Relationships Between Student Perception of Teacher-Student Relations and PISA Results in Mathematics and Science

Jaan Mikk[1] · Heiki Krips[1] · Ülle Säälik[1] ·
Karmen Kalk[1]

Abstract Teacher-student relations have a significant correlation with student motivation, academic performance and discipline. For example, the meta-analysis by Hattie (2009) revealed an effect size of $d = 0.72$ for the effect of relations on achievement, and the meta-analysis by Finn, Schrodt, Witt, Elledge, Jernberg & Larson (*Communication Education, 58*(4), 516–537, 2009) showed a correlation of 0.55 between the perceived care by teachers and student achievement. These were established by comparing students, but comparisons of schools or countries with high or low levels of teacher-student relations are missing. The present paper analyses the correlation between teacher-student relations and Programme for International Student Assessment (PISA) 2009 results in science and mathematics on three levels: student, school and country level. The study shows a weak positive relationship (correlations up to 0.16) at the student level, and a positive relationship (up to 0.34) at school level. The multilevel analysis revealed a negative relationship between teacher-student relations and PISA results ($r = -.51$) at the country level. To understand the negative relationship, also known as an ecological fallacy, the countries were grouped into geographical regions in which the relationship was insignificant and the positive effect of teacher-student relations was found by comparing with some neighboring countries. Implications for practice and further studies are proposed on the basis of these findings.

Keywords Ecological fallacy · Multilevel analysis · Physics and mathematics education · PISA · Teacher-student relations

✉ Jaan Mikk
jaan.mikk@ut.ee

[1] Institute of Education, University of Tartu, Tartu, Estonia

Introduction

Science and especially mathematics have a special place in school curricula due to the abstract nature of their content which may cause low motivation and difficulties in learning. To surmount these difficulties, mathematics and science teachers use different approaches, including focusing on good teacher-student relations. Hattie (2009, p. 118) classifies the overall effect of teacher-student relationships ($d = 0.72$) as the eleventh-highest association among 138 contributors to learning outcomes.

Investigations of teacher-student relations have been the focus of studies at the individual level. At the same time, group effects are important in classrooms. In a synthesis of meta-analyses, the effect of peer influence on achievement has been found to be 0.53 (Hattie, 2009). The effect is usually related to student background (Ammermueller & Pischke, 2009); however, there is also evidence that perceiving classroom environments as more caring leads to significantly higher levels of math self-efficacy, and this enhances math performance (Fast, Lewis, Bryant, Bocian, Cardullo, Rettig & Hammond, 2010). Research into teacher-student relations at the group level is important as well.

The Programme for International Student Assessment (PISA) provides the opportunity to take a broader look at the relationship between teacher-student relations and educational outcomes. PISA aims to facilitate education by comparing the context and achievement of students in different countries. The PISA survey gathers data not only about the level of student knowledge and skills but also about important features of school activities and home conditions, which may facilitate educational attainment. The data includes student assessments of teacher behavior, which makes it possible to investigate the correlation between teacher-student relations and mathematics and science achievement not only at student level but also at class and country level.

At first sight, the correlations at the three levels might be approximately the same. However, some researchers have found that relationships found at individual level may not exist at higher levels (Rindermann & Ceci, 2009). This especially concerns self-assessments of personality and such aspects as teacher-student relations. The study of the correlations on three levels shows how important teacher-student relations are for individual students, for groups of students and for a country in comparison with other countries.

Teacher-Student Relations and Student Achievement

Classical, humanistic education and today's constructivist learner-centered view of learning accentuates positive teacher-student relationships that support optimal, holistic learning (Cornelius-White, 2007). The constructivist approach to education changes the role of teachers: their main role is no longer the transmission of knowledge, but the facilitation of learning (Korthagen, Klaassen & Russell, 2000).

Teacher-student relations include teacher support behaviors (Hughes, 2011; Patrick, Anderman, Ryan, Edelin, & Midgley, 2001) and teacher care behaviors (Noddings, 1992; Teven & McCroskey, 1997; Wentzel, 2003). Teacher fairness and honesty are important for good relations between teachers and students (Minor, Onwuegbuzie, Witcher & James, 2002). Teachers can express care by listening to students, expressing feelings and demonstrating honesty, trust, humility, hope, and courage (Collinson,

Killeavy & Stephenson, 1999). Good student-teacher relations emerge in a safe and caring classroom environment.

Good relations between teachers and students are known to facilitate learning and motivation in students (Fan, 2012; Hamre & Pianta, 2001; Hughes, Wu, Kwok, Villarreal & Johnson, 2012; McCormick, O'Connor, Cappella & McClowry, 2013; Roorda, Koomen, Spilt & Oort, 2011; Sanders & Jordan, 2000). Marzano & Marzano (2003, p. 6) declare that, "teachers' actions in their classrooms have twice the impact on student achievement as do school policies regarding curriculum, assessment, staff collegiality, and community involvement". In teaching, the most important behaviors are those associated with expressing care for the students, supporting students in different ways and achieving control in the classroom.

Several studies have demonstrated the importance of teacher-student relations for success in learning mathematics (Crosnoe, Morrison, Burchinal, Pianta, Keating, Friedman & Clarke-Stewart, 2010; Fast et al., 2010; Fisher & Rickards, 1998; Riconscente, 2014; Veiga, 2005). Teacher-student relations are especially important for those students struggling in mathematics (Hughes et al., 2012). Some students in the eighth and ninth grades assessed the behavior of literary teachers as being more caring and supportive than the behavior of math teachers (Säälik, Mikk, Krips & Kalk, 2014). Math teachers are not eager to solve mathematical problems in different ways in the classroom (Leikin & Levav-Waynberg, 2007). This may also explain their difficulties in adopting new relationships with students. Math teachers may have an important opportunity to support student development by paying special attention to their own behaviors that express caring and support for the students.

Summarizing the results of over 100 studies revealed that, on average, good relations reduced difficulties with discipline and rule violations by about 30 % (Marzano, Marzano, & Pickering, 2003). In a later meta-analysis of 119 studies, a correlation of 0.34 was found between person-centered teacher variables and learning outcomes combined (Cornelius-White, 2007). The effective teacher variables were non-directivity ($r = 0.35$), empathy ($r = 0.32$), warmth ($r = 0.32$) and the encouragement of higher-order thinking ($r = 0.29$). In cognitive outcomes, the critical/creative thinking of the students related most to person-centered teacher variables ($r = 0.45$) and this was followed by math ($r = 0.36$). Cornelius-White (2007, p. 131) concludes that "… basic learning (IQ, verbal, math) skills appear more associated with learner-centered teacher variables than success in more specific areas …". Still another meta-analysis came down to a correlation of 0.55 between the outcomes of learning and perceived care by teachers (Finn et al., 2009).

Researchers have explained the effect of the quality of teacher-student relationships on student academic motivation and achievement using attachment theory (Bowlby, 1969; Goldstein, 1999), self-determination theory (Deci & Ryan, 1985; Deci & Ryan, 2008), and social-cognitive theory (Bandura, 1986; Urdan & Schoenfelder, 2006).

The most important for our study is social-cognitive theory, according to which people do not operate as autonomous agents nor is their behavior wholly determined by situational influences. The motivation to learn and the efficiency of learning are affected by the interaction between individuals within the social context of the classroom and the school (Fraser, 1998; Urdan & Schoenfelder, 2006). La Paro and Pianta (2003) have suggested that an optimal classroom environment is characterized mostly by strong interest and focus on task, respectful communication and supportiveness, and responsiveness to individual differences.

Despite numerous studies, Bernstein-Yamashiro and Noam (2013) declare that teacher-student relationships is still a growing field of research. Studies of the effect of teacher-student relations at class and country level are especially important.

International Assessments

An international student assessment study, such as PISA, in its essence, is one example of the spread of worldwide educational ideologies and norms (Kamens & Benavot, 2011). The skills measured, and the indicators of different phenomena, such as teacher-student relations or disciplinary climate, are likely to influence the understanding of the aforementioned phenomena in all countries.

PISA data can be analyzed on three levels: student level, school level, and country level. For example, correlations between teacher-student relations and student achievement can be calculated using individual student data, or using average values of the variables for schools, or average values for countries. As a rule, the three correlation coefficients are different. This phenomenon is known as the ecological fallacy: relationships found on one level cannot be carried over to another level (Brewer & Venaik, 2014). Correlation coefficients at the individual level are usually weaker than the coefficients at group level.

One of the possible reasons for the ecological fallacy effect is that some variables, constant at school level, may vary at school or country level (Finney, Humphreys, Kivlahan & Harris, 2011). For example, school leadership is the same for all students in the school but the leadership differs in between-school comparisons. So school leadership may confound correlations between teacher-student relations and achievement in between-school comparisons, but leadership is not related to the correlation within schools. At the country level, the index of democracy may affect both, teacher-student relations and PISA scores, and cause a correlation between these variables, but the index is the same for all schools in a country and the constant variable does not affect the correlation.

Individual student assessments of teacher behavior can be seen as being composed of two parts: (1) overall assessment in a culture that is the same for all students in the culture and (2) the personal assessment of individual students that differs from student to student. Individual assessments are comparable and can be related to student achievement if the students are from the same culture. If the students are from different cultures then cultural differences may mask personal assessments and such assessments cannot be directly related to student achievement. In other words, within different countries and different cultures, the assessment of behavior may be based on different traditions and so the comparison of a country's average assessments may be misleading (Kjærnsli & Lie, 2011). Täht & Must (2013, p. 19) concluded even that "as PISA measures are not invariant in scalar sense, the comparisons across countries with nationally aggregated scores are not justified". Self-assessments of personality have been found to be rather problematic when comparing different cultures (Schmitt, Allik, McCrae & Benet-Martinez, 2007).

One more example of this situation can be found in the study by Shen & Tam (2008). They found that achievements in mathematics and science—according to the Trends in International Mathematics and Science Study (TIMSS) tests and student perceptions of these two subjects—were positively related at the student level but negatively related at

the country level. The authors supposed that the negative correlation at the country level reflects high academic standards in high-performing countries that may reduce the students' self-perception. Evaluative variables are dependent on the surrounding culture, and so students in different countries may assess the same situation differently.

However, international studies and their results can provide useful findings and comparisons with possible causes for the differences being discussed. Rindermann & Ceci (2009) present six different paradigms to explain differences in cognitive competence at the international level: culture, genes, wealth, politics, geography, and education. Cultures, countries, and people are more related to their neighbors than those living far away and may be seen to adapt their customs, and benefit from the progress and wealth of their neighbors or meld their cultures and peoples (Rindermann & Ceci, 2009).

Aim and Hypotheses

To the best of our knowledge, previous studies have investigated the relationship between teacher-student relations and student achievement at the student level. However, the relationships found at the student level may or may not exist at school or country level. The ecological fallacy effect may exist for teacher-student relations but this question is not studied. In addition, PISA reports include the values of the PISA index for teacher-student relations at the individual level and country level (Organisation for Economic Co-operation and Development (OECD), 2010b), but the relationship of this index to student achievement is not given.

The objective of our research was to study the relationship between student perceptions of teacher behavior and student test scores in PISA 2009 in mathematics and science at student, school, and country level. Four hypotheses were formulated:

1. Individual student perceptions of teacher behavior and student test scores in PISA 2009 are positively correlated in countries.
2. The student population in a school who perceives their teachers as being more caring, helpful and fair will have higher PISA test results than the students in schools where students perceive their teachers as unconcerned, keeping at a distance, and biased.
3. PISA test results are better in countries with a lower index of teacher-student relations. In other words, the ecological fallacy effect can be observed in the case of teacher-student relations. This hypothesis is raised in analogy with the results from the study by Shen & Tam (2008).
4. The negative relationship between the teacher-student relations index and the PISA results of countries could not be observed if the countries are culturally similar to each other. This hypothesis is based on findings from Kjærnsli & Lie (2011), who explained the negative relationship in terms of the cultural differences between countries.

Method

Subjects

The data for the research were taken from a PISA survey (Database—PISA, 2009). The PISA tests measure the levels attained in reading, mathematics, and science near the

end of compulsory education. In 2009, the tests were carried out with 15-year-olds in 65 countries. The total sample size was approximately 470,000 students (OECD, 2010a). The sample was representative of 15-year-olds in each country.

Instrument

PISA tests for measuring the students' competence in math and science were very carefully composed. Assessment items were developed according to the PISA framework and tested in all PISA countries. Great care has been taken that the items measure student competence in different topics of the subject, in different competency clusters, and in different situations. Five item types were used and the reliability of scoring the responses was ensured along with the other aspects of the quality of the instrument (OECD, 2010a).

Teacher-student relations were studied from the very beginning of the PISA studies in 2000 (Adams & Wu, 2002). The five items cover important aspects of teacher-student relations: caring, helpfulness, and fairness. The content validity of the items was carefully tested during the composition of the scale. Although there were only five items, the median reliability of the scale in OECD countries in 2009 was 0.83 (OECD, 2012). Data on the predictive validity of the scale could not be found in the description of the scale.

In 2009, the student questionnaire included the following five statements about teacher-student relations:

(1) I get along well with most of my teachers.
(2) Most of my teachers are interested in my well-being.
(3) Most of my teachers really listen to what I have to say.
(4) If I need extra help, I will receive it from my teachers.
(5) Most of my teachers treat me fairly.

The students had to select one of four options: strongly disagree, disagree, agree or strongly agree. The answers were summarized into an index of teacher-student relations (STUDREL) in the PISA study—the higher the value, the more positive the perceived teacher-student relationship. The index was used in our study together with PISA scores in mathematics and science.

Procedure

In PISA tests, each student in the sample carried out tasks in math, science, and reading. Some tasks required students to construct answers; others were multiple-choice questions. Students spent 2 h on these tests. After a short break, students answered questions about their background, learning habits, and their involvement in learning. Filling in the questionnaire took about 30 min.

Data Analysis

The main variables of the research—PISA scores in math and science and PISA index of teacher-student relations—were all scale variables and in this case the linear correlation coefficients were used as indicators of the relationship between student

perceptions of teacher behavior and student test scores in mathematics and science. However, PISA data are hierarchical: students are grouped in schools and schools are grouped in countries. In the case of such grouped data, a multilevel analysis (Luke, 2004) will reveal more precise results than analysis at one level only. For example, the correlation between the index of teacher-student relations and PISA results in math may be different at the individual level and at the school level in a country, but the difference cannot be identified using a simple correlation analysis of the data from these countries.

To test hypotheses 1 and 2, the relationship between teacher-student relations and PISA results at the student and school level were calculated for several PISA countries. For every country, the PISA index of teacher-student relations and the test results for math and science were used in the calculations. A multilevel regression analysis was conducted using the MPlus software. The analysis resulted in regression and correlation coefficients at the student and school level. Correlation coefficients are reported in this study while the coefficients do not stress the direction of the impact of teacher-student relations on PISA results or vice versa.

The third hypothesis was also tested via the multilevel analysis of PISA data from all participating countries. Student data were taken for the first level and country data for the second level. The same variables—index of teacher-student relations and PISA results—were used. The analysis was conducted separately for math and science as in testing the other hypothesis.

The relationship between teacher-student relations and PISA results in neighboring countries was studied at the country level only. The regression analysis of the same variables revealed the square of the multiple correlation coefficient, which is reported in the figures. The square root of this is reported in the final table. The final analysis was conducted using the SPSS software.

Results

The first multilevel analyses were carried out at the student level and at the school level in different countries. The countries for the analysis were selected on the basis of two criteria: (1) countries from the three regions of the world should be represented in the PISA study: Europe, Asia, and America; (2) there should be small and large countries.

Table 1 presents the results of testing the first hypothesis. In the table, the degrees of freedom is the number of students in the country minus two. While there were several thousands of students participating in PISA in all countries, even small correlation coefficients were statistically significant (two-tailed significance level p is given in the tables). Most of the correlations between perceived teacher behavior and PISA test scores in math and science were positive. The negative correlations for Indonesia were not statistically significant. The median correlation coefficients were $r(10406) = 0.054$ ($p = .00$) for math and $r(10406) = 0.113$ ($p = .00$) for science. The students who assessed their teachers as being more caring, helpful, and fair had higher results in PISA test in math and science.

The relationship between teacher-student relations and PISA test scores was stronger in countries with high human development, for example Sweden. In countries with lower human development, the relationship was very weak, for example Mexico (Table 1). Correlation coefficients were calculated between the relationship value in

Table 1 Correlation coefficients between student-teacher relations and PISA results in different countries at the student level, according to two-level analysis

Country	Degrees of freedom	STUDREL correlation with	
		Maths	Science
Sweden	4,565	0.146***	0.158***
Estonia	4,725	0.158***	0.159***
Russian Federation	5,306	0.132***	0.151***
Azerbaijan	4,725	0.040**	0.035*
Turkey	4,994	0.037**	0.100***
Indonesia	5,134	−0.021	−0.013
Chinese Taipei	5,829	0.064***	0.112***
Brazil	20,125	0.039***	0.080***
Mexico	38,248	0.054***	0.039***

*Correlation coefficient is significant at .05 level

**Correlation coefficient is significant at .01 level

***Correlation coefficient is significant at .001 level

Table 1 and the Human development index in countries. The correlations were $r(7) = 0.80$ ($p = 0.03$) for math and $r(7) = 0.77$ ($p = 0.04$) for science. The power of teacher-student relations in predicting PISA results was stronger in countries with higher human development.

The results of testing the second hypothesis are given in Table 2. Here the degrees of freedom is the number of participating schools minus two. Most of the correlations were positive and statistically significant again proving our hypothesis about the higher PISA test results in schools in which students in general perceive their teachers as being more caring, helpful, and fair. However, in two countries (Indonesia and Turkey), the relationship was the opposite, but three of the four negative correlations were not statistically significant. The median correlation coefficients were $r(410) = 0.204$ ($p = .00$) for math and $r(410) = 0.115$ ($p = .02$) for science.

Once again, the relationship between teacher-student relations and PISA test scores was stronger in countries with high human development. Correlation coefficients between the relationship value in Table 2 and Human development index were $r(7) = 0.77$ ($p = .04$) for math and $r(7) = 0.74$ ($p = .04$) for science. The power of teacher-student relations in predicting PISA results on class level was also stronger in countries with higher human development.

Comparing the two tables, we see that in most cases, the correlations were stronger at the school level than the individual level. When comparing subjects, the correlations were somewhat stronger for math at the school level and for science at the student level. The students' average perception of teacher behavior in class explained about 10 % of their math achievement in Estonia and Chinese Taipei.

To test the third hypothesis, all 65 PISA countries were included in the next multilevel analysis, which was carried out at the student level and the country level. At student level, the degrees of freedom is the average number of participating students in a country minus two. The degrees of freedom for countries is the number of countries participating in PISA

Table 2 Correlation coefficients between student-teacher relations and PISA results in different countries at the school level, according to two-level analysis

Country	Degrees of freedom	Correlation with STUDREL	
		Maths	Science
Sweden	187	0.245***	0.173*
Estonia	173	0.345***	0.338***
Russian Federation	211	0.230***	0.115
Azerbaijan	160	0.204**	0.040
Turkey	168	−0.171*	−0.117
Indonesia	181	−0.027	−0.027
Chinese Taipei	156	0.337***	0.338***
Brazil	924	0.112***	0.107***
Mexico	1,529	0.179***	0.156***

*Correlation coefficient is significant at .05 level

**Correlation coefficient is significant at .01 level

***Correlation coefficient is significant at .001 level

minus two. At the student level, the average within-country correlation between teacher-student relations and math results was statistically significant but very weak—$r(7458) = 0.078$ ($p = .00$). The average within-country correlation with science results was also highly significant and weak—$r(7458) = 0.084$ ($p = .00$). The correlation coefficients are nearly the same as the median correlation coefficients in Table 1, and that was expected while countries from different regions were included in the table.

But at the country level, the analysis revealed strong negative correlations between teacher-student relations and PISA test results—$r(63) = -0.45$ ($p = .00$) for math and $r(63) = -0.51$ ($p = .00$) for science. The students' knowledge of mathematics and science was higher in countries in which students assessed their teachers as less caring, helpful, and fair. This contradicts the previous findings at the student and school level.

To understand the negative correlation between perceived teacher behavior and PISA test results at the country level, it was assumed that students in countries geographically and culturally far from each other may evaluate teacher behavior differently. In this case, the correlations should be positive in smaller geographical regions than the entire PISA set of countries.

The regions of countries were taken from the study by Smith (2009). He grouped 138 countries into 18 regions on the basis of democracy, corruption, religion, and human development. From these 18 regions, those with a relatively large number of countries in the PISA study were included in our analysis of correlations.

The average within-country correlation between teacher-student relations and PISA test scores at the student level was positive but weak. Considering this finding, the fourth hypothesis was tested via regressions and correlations at the country level only.

In the group of East Asian countries, teacher-student relations significantly predicted student scores in math, $\beta = .82$, $t(4) = 2.91$, $F = 8.44$, $p = .044$. Among these six countries, the relations were the lowest in Japan and student achievement in math in

Japan was the second lowest (Fig. 1). In Shanghai-China, the students assessed their teachers as being caring and helpful, and Shanghai-China achieved the best results in this group of countries.

In North European countries, teacher-student relations explained a rather large proportion of the variance in math test scores, $R^2 = .21$, $F = 1.05$; the relationship was positive but not statistically significant, $\beta = .46$, t = 1.03, $p = .36$. In particular, relations in Denmark were assessed as being higher than in Norway, and the PISA score in math was higher in Denmark (Fig. 2). The same was true for the UK and Ireland—the UK having higher scores in both measures. However, students in Sweden assessed their teachers as being more positive than in Norway, while students in Norway had higher PISA math scores.

Summative results from comparing countries in groups are given in Table 3. The results are mixed: in some cases, the correlation was positive, in other cases negative. Due to the small number of countries in the groups, only one of the correlations was statistically significant and indicated higher test results in countries with higher teacher-student relations.

Discussion

The results at the student level supported the first hypothesis that good student-teacher relations have a positive correlation with student achievement (Table 1). Good results in
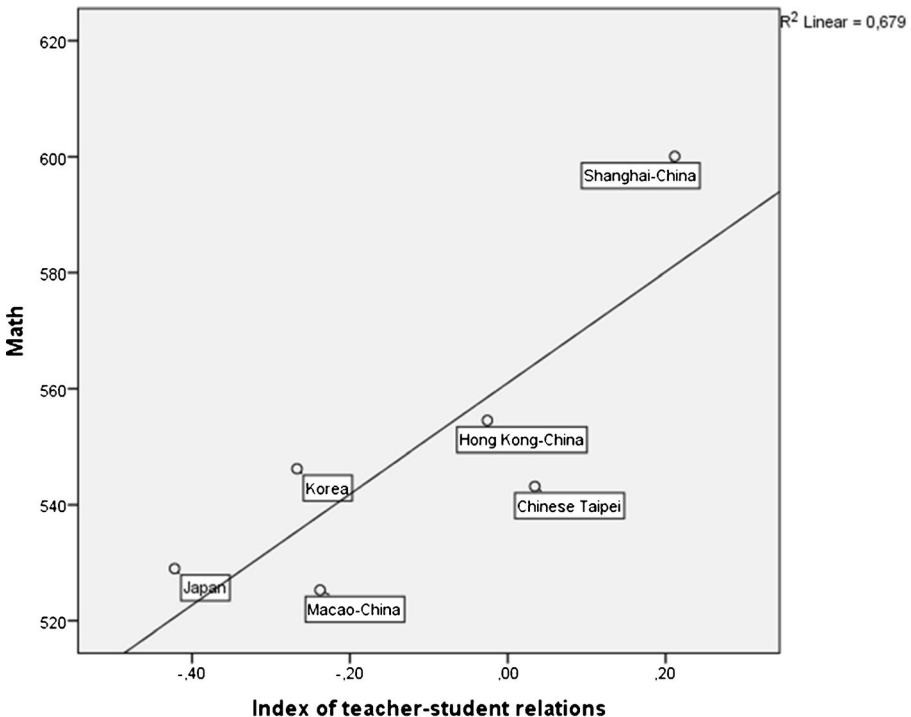

Fig. 1 The relationship between teacher-student relations and math achievement in East Asian countries
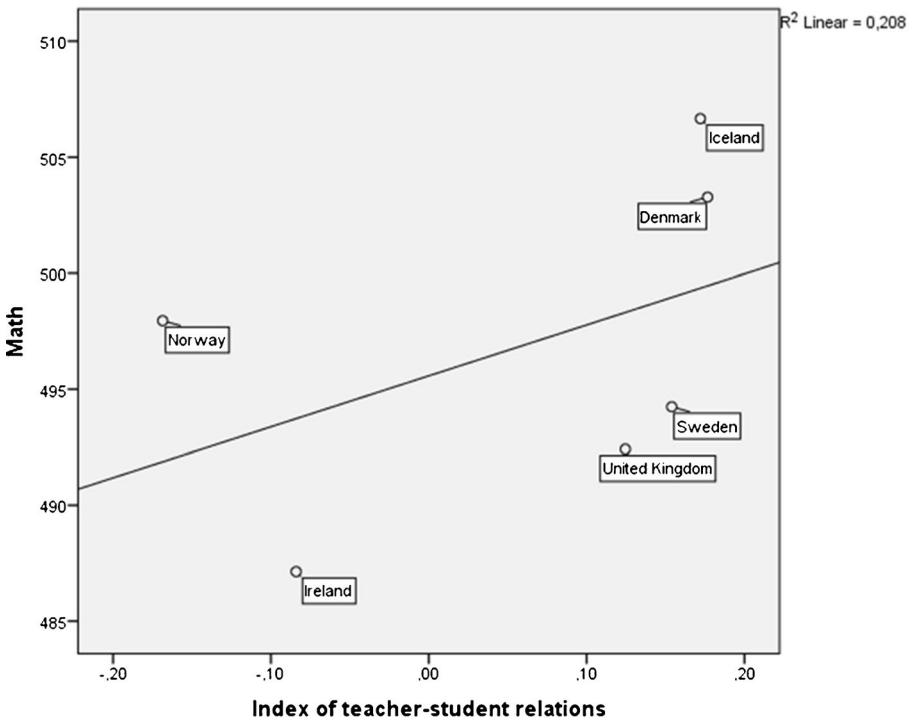
Fig. 2 The relationship between teacher-student relations and math achievement in North European countries

math and science tests in a country were achieved, as a rule, by students who claimed that they got on well with their teachers at school and who found that their teachers were caring and treated them fairly.

Table 1 shows that the correlations are relatively stronger in Sweden and Estonia, which are both small countries and culturally more homogeneous than the large countries. The lowest correlations in Table 1 are for Indonesia, a large country spread

Table 3 Correlations of the index of teacher-student relations with PISA results in different geographical regions

Geographical region	Countries	Correlation with Maths	Correlation with Science
East Asia	Chinese Taipei, Hong Kong China, Japan, Korea, Macao-China, Shanghai-China	0.82*	0.51
Central and Western Europe	Austria, Belgium, France, Germany, Luxembourg, Netherlands, Switzerland,	0.53	0.27
Eastern Europe	Czech Republic, Hungary, Poland, Romania, Russian Federation, Slovak Republic	−0.63	−0.61
North Europe	Denmark, Norway, Iceland, Ireland, Sweden, United Kingdom	0.46	−0.23

*Statistically significant at 0.05 level

over many islands. Indonesia has six religions and over a hundred native ethnic and linguistic groups. The cultural diversity of the Indonesian regions may lead to the ecological fallacy effect within Indonesia and this may explain the negative correlation between teacher-student relations and student achievement.

Researchers have different explanations for how the quality of the teacher-student relationship affects children's academic motivation and achievement. Some researchers have described the position of the attachment theorists, which asserts that a warm and supportive teacher-student relationship may provide a child with a feeling of security that promotes the child's free and active participation in learning activities within the classroom (Pianta, 1999). Hughes (2011) sums up the view taken by the social motivation theorists—also described by Connell & Wellborn (1991); and Furrer & Skinner (2003)—which posits that children who enjoy social support from teachers will construct a positive view of school life and academic endeavors. This, in turn, will promote greater effort and persistence as well as commitment to conforming to school rules and norms. Finally, according to Noddings (1992) and Urdan & Schoenfelder (2006), social-cognitive theory postulates that teachers who are adept at creating a positive social-emotional climate in classroom provide more responsive instruction and better-organized classrooms. Multiple processes may explain the beneficial association of good teacher-student relations with student achievement.

Schools within a country differ in terms of teacher-student relations. In schools where relationships were described as positive, achievement was higher than in schools where relationships were not so good (Table 2). The second hypothesis about the positive correlation between good relations and achievement also proved to be correct at the school level.

It is difficult to explain why the predicting power of teacher-student relations is stronger in highly developed countries. The questions in the PISA index of teacher-student relations may work differently in countries with low and high human development. Students in low-developed countries may be more often ready to answer to the questions in PISA questionnaires, as teachers and parents have implied in previous years. Students in highly developed countries may be more often ready to express their own opinion. Therefore, the validity of the PISA index of teacher-student relations may be higher in well-developed countries.

The correlations in Table 2 are generally higher than the correlations in Table 1. This difference can be explained in two ways. First, students in groups are subjected to group influence (Krips, 2014). This concerns learning motivation, educational achievement and assessments of teacher behavior. Hattie (2009) has found that peer influence had a moderate effect (effect size 0.53) on student achievement but it had a high effect (effect size 0.80) on classroom behavior. Second, the standard errors in the aggregated data are smaller than the errors in individual measurements and higher correlations are expected on the basis of data with smaller measurement errors. However, these are not the only causes of the differences in the correlations at individual and group levels. Groups of students may have a different reference basis when assessing teacher behavior and then the correlations at group level will be lower than those at individual level.

Many relationships in Tables 1 and 2 do not reach the level found for teacher-student relations and achievement in the meta-analyses by Cornelius-White (2007) and Hattie (2009). This may be because PISA questions focus on the caring and helpfulness in teachers. At the same time, Hattie also adds teachers' efforts in motivating students to

learn and developing different aspects of their personality to the concept of teacher-student relations. Using such a broader concept of teacher-student relations may have led to higher correlations in some previous studies. The other reason for the lower correlations in Tables 1 and 2 in comparison with previous studies may be the large sample, which included culturally diverse subgroups. In these subgroups, the basis for the evaluation of teacher-student relationships may differ within a single country.

The findings on the effectiveness of a school indicate that the achievements and behavior of students can be influenced—negatively or positively—by the overall characteristics of the school environment. This means focusing on those features that promote good functioning at the level of the classroom, department, or entire school. Such features involve both the peer group and interactions between teachers and students (Rutter & Maughan, 2002).

The results at the country level supported our third hypothesis for the entire set of PISA countries. In developed countries, the PISA test results were good, but students here perceived relationships with teachers as poorer compared with those in developing countries. The correlation between PISA test results and teacher-student relations was −.45 for math and −.51 for science. The ecological fallacy effect proved true for perceived caring, helpfulness, and fairness in teachers. An analogical result using PISA variables led Henno (2015) to the conclusion that some PISA variables cannot be applied in some countries, and Buckley (2009) concluded in his analysis of PISA 2006 data that cultural differences in response style may lead to inferences that are biased and misleading.

Loogma, Ruus, Talts & Poom-Valickis (2009) have given one explanation of the ecological fallacy effect. They discussed the outcomes of the TALIS research carried out in 2007–2008. Their study researched a similar topic—teacher-student relationships and discipline in the classroom—and a certain pattern was discovered. In several post-Soviet countries, such as Estonia, Bulgaria, Hungary, and Lithuania, most teachers believed they could maintain excellent discipline in their classrooms, but it seems that this was achieved at the expense of good relationships with students.

Täht (2012) has studied the correlation between learning motivation and educational achievement relying on PISA data. She has found a strong negative correlation (−.82) between the variables, which is a manifestation of the ecological fallacy effect. She has explained the effect in terms of the following indicators of the level of development in the countries: democracy, innovation, and the Human Development Index. When controlling for level of development, the negative correlation between motivation and achievement no longer appeared. Shen & Tam (2008) have explained the ecological fallacy effect in terms of the high academic standards in high-performing countries.

Our results can be explained in a similar way. Countries with relatively high achievement and low teacher-student relations, for example, were Japan, Korea, and Macao-China—all countries where there is high pressure on student achievement. On the other hand, countries with good relations but low achievement were Albania, Turkey, and Azerbaijan. In these countries, students may evaluate education and teachers highly but their results in learning are not yet at the level of the students in more developed countries, where education is no longer evaluated so highly.

Comparing cultures in different countries has shown that the culture in the society and in the school may affect learning (Planel, 1997; Tao, Oliver & Venville, 2013). Therefore, our last hypothesis assumed that the negative relationship between the index of teacher-student relations and PISA country results could not be observed if culturally

similar countries were compared. The results of testing the hypothesis are presented in Figs. 1 and 2 and Table 3. In the table, we see five positive correlations out of eight correlations between teacher-student relations and PISA test results in math and science. In general, if countries of a similar culture were compared, students achieved higher results in the PISA test in countries where students perceived their teachers as being more caring, helpful and fair. Negative correlations between teacher-student relations and student achievement in the groups of countries were found, but these were in the minority. The statistically significant negative correlation between teacher-student relations and student achievement found in the country analysis for all PISA countries did not appear in the analysis of groups of countries.

To sum up the findings of the between-country comparison, we might accept that evaluative characteristics, such as teacher-student relations, may lead us to unexpected results when countries from different regions are compared. Geographical and cultural differences should be considered before giving recommendations based on between-country comparisons. In the methodology of educational research, the potential for achieving more comparable results using self-evaluations by respondents from different cultures should also be considered.

Kamens & Benavot (2011) express the important idea that international assessments in developing countries should not drive out national or regional assessments. The latter are more closely aligned to their educational goals and realities. Developing countries should not imitate the fate of educational reforms in the developed world, where the race to find the most effective means of increasing test scores appears much too often.

The discussion above is based on correlations that do not show which of the correlated variables is the cause and which is the consequence. However, the authors of the reviewed literature have expressed the conviction that good teacher-student relations enhance learning to a greater degree than good results in learning raise the quality of relations. Good relations promote greater effort and persistence in students that lead to higher results in learning. Developing teacher-student relations is one of the ways to raise the efficiency of learning mathematics and science.

Limitations

PISA aims to provide an overall description of the process of education, and therefore, among the very many questions, there were only five that describe teacher-student relations. Some important aspects of these relations; for example, engaging students in learning, were not included in the PISA questionnaire and could not be analyzed in this paper.

The PISA index of teacher-student relations is calculated on the basis of student answers about the relations. Strictly speaking, the index provides a student perception of the relations and this may be different from the actual relations.

Conclusion

To the best of our knowledge, the study above explored the relationship between PISA test results and teacher-student relations on three levels for the first time. Several new ideas emerged from the study:

a. The relationship between teacher-student relations and PISA test results was different in different countries, being stronger in countries with high human development,

b. The relationship was mildly stronger at the class level than the individual level, which emphasizes that teachers should pay special attention to group processes in schools,

c. The analysis at the country level revealed the ecological fallacy effect in the case of teacher-student relations in all PISA countries but the negative correlation between teacher-student relations and PISA results was not observable if geographically neighboring countries with similar culture were compared.

In most cases, there was a weak positive association between the PISA index of teacher-student relations and PISA scores in math and science at both the student and at the school level. To foster the development of students, teachers might take care of the perceptions students have about their teaching practice. Not only is the content of mathematics or science important but so also is the school climate including teacher-student relations. Teachers have the opportunity to enhance student satisfaction and achievement by adopting caring, helpful, and fair relations with students. The development of such a mentality in teachers should be one aspect of teacher training and in-service training. This is especially important in the case of weaker students and in mathematics where teachers are usually forced to pay much attention to the content of the subject.

The PISA study is carried out to compare education in different countries; however, the study above confirmed that a simple comparison of the mean values of evaluative characteristics is not always justified. Simple comparisons may lead to erroneous conclusions due to covariates not included in the analysis. The study above demonstrated that culture is one variable that must be considered when comparing evaluative variables such as student perception of teacher-student relations in different countries. Presumably, this concerns the usage of evaluative variables in other international studies as well. Researchers should be rather careful when using findings from international studies to draw conclusions for their own national educational ideology and norms.

Further research is needed to test the new ideas about stronger relationships between teacher-student relations and PISA test results—(1) in countries with high levels of human development, and (2) at the class level rather than at the individual level. Exploring whether the relationship is weaker in culturally diverse countries; that is, if the ecological fallacy effect exists not only between countries but also within culturally diverse countries would be very interesting to explore.

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