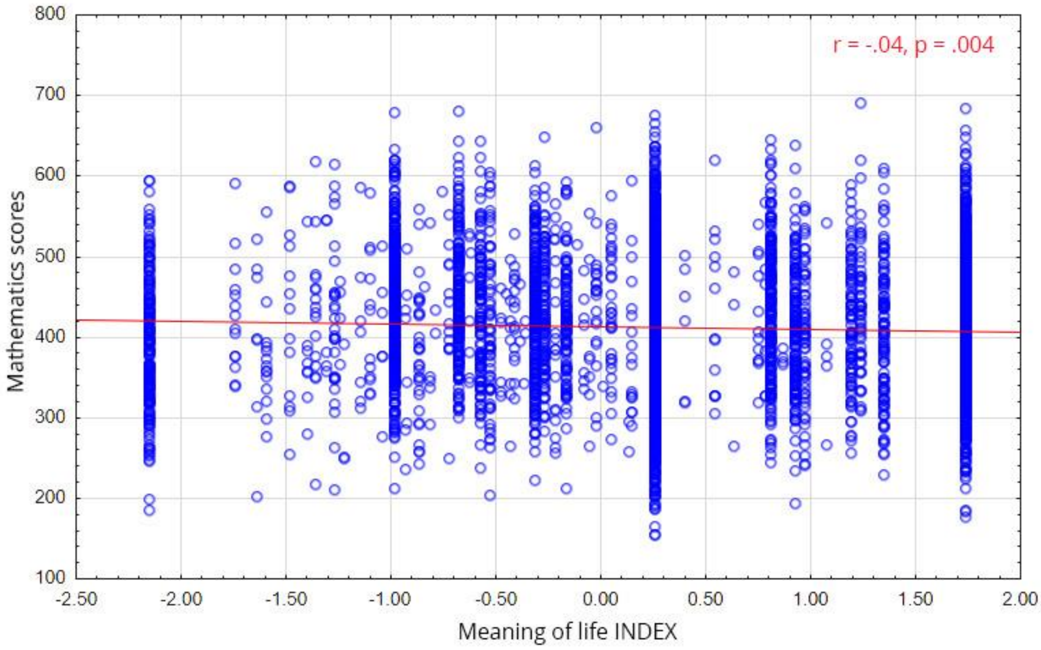

Figure 1. The Relationship Between the Meaning of Life and Mathematics Scores

As can be seen from Figure 1, the relationship between mathematics and the meaning of life is negative and small but still statistically significant. Contrary to our expectations, higher scores in mathematics were related to lower scores in the meaning of life index.

We next conducted an independent t-test to examine the mean differences in math scores between male and female students. These results are shown in Table 1.

Table 1. The Mean Scores of Male and Female Students in Mathematics Achievement

	Mathematics scores M SD	t-test	p	Cohen's d effect size
Boys	409.7 83.1	2.5	.01	0.06
Girls	404.5 81.1			

As can be seen from Table 1, there were statistically significant differences in mathematics mean scores between boys and girls, however, the effect size was rather small, indicating no meaningful differences.

We next created a model predicting mathematics scores from gender, meaning in life index score, and the interaction effects.

Table 2. Factors Predicting the Mathematics Scores

Factor	B	SEB	β	p
Gender	-3.13	1.16	-.04	.007
MIL index	8.71	1.16	.10	<.001
Gender*MIL index	3.90	1.16	.05	.001

Note. R= .014.; MIL- meaning in life.

The model presented in Table 2. is statistically significant (F=29.1, p<.001), but it only captured around 1.4% of the variance in the scores. Although, as such, it cannot be meaningfully used in predicting mathematics scores, it does provide some interesting information. As can be seen from Table 2, there was a significant interaction effect between gender and meaning of life index on mathematics scores. In addition, both main effects of gender and meaning of life were also statistically significant. In order to better illustrate these results, we converted meaning of life scores into dichotomous "low" and "high" meaning of life scores, which are shown in Figure 2.

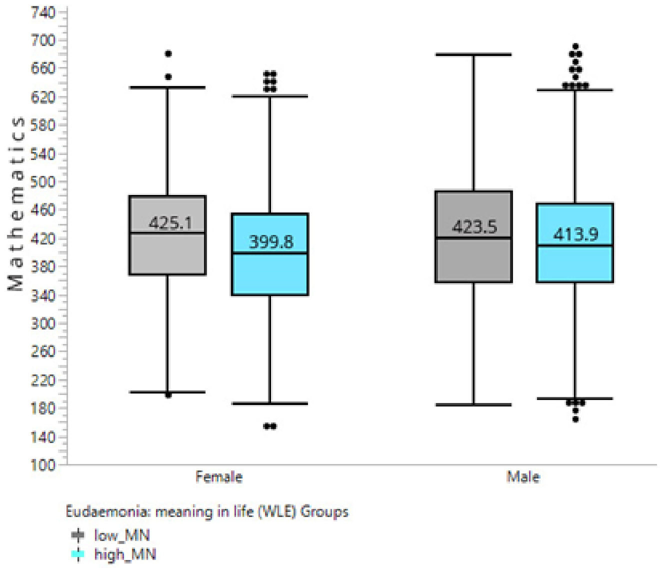

Figure 2. Mean Mathematics Scores of Male and Female Students in Relation to the Level of Meaning of Life Scores

It is evident that math scores were lower in the high meaning of life group than in the low meaning of life group, however this difference was larger in females than in males. Lastly, we examined differences in meaning in life scores in male and female students. These results are presented in Table 3.

Table 3. The Mean Scores of Male and Female Students in Meaning in Life Achievement

	meaning in life M SD	**t-test**	**p**	**Cohen's d effect size**
Boys	0.41 0.96	8.5	<.001	0.21
Girls	0.21 0.92			

As can be seen from Table 3. male students have reported higher meaning in life scores than female students. Besides being statistically significant, the effect size is in the range of small to medium.

Discussion

The goal of the present study was to examine the relationship between the construct of "meaning in life" with mathematics achievement according to the PISA 2018 data in BIH. The relationship was small and negative, although statistically significant. It is important to emphasize that in samples of this size, even the small relationship will be counted as a statistically significant. The relationship is rather small in terms of effect size, which is a more valid measure. However, the direction of this relationship was somewhat unexpected. Higher mathematics scores, lower the perception of meaning in life. Although this trend in scores was reported for reading achievement as well, we expected to find a positive relationship between math scores and meaning in life. Intuitively, mathematics and meaning in life are somehow related to philosophy, which was why we expected to find a stronger and more positive relationship. Some studies have linked the learning of mathematics with the exercise of philosophizing (Hernández & Díaz, 2021). On the other hand, one of the main themes of philosophy is the search for the meaning of life (Nath, 2018; Tartaglia, 2016). Perhaps, this assumption of the relationship between mathematics and meaning in life would be more accurate for older participants. Here we offer several potential explanations for the finding of a lack of relationship. The first one is that the obtained data are accurate and that there is in fact, no relationship between students' perception of meaning in life and mathematics achievement. The second potential explanation is that the PISA construct of "meaning in life" does not correspond to the actual breadth of this concept in the real life. This seems like a reasonable assumption given that meaning in life cannot be captured with only three questions. For example, one of the most widely used meaning in life Questionnaires (MLQ) has 10 items (Steger et al., 2006). The final explanation is perhaps related to the age of the participants. It is a dubious assumption that at age 15, young adolescents can answer whether they have discovered a satisfactory meaning in life. In conclusion, finding a purposeful meaning in life might not help to be better at mathematics, but it is certainly related to many other positive outcomes, such as a decrease in unwanted behaviors (Aladwan et al., 2021) and decrease in internet addiction (Angulo et al., 2021).

The next research question was the comparison of math achievement between male students and female students. In our analysis we found a small male advantage in the PISA math scores. Again, the difference was statistically significant but rather small. The effect size, Cohen's d, was close to zero, or 0.06, indicating a very small effect size. These results have some important implications for the practice. A lot has been written on math-gender stereotypes. Even as early as second grade of elementary school, children believe that math is for boys, on both explicit and implicit measures (Cvencek et al., 2011). Similar findings were found by Passolunghi et al. (2014), who found that both 8th-grade boys and 8th-grade girls associated math with male rather than female gender. Results from our study, along with some other analyses of PISA math results (Halldórsson & Ólafsson, 2009), strongly defy math-gender stereotypes. In another study that examined differences in math achievement of 1st to 3rd elementary grade students in BIH, authors did not find statistically significant differences between boys and girls (Memisevic et al., 2018). In a study by Cheema and Galluzzo (2013), authors have also found that the gender gap in mathematics achievement disappears once factors such as math-specific self-efficacy and anxiety are controlled for. Of course, many studies favor boys in math achievement over girls (Manger & Eikeland, 1998). However, this is not a universal finding. Thus, it is crucial for educational stakeholders to actively work on eliminating math-gender stereotypes. This can be achieved in several ways, such as through the creation of adequate role models, the same treatment of males and females in schools, and the elimination of stereotype threat (Spencer et al., 2016). Lower performance in mathematics in females that is found in numerous studies and PISA analysis (Close & Shiel, 2009; Liu & Wilson, 2009a) is more likely a result of societal stereotypes than any internal characteristics, such as abilities or internalized cultural orientations (Spencer et al., 2016). Various interventions can also impact math-gender stereotypes. One such intervention based on the identity threat model has been shown to reduce math-gender stereotypes and improve math scores in middle school girls (Zhao et al., 2018). Confidence plays an important role in mathematics learning; thus, increasing confidence in girls will also lead to better mathematics outcomes. One strategy that has been shown to be useful in increasing girls' confidence is involving them in school-based research, thus demonstrating their own confidence levels (Jones, 1995). In line with these efficient strategies, educational stakeholders need to be aware of these interventions for reducing math-gender stereotypes and increasing confidence in girls from the early elementary school grades.

Our next research question dealt with the moderating effect of gender on the relationship between mathematics achievement and meaning in life. The results have shown a moderating effect of gender. In particular, this was evident for females. While the level of math achievement in male students was similar across meaning in life scores, the trend was different in female students. Female students with higher perceptions of meaning in life achieved the lowest math results. As there is no theoretical framework for explaining these results, we can assume that this might be because females generally achieved lower results on the meaning in the life index. In relation to meaning in life, female students have reported lower meaning of life results than male students. Research on meaning in life in relation to gender seems to be inconsistent. In a study of Spanish adolescents between the ages of 12 and 19, authors have found no differences between males and females in the meaning of life (García-Alandete et al., 2019). On the other hand, in a group of Hong Kong adolescents aged 12 to 16, the authors found that females achieved higher scores than males in meaning in life (Sun et al., 2016). The female advantage in meaning in life was also found in a study of adolescents in Israel (Hamama & Hamama-Raz, 2019). Given the heterogeneous results of the effect of gender on meaning in life, we can assume that, among other things, it also depends on some cultural factors. Further investigation of these factors is warranted, given the positive effects of meaning in life on some life outcomes, such as mental health.

Generally, students from BIH achieved low scores in PISA testing in comparison to their peers from other European countries. Thus, it is obvious that something needs to be changed in light of education. Research has identified several factors that can have a meaningful effect on the math performance of students. One of the first factors is teacher education. Many teachers believe they need more knowledge in order to engage their students more deeply in the mathematics curriculum (Koency & Swanson, 2000). Thus, school authorities need to design better programs of professional development for mathematics teachers. On the side of students, negative attitudes towards mathematics seem to be a large barrier to learning mathematics. In light of this, teachers might incorporate "the anti-anxiety curriculum" in their mathematics lessons (Geist, 2010) and help them cope better with math anxiety. Finally, let us mention the need to incorporate more technology and computer software in the mathematics curriculum. Research has demonstrated the positive effects that computer games and technology can play in learning mathematics (Demirbilek & Tamer, 2010; Zilinskiene & Demirbilek, 2015).

Conclusions

There is a small, negative, relationship between mathematics achievement and meaning in life. Male students achieved higher results on math tests than female students, but the difference, although statistically significant, is rather small. Females who reported higher meaning in life achieved the lowest math scores, thus indicating a moderating effect of gender on the relationship between meaning in life and mathematics achievement. Male students reported higher meaning in life than female students, and this difference was statistically significant.

Recommendations

Teachers and other stakeholders need to work hard to eliminate math-gender stereotypes. There are several highly efficient programs at their disposal that can be used to increase a female sense of confidence in mathematics. Examination and creation of programs aimed at reducing math stereotypes are warranted. Future studies also need to examine cultural factors that might affect the meaning in life scores and examine how those factors are associated with math scores. Additionally, it would be useful to longitudinally track the relationship between math scores and meaning in life and to examine if these relationships change as a function of maturity.

Limitations

This study is not without limitations. Some of these limitations are inherently related to PISA testing itself. What PISA intends to measure is not equal to what it actually measures (Eivers, 2010). A good example of this point comes from the present study and is related to the meaning in life construct, which is measured by three items only. Another limitation is the number of variables included in this study. It would probably be more meaningful to include several related variables and explore them in relation to mathematics achievement. Lastly, we do not know how motivated students were when they completed questionnaires, so there is a risk that they might have provided inaccurate answers. However, this risk is minimal given the large sample of 15-year-old students included in PISA testing.

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