



Importance of students' social resources for their academic achievement and well-being in elementary school

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Received: 11 November 2023 / Revised: 27 April 2024 / Accepted: 19 June 2024 /
Published online: 22 July 2024
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Abstract

Based on the relationships motivation theory, it can be assumed that social interactions in elementary school are essential for students' development and especially for their school success. Thus, this study examined how vital social resources, more precisely social interactions with peers and teachers, are for two central aspects of school success, namely academic achievement and well-being. To this end, the representative German PIRLS 2016 data of 3959 fourth-grade students ($M_{\text{Age}} = 10.34$ years; $N = 1,940$ girls, 71% white) were analyzed. Social interactions were operationalized using factors indicating whether students experienced bullying from peers, and how much teacher support they perceived. We found that fewer bullying experiences and more perceived teacher support were positively related to academic achievement and enjoyment of school as a prominent aspect of school-related well-being. Applying machine-learning methods to avoid overfitting while including important control variables, only the effects of bullying experiences and perceived teacher support on well-being remained robust. The results underlined that positive relationship experiences were particularly important for students' well-being but not necessarily incremental to students' academic achievement.

Keywords Academic track recommendation · Educational goals · Enjoyment of school · Large-scale assessment data · Machine learning application · Social interactions

Introduction

Resources play an important role for student outcomes such as academic achievement and well-being (Diener & Fujita, 1995; Jopp & Smith, 2006). These resources fall into three categories: material, personal, and social resources (Diener & Fujita, 1995; Lazarus &

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Folkman, 1984). While family background and general cognitive abilities are examples of material and personal resources, respectively (Broer et al., 2019; Peng & Kievit, 2020), social resources refer to different socialization agents in a student's environment. In the relationships motivation sub-theory of self-determination theory (Deci & Ryan, 2014; Knee & Browne, 2023), social interactions are prominent examples of social resources, which support or endanger students' psychological need for relatedness (Deci & Ryan, 2014). Since students spend a lot of time at school, many of their social interactions take place in this environment, where peers and teachers are the two central agents of socialization (Grusec & Hastings, 2014; Malecki & Demaray, 2003).

Studies have revealed that social resources, especially support, are positively associated with students' academic achievement and well-being (Chu et al., 2010; Cornelius-White, 2007; Kiuru et al., 2020; Kleinkorres et al., 2023a; Liu et al., 2016), while stressors like victimization are negatively associated with these outcomes (Nakamoto & Schwartz, 2010). However, most of these findings are for secondary school students. Elementary school marks a crucial developmental period in which the role of peers and teachers begins to intensify, complementing family influences (Kilday & Ryan, 2022; Valiente et al., 2020). In addition, elementary school teachers often form deep, multifaceted relationships with students (Davis, 2001; Wentzel, 2016) because they teach students in most subjects throughout their elementary school careers (in Germany), in contrast to secondary school teachers, who typically engage with students on a more subject-specific basis. Furthermore, early childhood experiences can create path dependencies with long-lasting effects (Elder et al., 2003; Heckman et al., 2013; Tymms et al., 2018), making elementary school a critical developmental stage. Thus, evidence on the effect of social resources for student academic achievement and well-being is much needed for this age group.

Furthermore, as most studies focused only on a small subset of theorized predictors, there are a lack of studies including a rich set of control variables (Byrnes & Miller, 2007). This is (at least partly) due to methodological limitations that preclude handling a larger number of relevant predictors.

This study addresses these gaps by investigating the importance of positive and negative social resource factors for two central outcomes related to students' school success: academic achievement and school-related well-being. We rely on representative German PIRLS 2016 data, a large-scale assessment of 4th grade elementary school students with an average age of 10. A double machine learning approach to include a rich set of additional information increased the robustness of the estimation results by considering a rich set of potential confounders. This helps to ensure that the effects are not simply driven by other (omitted) variables and gives evidence for a causal association, increasing external validity.

Two sides of social interactions: experienced bullying and perceived teacher support

Similar to the basic psychological needs for autonomy and competence, the need for relatedness, which is the desire to belong and connect with others (Ryan & Deci, 2022), is of great importance in the educational context. Satisfying the need for relatedness is related to students' achievement, motivation, and well-being (e.g., Ryan & Deci, 2000; Abidin et al., 2023). In the school context, this need refers to social resources as reflected in social interactions with peers and teachers, and whether these interactions support or endanger the need for relatedness. One negative aspect of social interactions is students' experiences with bullying (Andreou et al., 2020; Nakamoto & Schwartz, 2010). Bullying

is an aggressive intentional act or behavior perpetrated by a group or individual repeatedly and over an extended period of time against victims who cannot easily defend themselves (Andreou et al., 2020; Slonje & Smith, 2008; Whitney & Smith, 1993). Bullying can be physical, verbal, social, or cyber, with the latter including, e.g., spreading rumors or public humiliation online (Xu & Fang, 2021). Therefore, being bullied is a risk factor that reduces students' feeling of safety. Nakamoto and Schwartz (2010) found in their meta-analysis a significant negative relation between experiencing bullying and academic success (see also, Schaufelberger et al., 2024; Swearer et al., 2010). Additionally, Xu and Fang (2021) found a negative relation between experiencing bullying and school-related well-being (see also, European Commission, 2023).

Conversely, one positive aspect of social interactions in the school context is perceived teacher support (Artuch-Garde et al., 2017; Rotter & Timpe, 2016). Teacher support reflects whether teachers help their students and whether they are interested in students' learning. As such, it is an essential protective factor that improves students' connectedness with school (Sun & Stewart, 2007; Wentzel et al., 2016). Empirical evidence has revealed positive relations between perceived teacher support and academic achievement (Erkman et al., 2010; Mercer et al., 2011; Pianta & Hamre, 2009; Wentzel et al., 2016) as well as well-being (Liu et al., 2016; Raufelder et al., 2018; Segool et al., 2013; Suldo et al., 2009; Tennant et al., 2015; Vedder et al., 2005). Important to note is that, with the exception of Liu et al. (2016), who focused only on student well-being but not academic achievement, the studies reported in this subsection all examined secondary school students.

When zooming in on possible subgroup effects, the literature has highlighted several subgroup differences with respect to social interactions. Regarding gender, Cross and Madson (1997) suggest that social interactions are more likely to influence the thinking and feeling of females than of males, while Pianta and Hamre (2009) showed that boys particularly suffer from bad teacher-student relationships. Additionally, there might be differences in terms of immigrant background, as good social interactions are particularly beneficial for students with immigrant backgrounds to help them cope with migration-related stress and increase school engagement (Katsiaficas et al., 2013; Kurdi & Archambault, 2020; Suárez-Orozco et al., 2018). Teachers play a particularly important role in integrating immigrant students and promoting their social embeddedness by offering support (Ryan & Deci, 2017). Lastly, research has suggested that the school climate is especially important in promoting positive outcomes, such as academic performance, among youth from low SES backgrounds (Berkowitz et al., 2017).

Importance of central school-related student outcomes

To investigate the importance of social resources in elementary schools, we focused on two central school-related student outcomes among fourth graders: Academic achievement and school-related well-being, as both have long-lasting effects on students' educational careers (Kleinkorres et al., 2020; Borghans et al., 2016; Gertler et al., 2014; Hernandez-Martinez & Williams, 2013; OECD, 2017; Sattler & Gershoff, 2019). Therefore, knowing what explains students' early academic achievement and well-being is essential to improving their school experience and promoting their educational trajectory.

To operationalize academic achievement, we used the academic track recommendation students receive at the end of fourth grade. In Germany, students are assigned to different secondary school tracks after elementary school based on the recommendations of their

elementary school teachers. This recommendation is not determined by standardized test scores, but by combining student grades, teacher evaluations, and a holistic assessment of the student's abilities. Therefore, academic track recommendation is based on students' achievement and level of development in different domains and thus reflects a student's overall achievement in elementary school and not only in one subject (Maaz & Nagy, 2010). Teachers pass this recommendation on to parents, and although the binding nature varies from state to state, most parents follow these recommendations (above 80% or 90%, depending on the federal state; Bos, 2003; Dietze, 2011). While there may be cases where parents advocate on behalf of their students, this should not influence the teacher's ultimate decision, so no data on parental advocacy are available. However, students with higher SES are more likely to receive an academic-track recommendation at the same level of achievement (Dumont et al., 2014, 2019), highlighting the importance of appropriate control variables when analyzing this variable.

These recommendations are given at the end of fourth grade, when students are about 10 years old. Although it is difficult to define a hierarchy of secondary schools, there are significant achievement differences between students in the so-called academic track ("Gymnasium") from which graduates receive the higher education entrance qualification, and students in other (lower) tracks (Hübner et al., 2017; Maaz et al., 2020). Students from the academic track have historically made up the majority of all university students (94% in 2004: Konsortium Bildungsberichterstattung, 2006), meaning that an academic track recommendation can have a long-lasting effect on students' academic and professional success (Legewie, 2012). Although it is theoretically possible for students to switch to a higher school track later on in secondary school, this rarely happens, particularly among lower SES students (Biewen & Tapalaga, 2017). Thus, since Germany has no country-wide testing for track selection, being recommended for an academic-track secondary school (hereafter: academic track recommendation) is a relevant proxy for academic achievement.

In addition to achievement, we further focused on the other central educational goal: student well-being (Govorova et al., 2020). Subjective well-being, which comprises cognitive and affective components (Diener, 1984), is a general term used to describe people's well-being based on subjective estimations (Diener & Ryan, 2009). Similarly, school-related well-being can be defined as students' positive cognitions and emotions toward school life (Hascher, 2008; Stang-Rabrig, 2022a). In this regard, enjoyment of school is a prominent component of school-related well-being, as it reflects positive affect and indicates whether students like school (Hascher, 2008; Stang-Rabrig et al., 2022a). Besides reflecting students' subjective experiences at school, students' well-being can also serve as an indicator of a positively designed school environment and, more broadly, of the effectiveness of the educational system (Seligman et al., 2009; Steinmayr et al., 2018; Suldo et al., 2006).

Potential confounders related to achievement and well-being

To improve the robustness of our estimation of the relationship between social resource factors and academic achievement and well-being, it is critical to rely not only on a small subset of theorized predictors (Byrnes & Miller, 2007), but to identify additional variables that predict these outcomes in a so-called "multiverse" analysis (Serra-Garcia et al., 2020; Steegen et al., 2016). This allows us to construct a comprehensive working model that includes key predictors of academic achievement and well-being. We were able to identify four groups of potentially central predictors: (a) demographic information (DI),

(b) cognitive prerequisites (COP), (c) self-regulated learning (SRL), and (d) motivation (MOT). Regarding demographic information, students' background, skills, and characteristics may affect their academic achievement and school-related well-being (Dumont et al., 2014; Hascher, 2008; Liu et al., 2016; Mikus et al., 2021; Nurmi, 2012) alongside social resources. Students from immigrant backgrounds are often disadvantaged due to their lower socioeconomic status and language barriers (in Germany; Diehl et al., 2016; Hernandez-Martinez & Williams, 2013; Hußmann et al., 2017; Siraj-Blatchford, 2010). Moreover, gender-related differences in favor of girls have been found for reading literacy in elementary school, which is a key competence for academic success in elementary school (McElvany et al., 2017; McBreen & Savage, 2020) as well as for well-being (Kleinkorres et al., 2023b; Liu et al., 2016).

Moreover, in terms of cognitive prerequisites, cognitive skills, which involve the ability to process, retrieve, and use new information, are important for educational success (Bernal & Keane, 2010). Alongside cognitive skills, cognitive activation from the students' environment in the form of out-of-school activities, early childhood education, and out-of-school support explains differences in cognitive skills among elementary school students (Mikus et al., 2021).

Another important factor related to educational outcomes is self-regulated learning. Self-regulated learning comprises the competencies of attentional focus, inquiry, and self-evaluation (Leidinger & Perels, 2012; Spruce & Bol, 2015). Numerous studies have shown a relation between self-regulated learning and academic achievement, regardless of students' age or context (Artuch-Garde et al., 2017; Dignath & Veenman, 2021; Dignath et al., 2008), as higher self-regulated learning is related to coping and confidence, tenacity and adaptation, and tolerance for negative situations (Artuch-Garde et al., 2017).

A final important concept to consider is motivation. Motivation is characterized by the willingness to set goals independently, self-activate, and adaptively cope with success and failure (Dignath et al., 2008). Motivation is related not only to academic achievement and well-being but also to self-regulated learning and cognitive skills (Brooks, 2001; Donker et al., 2014; Knight, 2007; Kramarski et al., 2013; Leidinger & Perels, 2012; Zimmerman, 2008). Two important motivational constructs are students' ability self-concept (Wigfield & Eccles, 2000) and interest (Hidi & Renninger, 2006).

Present study

Students' achievement and well-being are central educational goals. It is particularly important to understand which factors are benevolent or adverse for students' achievement and well-being at the end of elementary school, right before the transition to secondary school. Drawing upon theory regarding resources and the importance of social relationships, as well as empirical results, albeit often based on older students, we simultaneously investigated two central social resources, covering one positive and one negative aspect of social interactions, and their relations with student achievement and well-being. We focused on these two social resources because they are potentially modifiable, whereas other aspects such as personal factors (gender, MIG, etc.) are less malleable to influence by instructors or politicians, leaving less scope and fewer entry

points for potential interventions. To investigate our research questions, we applied cutting-edge machine learning methods that simultaneously allow for the theoretical inclusion of a rich set of control variables while also avoiding overfitting when selecting the essential variables. The specific research questions were as follows:

1. What is the relationship between the social resource factors and students' academic achievement and well-being among Grade 4 students?
 - a. Do social resource factors (bullying experiences, perceived teacher support) positively or negatively relate to academic achievement (here: track recommendation) and students' school-related well-being (here: enjoyment of school)?
 - b. Are the effects of the social resource factors robust after including central student characteristics – specifically students' demographic information, cognitive prerequisites, self-regulated learning, and motivation – in the analysis?
 - c. Do the regression results change when all information surveyed in the PIRLS 2016 is (potentially) used? (How robust are the results when not just a selected set of variables is included in the regression analysis, but all information is potentially used?)
2. Additionally, are the estimates for experiencing bullying and perceived teacher support constant across...
 - a. girls and boys (RQ2a),
 - b. students from immigrant and non-immigrant backgrounds (RQ2b), and
 - c. students with low and high SES (RQ2c)?

Following the theory and empirical results presented above, we expected lower levels of experienced bullying and higher perceived teacher support to help make students' school experience more positive, thus leading to higher academic achievement and school-related well-being (e.g., Liu et al., 2016; Nakamoto & Schwartz, 2010; Sattler & Gershoff, 2019). Since the literature details the relevance of various other variables for the outcomes examined here and since previous studies did not include a rich set of control variables in their analyses (if any at all), it is unclear whether the effects of experiencing bullying and perceived teacher support on academic track recommendation and enjoyment of school persist once we include the additional control variables. Such an analysis is important to gain insight into the importance of social resource factors for the outcomes of interest. Given the previously reported associations between the additional included variables and our outcomes as well as social resource factors, it is likely that the effects of experiencing bullying and perceived teacher support on academic track recommendation and enjoyment of school will decline when including these control variables.

Lastly, since the above-mentioned literature reports subgroup differences for gender, immigrant background, and socio-economic status, we expected to find that the social resource factors are particularly important for girls, students from immigrant backgrounds, and students with a low socio-economic status. However, given the sparse evidence for these relations, we conducted an exploratory analysis.

Method

Sample

To answer our research questions, we used data from the German sample of the *Progress in International Reading Literacy Study (PIRLS) 2016* (Hußmann et al., 2017), a large-scale assessment study with 3959 4th-grade students (49.2% female), with an average age of 10.34 years ($SD=0.52$) in Germany. 5.2% of the students were not born in Germany, while 17.0% of the students had two foreign-born parents and 28.8% had at least one foreign-born parent. Furthermore, 17.2% of the students were being raised by single parents, 8.6% had at least one stepparent, and 2.6% were adopted. The mean HISEI (highest international socioeconomic index of occupational status) was 54.0 points ($SD=20.24$), which is slightly higher than in the PISA 2018 study in Germany ($M=51.8$ points) and the OECD average in PISA ($M=52.4$ points; Reiss et al., 2019).

Measures

An overview of the variables, their scales, response format, the survey, and associated descriptive statistics can be found in Table 1. The respective survey questions are in Table 5 in the Appendix.

Outcome variables

The present study included two outcome variables: academic track recommendation as an indicator of students' academic achievement and enjoyment of school as a key component of students' school-related well-being. Academic track recommendation was evaluated using administrative information, with 13 possible categories. We simplified this information into a dichotomous variable (1 = recommended for the academic track, 0 = not recommended for the academic track). Enjoyment of school was measured by students' level of agreement with statements that include feelings of looking forward to school, pride in their school, a sense of belonging, and safety in the school environment (five items, $\alpha = 0.79$, e.g., "I like going to school", Hußmann et al., 2020).

Social resource factors

The social resource factors *experiencing bullying* and *perceived teacher support* represent two important aspects of social interactions in the school context. While bullying represents a negative aspect, support is a protective factor in the children's environment. The experiencing bullying scale included eight items assessing how often students experience harmful behavior by their peers (eight items, $\alpha=0.82$, e.g., "...made fun of me or called me names", Mullis et al., 2015; see also Hußmann et al., 2020) and the perceived teacher support scale included seven items assessing the teacher's support behavior from the students' perspective (seven items, $\alpha=0.79$, e.g., "believes that I can solve difficult tasks", Mullis et al., 2015; see also Hußmann et al., 2020).

Table 1 Overview of variables

Variable	Values	Survey	N	M	SD	α
Outcomes						
Academic track recommendation	0 = other, 1 = academic track recommendation	Administrative data	3856	0.36	0.48	-
Enjoyment of school*	1 = strongly disagree to 4 = strongly agree	Students	3493	3.30	0.66	0.79
Resources (RES)						
Bullying experiences*	1 = never to 4 = at least once a week	Students	3454	1.61	0.62	0.82
Perceived teacher support*	1 = strongly disagree to 4 = strongly agree	Students	3333	3.31	0.55	0.79
Demographic information (DI)						
Female	0 = male, 1 = female	Administrative data	3959	0.49	0.50	-
Age	Age in years and months	Administrative data	3959	10.34	0.52	-
Books at home	1 = none or very few (0–10 books) to 5 = three or more bookshelves (over 200 books)	Students	3419	3.13	1.18	-
HISEI	Values between 10 and 90	Students	2563	53.96	20.24	-
Foreign-born	0 = German-born, 1 = foreign-born	Students	3443	0.05	0.22	-
One foreign-born parent	0 = no, 1 = yes	Parent	3959	0.12	0.32	-
At least one foreign-born parent	0 = no, 1 = yes	Parent	3959	0.29	0.45	-
Two foreign-born parents	0 = no, 1 = yes	Parent	3959	0.17	0.38	-
Siblings (in household)	Number of siblings in the household	Students	3273	0.83	0.37	-
Raised by single parent	0 = no, 1 = yes	Students	2837	0.17	0.38	-
One stepparent	0 = no, 1 = one stepparent	Students	3959	0.09	0.28	-
Adopted	0 = no, 1 = is adopted	Students	3959	0.03	0.16	-
Cognitive prerequisites (COP)						
Cognitive skill test score	Test score results	Competence test	3931	49.16	9.58	-
Early childhood education before age 3	0 = no, 1 = yes	Students	2552	0.28	0.45	-
Preschool	0 = no, 1 = yes	Students	2813	0.90	0.30	-
Enrichment activities*	1 = no, never; 2 = yes, occasionally; 3 = yes, regularly	Students	2707	0.17	0.29	0.70

Table 1 (continued)

Variable	Values	Survey	N	M	SD	α
Non-digital reading for entertainment*	1 = no time to 5 = 5 h or longer	Students	2670	1.55	0.85	0.71
Digital devices for entertainment*	1 = no time to 5 = 5 h or longer	Students	3029	1.64	0.87	0.78
Self-regulated learning (SRL)						
Concentration ability*	1 = strongly disagree to 4 = strongly agree	Parents	2821	2.89	0.86	-
Teacher feedback on homework in class*	1 = never or rarely to 3 = always or almost always	Teachers	1642	2.67	0.52	-
Use of teacher feedback: correcting assignments and giving feedback*	1 = never or rarely to 3 = always or almost always	Teachers	1604	2.38	0.60	-
Emphasis on inquiry at school*	1 = strongly disagree to 4 = strongly agree	School principal	3513	3.34	0.66	-
Digital inquiry experience*	1 = not at all to 3 = longer than 30 min	Students	3407	0.59	0.49	-
Use of self-evaluation*	1 = never to 3 = once or twice a week	Teachers	1709	3.11	0.68	-
Motivation (MOT)						
Reading self-concept*	1 = strongly disagree to 4 = strongly agree	Students	3445	3.33	0.64	0.82
Reading interest	1 = strongly disagree to 4 = strongly agree	Students	3448	3.02	0.73	0.86
Extracurricular reading for fun*	1 = never or rarely to 4 = every day or almost every day	Students	3439	2.99	1.10	-
Extracurricular reading to learn*	1 = never or rarely to 4 = every day or almost every day	Students	3428	2.85	1.05	-

Teacher and school principal responses are merged with the student (and parent) data. Thus, the number of observations (N) indicates how many students have teacher and school principal responses. HISEI refers to the Highest International Socio-Economic Index of Occupational Status. *Standardized

Additional covariates

We controlled for several important factors that are highly related to academic achievement and school-related well-being: demographic information, cognitive prerequisites, self-regulated learning behavior/opportunities, and motivation.

Demographic information (DI) Students' sex and age were reported based on administrative data in PIRLS 2016. Students' socio-economic background was measured using a variable that accounts for the number of books students have at home and their calculated HISEI. Students' immigrant background was measured firstly based on whether students were born outside Germany (foreign-born). As only a few children were born outside Germany, and an immigrant background can extend into the second generation, we further looked at whether one, both or at least one parent was foreign-born. We created these variables based on the parents' answers to the question regarding place of birth. Furthermore, we included the number of siblings living with the student in the same household as well as whether the students were being raised by a single parent, had at least one stepparent, or were adopted.

Cognitive prerequisites (COP) To measure students' general abilities, we included the results of a test measuring their cognitive skills. For this purpose, we used students' performance on 24 exercises from the Cognitive Abilities Test for Grades 4 to 12 (Heller & Perleth, 2000). We also measured cognitive activation with five variables measuring students' educational and non-educational activities in (pre)school. Whether students were enrolled in early childhood education before and after the age of three (preschool education) was measured with two dichotomous variables answered by the students' parents. The variable "enrichment activities" measured the extracurricular activities students received to promote their special talents (11 items, $\alpha=0.70$, e.g., "promoting mathematical talent" Hußmann et al., 2020). To measure whether students read for pleasure as an out-of-school activity, we combined two items about students' reading behavior (two items, $\alpha=0.70$, e.g. "Read stories or texts in books or magazines", Hußmann et al., 2020). Finally, to measure students' digital leisure activities, we combined two items on their use of television and video games ($\alpha=0.78$, e.g. "Play video or computer games [including Nintendo, Gameboy, or PlayStation]", Hußmann et al., 2020).

Self-regulated learning (SRL) Self-regulated learning techniques were measured via six distinct single-item variables from all four survey perspectives. First, the ability to focus attention was assessed by asking the child's parents about the child's level of focus and persistence. Second, teachers reported on the frequency with which they conducted two forms of feedback activities in class (providing feedback on homework during class and correcting assignments and giving feedback). Third, to measure inquiry activities, we used one item about whether finding information in a text is used as a learning strategy at that school, answered by school principals. A second variable used to assess students' inquiry addressed their self-reported digital media use for research purposes. Finally, self-evaluation in class was measured using one question from the teacher questionnaire about students' self-monitoring opportunities. The exact names of the items can be found in the appendix.

Motivation (MOT) We measured four aspects of students' motivation. First, we included two essential and widely used motivation facets, reading self-concept (six items, $\alpha=0.82$, e.g., "I understand difficult stories.") and interest (three items, $\alpha=0.86$, e.g., "I like to read"). As PIRLS 2016 focuses on reading, self-concept and interest are reading-specific. Second, we additionally used two items capturing whether students like to read for fun and whether they read to learn.

Additional PIRLS information We also included all additional PIRLS 2016 information from the student, parent, teacher, and principal surveys in a variable selection method to select the variables with the highest predictive power for the outcomes and social resource factors (see below). The student survey included 58 questions covering demographic details (such as gender and age), home and learning environments, and individual school experiences, yielding a total of 135 variables after recoding nominal variables into binary dummy variables. The parent survey, with 64 questions, yielded 241 variables, providing insight into the family's living and learning environment and the child's educational history, including parents' educational and occupational details. The teacher survey consisted of 84 questions, including demographic information, professional background, attitudes toward teaching, working conditions, and specific teaching practices, resulting in 204 variables. Finally, the principal survey included 75 questions on school structure and resources, which were transformed into 251 variables. In total, this sums up to 831 variables.

Variables were included on the basis of their completeness and variability, excluding those that depend on specific answers or have minimal variance. For example, data on differentiation and support services were omitted due to their limited applicability across the sample. In addition, we aggregated related questions into latent variable scores, using Cronbach's alpha to assess reliability and proceeding without adjustment if alpha was less than 0.70. The variables are detailed in Table 6 in the appendix.

Statistical analysis

Ordinary least squares regressions were performed to estimate the relationships between the outcome variables of academic track recommendation and enjoyment of school and the social resource factors. The regression equation is as follows:

$$y_i = \alpha + \rho' SRF_i + \beta'_1 DI_i + \beta'_2 COP_i + \beta'_3 SRL_i + \beta'_4 MOT_i + \varepsilon_i, \quad (1)$$

where index i stands for the individual and ε_i is the idiosyncratic error term. y_i is a placeholder for the outcome variables academic track recommendation and enjoyment of school. The vector SRF_i includes the social resource factors introduced in Table 1. Therefore, the vector ρ' captures our two main coefficients of interest. The regression specification only including these variables is our baseline (Model 1). However, only regressing the social resource factors on the outcomes may introduce omitted variable bias. Therefore, we included all variables in DI_i accounting for demographic information in a second regression specification (Model 2).

Next, we wanted to include all variables in the vectors DI_i , COP_i , SRL_i , and MOT_i as presented in Table 1 for our third regression specification. However, since this might be an unnecessarily high number of variables, we used a variable selection method to identify a sparse set of control variables and avoid overfitting the data. Therefore, we followed the

post-double selection method introduced by Belloni et al. (2014). Belloni et al. (2014) suggest a two-stage selection procedure: First, select variables that explain the outcome variable and then additionally select variables explaining the main explanatory variables of interest (i.e., the double selection, see also Schwerter et al., 2022). This gave us a sparse set of essential variables from DI_i , COP_i , SRL_i , and MOT_i that explain the outcomes and social resource factors. Second, run a post-double selection OLS regression including the pre-selected variables and the resource variables on the respective outcome. We followed Belloni et al. (2014) and used the machine learning method LASSO (least absolute shrinkage and selection operator; Hastie et al., 2009) for variable selection. As propensity score matching is not possible when more than one explanatory variable is of interest (here: experienced bullying and perceived teacher support), this approach is the next best to reduce omitted variable bias while simultaneously avoiding overfitting in situations where experimental manipulation is impossible. However, since we use multiple imputation due to missing information, simply running LASSO is difficult. We follow Du et al. (2022), who proposed stacking the imputed datasets into one long or stacked dataset and running a stacked adaptive LASSO. Since no inferential statistics are done within LASSO, this approach does not create problems such as p -value inflation. In the adaptive stacked LASSO, the sum of the loss function for each of the imputed datasets is jointly optimized to obtain just one parameter per variable for all imputed datasets (Du et al., 2022). The coefficients unequal to zero then show whether a variable is selected or not. In adaptive stacked LASSO, we select variables for both y_i as well as the social resource factors in SRF_i . This regression specification is called Model 3. Further, we separate the data by students' gender, immigrant background, and SES to analyze how the estimated effects differ in different subgroups of students.

Although the list of additional included variables is justified by the literature, even more information is available in the PIRLS 2016 data that could be important for our outcome variables and therefore could be reasonable control variables (see for example, Ansary et al., 2015; Burić & Kim, 2020; Cornell & Mayer, 2010; Havik, 2017; Nurmi, 2012; Osher et al., 2010; Pianta & Hamre, 2009). Therefore, we expanded the set of control variables in our regressions to see how sensitive the regression results are to the pre-selected variables (multiverse analysis, Serra-Garcia et al., 2020; Steegen et al., 2016). First, we included all available variables from PIRLS 2016 in the double selection of additional control variables as a sensitivity analysis (Model 4). Second, in addition to the first step, we added dummy variables for all schools to include school fixed effects in the regression (Model 5). Models 4 and 5 show how sensitive our results are to our preselected variables in Model 3.

However, since the dataset included 827 variables (without the school fixed effects), it was unclear how sparse the set of variables would be that really explain our outcome variables and main independent variables of interest. If the sparsity of the true effects is not high, a large number of variables can be selected, and a post-selection regression may include too many selected variables, obscuring meaningful insights and increasing the risk of overfitting. Therefore, we followed Hanushek et al. (2022) and Schwerter et al. (2023) and reduced the dimensionality of the data using principal component analysis (PCA) before performing the double selection. We grouped the variables according to the PIRLS 2016 taxonomy and generated principal components for each group (Schwerter et al., 2023). In choosing which components to retain, we followed a widely accepted guideline: retain principal components (PC) until the incremental explanatory power of each subsequent PC becomes relatively constant. This is more conservative than the method used by Hanushek et al. (2022), who simply used the first PC to proxy SES across multiple data sources. Following this strategy, we included one or more PCs from each variable group in the selection process. Thus, the third selection strategy included the PCs generated from

the student and parent survey because both of these data sources are at the student level (Model 6). In the fourth and final variable selection alternative, we expanded our scope to include PCs from the student, parent, teacher, and school principal surveys (Model 7). Because the data from the teacher and school principal surveys are school-level data, these variables remain constant for all students within the same school.

The overall goal of these rigorous analyses was to test the incremental effect of social resource factors against a rich set of control variables. Our goal was to ensure that our findings were not only insensitive to specific demographic characteristics but also remained robust to the comprehensive breadth of the PIRLS 2016 dataset.

For all estimations, we used the statistical software *R* (R Core Team, 2021). To account for the nested structure of the PIRLS data, we used the *R*-Package *survey* (Lumley, 2004) and calculated heteroskedasticity-robust and school-clustered standard errors. For variable selection, we used *miselect* (Alexander & Du, 2020). For imputation, we applied the *R* package *missRanger* (Mayer, 2021), which uses random forests and implements predictive mean matching due to its benefits for mixed data types, non-linear interactions between variables, and data with a large number of dimensions (Schwerter et al., 2024). We conducted 50 imputations.

Results

Descriptive results

Table 2 shows correlations between academic track recommendation, enjoyment of school, and the social resource factors experienced bullying and perceived teacher support. There were positive correlations between academic track recommendation and enjoyment of school and perceived teacher support. This indicates, for example, that students who reported higher levels of enjoyment of school, perceived teacher support, and experienced less bullying were more likely to receive an academic track recommendation. The other correlations were equally as expected.

Regression results

The baseline regression results presented in Table 3 for RQ1a show significant relations between the social resource factors and almost all outcomes. Model 1 for academic track recommendation and enjoyment of school contains the results without control variables.

Table 2 Correlations of outcomes and social resource factors

	ATR	EOS	EB	PTS
Academic track recommendation (ATR)	-	-	-	-
Enjoyment of school (EOS)	0.188***	-	-	-
Experienced bullying (EB)	-0.167***	-0.292***	-	-
Perceived teacher support (PTS)	0.224***	0.479***	-0.239***	-

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 3 Regression results

	Academic track recommendation			Enjoyment of School		
	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3
	SRF only	SRF + DI	SRF + Sel	SRF only	SRF + DI	SRF + Sel
(Intercept)	0.349*** (0.016)	0.555*** (0.170)	-0.490*** (0.177)	-0.009 (0.020)	-0.031 (0.021)	-0.979*** (0.133)
Experienced bullying	-0.062*** (0.009)	-0.038*** (0.008)	-0.011 (0.009)	-0.199*** (0.020)	-0.189*** (0.021)	-0.185*** (0.019)
Perceived teacher support	0.100*** (0.011)	0.060*** (0.009)	0.025*** (0.009)	0.485*** (0.023)	0.446*** (0.030)	0.361*** (0.023)
Set of cont	-	DI	PDS	-	DI	PDS
Number of variables	2	13	15	2	13	12
R ²	0.081	0.253	0.351	0.331	0.346	0.435
BIC	-317	-1039	-1495	-1577	-1566	-2057
N	3959	3959	3959	3959	3959	3959

Dependent variables: Academic track recommendation is dichotomous. Enjoyment of school is standardized. Independent variables: Experienced bullying and perceived teacher support are both standardized. DI includes all variables in Table 1 under demographic information. PDS is the result of the post-double selection, for which all variables in Table 1 were used. The selection was done using the *r* package *miselect*, which uses stacked adaptive LASSO for multiple imputed data

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Model 1 depicts that the probability of receiving an academic track recommendation increased by 6.2% if students experienced one standard deviation less bullying ($\beta = -0.062$ [$SE=0.01$], $p < 0.001$), and by 10.0% if perceived support by their teacher increased by one standard deviation ($\beta = 0.100$ [$SE=0.01$], $p < 0.001$). Similarly, for enjoyment of school, the effect was 0.199 of a standard deviation higher if students experienced one standard deviation less bullying ($\beta = -0.199$ [$SE=0.02$], $p < 0.001$), and 0.485 for one standard deviation more perceived teacher support ($\beta = 0.485$ [$SE=0.03$], $p < 0.001$). When we included demographic information in Model 2 (see Table 3 for the respective coefficients, standard errors, and significance levels), the results were robust in terms of both direction and strength.

Next, regarding RQ1b, the post-double selection method introduced by Belloni et al. (2014) was used to include the sparsest set of variables necessary to explain the effect of the social resource factors on our outcomes without overfitting (set of controls, PDS). The regression results can be seen in Model 3 (see Table 3). The effect of experienced bullying on academic track recommendation decreased toward zero (-0.011) and was no longer significant. Thus, the coefficient decreased significantly following the inclusion of the control variables. Though the coefficient for perceived teacher support decreased as well and now only revealed a 2.5% increase, it remained significant at the 0.001 significance level.

For enjoyment of school, including the additional variables did not change the effect of experienced bullying on enjoyment of school and only slightly decreased the effect size of perceived teacher support on enjoyment of school (from 0.446 to 0.361). Thus, the effect of the social resource factors on enjoyment of school is much more robust than on academic track recommendation.

Sensitivity: “Many-worlds” analyses

For RQ1c, we conducted an extensive sensitivity analysis regarding the effects of experienced bullying and perceived teacher support on our two key outcomes (see Table 4). Regarding academic track recommendation, which is primarily at the discretion of teachers, the picture was mixed. The trajectory of the coefficients from Model 4 to Model 7, compared to Model 3, suggested a clear trend toward (statistical) insignificance, implying that the influence of experienced bullying and perceived teacher support on academic track recommendation is not simply incremental. The observed effects appear to be significantly influenced by the set of controlled variables or PCs within each of the models.

The introduction of PCA into our methodological framework for academic track recommendation led to significant advances in model fit. Starting with an R^2 of 0.081 in Model 1, subsequent models showed significant improvement. In particular, Model 4 showed a peak R^2 value of 0.631. However, the Bayesian Information Criterion (BIC) showed a clear preference for Model 6, registering a value of -2057 . This value, which is substantially better than that of Model 3, highlights the gradual attenuation of the experienced bullying and perceived teacher support coefficients. This evolution suggests that the relevance of experienced bullying and perceived teacher support diminished as more variables were added to the model, making their contributions to the model increasingly marginal.

When examining students' enjoyment of school, a latent variable that students self-report, the landscape changed considerably. In contrast to the pattern observed for academic track recommendation, the influence of experienced bullying and perceived teacher support on school enjoyment stood out as robustly significant. Although the comparison of Model 3 and Model 4 showed a modest decrease in the strength of the coefficients, the statistical integrity of these coefficients remained firmly intact. For example, the coefficient for experienced bullying remained consistently bracketed between -0.114 and -0.160 across models. In contrast, the coefficient for perceived teacher support experienced a contraction, moving from an initial value of 0.361 in Model 3, then oscillating between 0.114 and 0.115 in Models 4 and 5, before settling within a range of 0.253 and 0.247 in Models 6 and 7.

Interestingly, the inclusion of PCA for the outcome of students' school enjoyment did not mirror the improvement observed for academic track recommendations. The basic model, with its robust R^2 value of 0.331 , showed only a slight increase to 0.435 in Model 3. This trend persisted even when an extensive set of variables or PCs were included in Models 4 to 7. The resulting variations in both the R^2 and BIC metrics were relatively muted, suggesting that the utility of PCA varies depending on the type of outcome being examined.

In summary, while PCA emerges as a central tool for refining model fit with respect to academic track recommendation, its contribution was less pronounced when we attempted to model students' enjoyment of school. Regardless of model evolution, the indispensable roles of experienced bullying and perceived teacher support remained prominent, underscoring their central importance in shaping our understanding of the multifaceted dynamics of students' enjoyment of school.

Table 4 Sensitivity results with additional variable selection

Panel A	Academic track recommendation			
	Variable selection		PCA selection	
	Model 4	Model 5	Model 6	Model 7
Experienced bullying	0.002 (0.013)	0.007 (0.013)	0.005 (0.007)	0.007 (0.007)
Perceived teacher support	0.002 (0.008)	0.001 (0.008)	0.002 (0.009)	0.005 (0.008)
Set of controls	All	All + SFE	PCA S + P	All PCs
R^2	0.631	0.656	0.448	0.502
BIC (null)	-1505	-1711	-2057	-1935
N	3959	3959	3959	3959
Number of variables/PCs	295	303	36	95
Panel B	Enjoyment of School			
	Variable selection		PCA selection	
	Model 4	Model 5	Model 6	Model 7
Experienced bullying	-0.114** (0.040)	-0.118** (0.039)	-0.160*** (0.021)	-0.150*** (0.020)
Perceived teacher support	0.114*** (0.024)	0.115*** (0.023)	0.253*** (0.025)	0.247*** (0.024)
Set of controls	All Var	All + SFE	PC S + P	All PCs
Number of variables/PCs	93	108	20	44
R^2	0.529	0.544	0.406	0.420
BIC (null)	-2213	-2215	-1896	-1794
N	3959	3959	3959	3959

“All vars”: All variables in PIRLS 2016 are used in the variable selection. All + SFE is the same as “All vars” but adds school fixed effects. “PC S + E” indicates PCs from student and parent surveys were used in the selection. “All PCs” indicates PCs from the student, parent, teacher and school principal surveys were used for the selection. The number of variables / PCs show how many variables or PCs were selected plus the two variables experienced bullying and perceived teacher support. Models 4 and 7 use the same variables, but we use the PCA of those variables in Model 7

*** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$; + $p < 0.1$

Group-specific effects of experienced bullying and perceived teacher support

Figure 1 compares the estimated effects of experienced bullying and perceived teacher support for three subsamples in which the data are divided by sex, immigrant background, and SES, using Model 3. First, splitting the data into female and male students revealed few differences (Panel A). The point estimates of perceived teacher support and experiencing bullying on academic track recommendation are very similar between boys and girls. However, the point estimate of the effect of experiencing bullying on enjoyment of school was bigger for girls than boys at the 5% level. In contrast, the positive effect of perceived teacher support on enjoyment of school was smaller for girls than for boys. However, the (inner) 83.4% confidence intervals overlapped, meaning that the latter difference is not significantly different at the 5% significance level (Knol et al., 2011).

Group-specific regressions

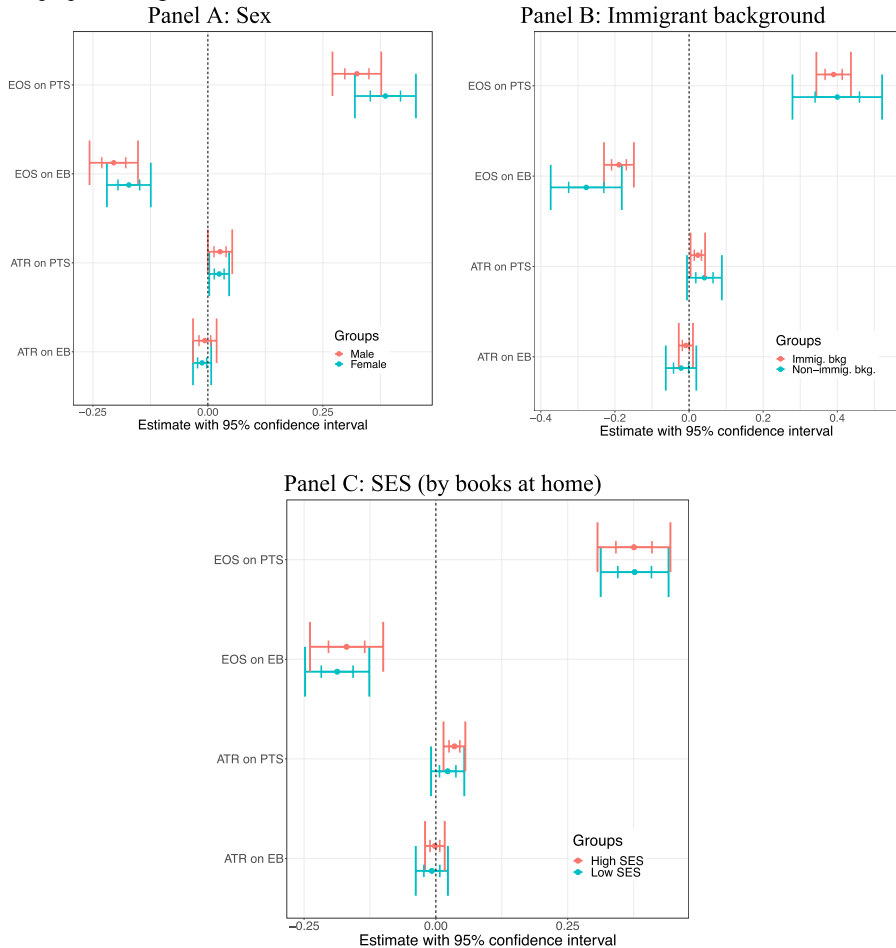


Fig. 1 Group-specific regressions. EOS, enjoyment of school; ATR, academic track recommendation; PTS, perceived teacher support; EB, experienced bullying. Results generated using Model 3. The large bars show the 95% confidence interval for each respective estimator. The inner, smaller bars show the 83.4% confidence interval. Following Knol et al. (2011), these intervals should be used for comparison if the sub-groups' estimates are statistically significantly different from each other

There were also only small differences in the regressions for students from immigrant and non-immigrant backgrounds (Panel B). However, the effect of experiencing bullying on academic track recommendation was only significant for students with at least one foreign-born parent, not for native-born students. In addition, the effect of experiencing bullying on enjoyment of school was significantly higher for students from non-immigrant backgrounds than those from immigrant backgrounds at the 5% significance level, as indicated by the non-overlapping (inner) 83.4% confidence intervals.

Comparing students with high and low SES (Panel C), the effects of experienced bullying and perceived teacher support on the dependent variables were mostly similar. However, one important difference is that perceived teacher support was statistically

significantly associated with academic track recommendation for high-SES but not low-SES students.

Discussion

The present study aimed to shed light on the relationships between students' social resource factors and both students' academic track recommendation as an important indicator for their academic achievement and enjoyment of school as a crucial aspect of school-related well-being. We focused on the central developmental phase of childhood and used a double machine learning approach to include important control variables from the rich set of possible variables from the representative German PIRLS 2016 large-scale dataset with almost 4000 fourth-grade students. We applied the double machine learning method to identify a sparse set of control variables that are important either for the outcomes academic track recommendation and enjoyment of school or our social resource factors experienced bullying and perceived teacher support. Using this method, we were able to include a rich set of control variables in the selection procedure to reduce possible bias to our variables of interest while avoiding overfitting the data. We included control variables in the categories of demographic information, cognitive prerequisites, self-regulated learning, and motivation.

The baseline regression supported the hypotheses and is in line with prior theoretical and empirical research that bullying experiences are related to lower academic achievement (Deci & Ryan, 2014; Erberber et al., 2015; Nakamoto & Schwartz, 2010) as well as lower enjoyment of school (Houbre et al., 2006; Xu & Fang, 2021). These results extended the evidence to another age and cultural group, demonstrating the massive negative impact experiencing bullying can have, as lower academic achievement and lower enjoyment of school can have far-reaching consequences such as school and learning alienation (e.g., Hascher & Hagenauer, 2010). Consequently, it is important to understand whether this effect is driven by experiencing bullying or caused by other variables that correlated with experiencing bullying. The results of the double machine learning method showed that the effect on academic track recommendation was not stable and almost vanished in our first post-double selection regression when we included the pre-selected variables. It completely disappeared in our "many-worlds" analysis, where we did not conduct a pre-selection of possible control variables. Thus, the effect of experienced bullying on academic track recommendation was mostly driven by other variables. Even though a meta-analysis found a statistically significant negative correlation between experienced bullying and academic achievement for students ranging from 8 to 13 years of age (Nakamoto & Schwartz, 2010), our results (for academic track recommendation) call a possible causal relation into question, as including even a few control variables is enough to reduce the previously strong effect to almost zero. Apart from that, our results showed that experiencing bullying reduced enjoyment of school, even after including the (very) rich set of selected control variables. This is very much in line with prior studies in elementary (Liu et al., 2016) and secondary school (Xu & Fang, 2021). Thus, a harmful peer relationship is likely to reduce students' school enjoyment.

Next, we looked at students' second prominent interaction partner in school, their teachers. The baseline regression results revealed that perceived teacher support was beneficial for both outcome variables: It increased the probability of receiving an academic track recommendation and enjoyment of school. This aligns with theoretical assumptions as well

as previous findings on the effects of perceived teacher support on academic achievement (Affuso et al., 2023; Erkman et al., 2010; Mercer et al., 2011; Wentzel et al., 2016) and well-being (Liu et al., 2016; Raufelder et al., 2018; Segool et al., 2013; Suldo et al., 2009; Tennant et al., 2015; Vedder et al., 2005), but for a younger age group. The effects for academic track recommendation and enjoyment of school remained statistically significant even for the post-double selection regressions using the pre-selected variables, emphasizing that teachers are important agents of socialization. Also notable is that the coefficient of perceived teacher support was either equal to or larger than the (absolute) coefficient of experienced bullying. This might suggest that higher perceived teacher support could buffer the effects of possible bullying experiences (Coyle et al., 2022). Our results also support findings highlighting the importance of teachers in general (Akiba et al., 2007). However, in our “many-worlds” analysis, the effects of perceived teacher support on students’ academic track recommendation vanished, while its effect on enjoyment of school remained. Therefore, similar to above, our results revealed no evidence for a causal effect of perceived teacher support on academic achievement but for enjoyment of school.

Our exploration of the large dataset from PIRLS 2016 highlighted a striking methodological observation. While LASSO in the context of education data tends to select a large pool of variables, the introduction of PCA reduces this to a more manageable ensemble of variables. However, the effectiveness of this approach is clearly outcome-dependent. The BIC indicated a superior model fit for academic track recommendation when LASSO operated on the principal components. However, this improvement was noticeably absent when modeling students’ enjoyment of school. This discrepancy underscores that PCA integration, despite its promise in certain contexts, does not uniformly lead to optimal fit for all educational outcomes. Another option for the future could be to use the concept of partialing-out the effects of the selected variables and then estimating a regression with only the variables of interest, which could result in a more interpretable R^2 (Chernozhukov et al., 2024).

Aside from just looking at how the coefficients changed because of the post-double selection regression, in the appendix, we also briefly looked at which variables were selected for Model 3. For example, we could confirm the importance of the relationship between self-regulated learning and academic achievement (Artuch-Garde et al., 2017; Dignath & Veenman, 2021; Dignath et al., 2008; Skinner et al., 2020). This list may help other researchers select control variables in future (intervention) studies.

Next, our subsample regressions revealed that the effects of experienced bullying and perceived teacher support are very homogenous between boys and girls. Notably, experiencing bullying statistically significantly reduced the likelihood of receiving an academic track recommendation for students from immigrant backgrounds but not for students from non-immigrant backgrounds. Thus, students from immigrant backgrounds suffer more from being bullied, with an increased likelihood of obtaining a lower-quality high school diploma because they were not recommended for an academic-track secondary school. Furthermore, the effect of perceived teacher support on enjoyment of school was statistically significantly higher for students from immigrant backgrounds than for students from non-immigrant backgrounds. Accordingly, students from immigrant backgrounds benefit more from perceived teacher support in terms of school-related well-being. In addition, the effect of perceived teacher support on academic track recommendation was significantly positive for students with a low SES, but non-significant for students with a high SES. Hence, students with a lower SES depend more on teacher support than students with a higher SES. These results connect to Kurdi and Archambault (2020), who showed that a good student–teacher relationship is particularly beneficial for students from immigrant backgrounds with low SES.

Limitations and strengths

There are some limitations to this data. First and foremost, only the positive affective component of students' well-being was measured. Other central school-related well-being components linked to the school context, such as satisfaction with school, were not measured. Second, our study's focus on the negative aspects of peer interactions, particularly through experiences of bullying, does not fully capture the complexity of social dynamics in school settings. The limitations of the PIRLS 2016 dataset precluded the inclusion of measures of positive peer relationships, such as peer support or cooperation, potentially limiting our understanding of their impact on academic and well-being outcomes. Future research should aim to balance this perspective by exploring both positive and negative facets of peer interactions to provide a more comprehensive analysis. Third, another limitation is that tracking decisions at the end of Grade 4 in Germany are not based on standardized test scores, so we had to use the academic track recommendation information as a proxy for academic achievement. Fourth, some variables did not measure whether students actively apply specific learning techniques, but rather whether teachers use or make space for specific learning techniques in class. Despite these limitations of the PIRLS 2016 data, its large sample size, representativeness, and standardized data collection protocol are clear strengths that yield meaningful insights into the importance of social relationships for both academic achievement and well-being among elementary school children. Furthermore, we applied a cutting-edge double machine learning approach that simultaneously allows for the theoretical inclusion of a deeply rich set of control variables while also avoiding overfitting by selecting the most important variables. Selecting for effects on both the outcomes and the main explanatory variables further decreased the probability of omitted variable bias when estimating the effects of the explanatory variables. Another strength of this manuscript lies in secondary use of data to address a critical research gap. This approach takes advantage of efficient and sustainable methodology by leveraging existing resources to answer new research questions, which is in line with current calls to justify new data collection and maximize the value of existing datasets.

Lastly, experimental studies are much better at substantiating causal effects (Levitt & List, 2007). Even though we included a rich set of control variables, our results could still be biased, as we need to assume no collider or mediation effects as well as no unmeasured confounders. Hence, our results are not necessarily causal. However, findings from large-scale datasets are essential to support effects found in small-scale experiments and field studies and put them into a larger context or present important evidence motivating future interventions. As A. Falke and J. Heckman note, "... it is important to acknowledge that empirical methods and data sources are complements, not substitutes. Field data, survey data, and experiments, both lab and field, as well as standard [statistical] methods, can all improve the state of knowledge in the social sciences. There is no hierarchy among these methods, and the issue of generalizability of results is universal to all of them" (Falk & Heckman, 2009, p. 537).

Implications for research and practice

Our findings prompt a critical evaluation of whether promoting positive experiences is more important than preventing negative ones for improving student outcomes. This perspective challenges us to prioritize enhancing positive interactions over simply reducing

negative ones, such as bullying. Accordingly, future studies should explore these dynamics through designs that assess both positive and negative aspects of peer and teacher interactions. Such research could critically inform educational strategies that emphasize the promotion of positive relationships to maximize student well-being and academic success.

Moreover, longitudinal studies that exploit variation over time or interventions that aim to improve teacher support could present additive evidence for causality. An example intervention would be to promote teacher support techniques as well as students' basic psychological needs (Ryan & Deci, 2000) while (a) examining the intervention effect and (b) testing a possible channel through which perceived teacher support or reduced bullying experience influences students' well-being. A connection between teacher-student interaction, satisfaction of basic psychological needs and well-being has already been demonstrated for other cultural groups and/or older students by Kurdi and Archambault (2020) as well as Stang-Rabrig (2022a), among others. For academic achievement, the social resource factors showed only a superficial effect, as it was not robust to our "many-worlds" analysis. Hence, to increase students' academic achievement, motivational interventions might be a better alternative (Gaspard et al., 2015; Piesch et al., 2020; Wigfield & Eccles, 2020).

Alongside implications for research, our study results also have clear practical significance. The finding that both social resources remained relevant for students' well-being after controlling for numerous variables underlines the relevance of a positive school or classroom climate, which is characterized by teacher support and positive peer relationships. A positive classroom context might be particularly important for "at-risk students," e.g., students with a low SES. Moreover, strengthening students' well-being is of high importance as it is associated with their achievement and can have an impact on future learning behavior (e.g., Kleinkorres et al., 2020; Hascher & Hagenauer, 2010). Strengthening students' (positive) social interactions with peers (thus mitigating bullying) and with teachers (by strengthening teacher support) may improve school life for elementary school children. Hence, we ask for more awareness among parents and teachers of how students perceive their social interactions in school.

Appendix

Detailed Overview and Taxonomical Grouping of Survey Variables

Table 5 summarises for each variable the corresponding values, the survey and the question. Table 6 then shows the variables grouped according to the PIRLS 2016 taxonomy.

Selection of variables

The regression results showed that additional control variables were essential in our case. Table 7 further highlights which of the control variables were selected by LASSO in the double selection procedure. It shows that variables from each group were selected in the respective selection steps. For academic track recommendation and perceived teacher support, two or three variables from DI were included. Interestingly, immigrant background was only an important predictor for perceived teacher support, while socio-economic background was relevant for academic track recommendation.

Table 5 Survey questions

Variable	Values	Survey	Survey question
Outcomes			
Academic track recommendation	0 = other, 1 = academic track recommendation	Administrative data	What recommendation for secondary school did the student receive?
Enjoyment of school Resources (RES)	1 = strongly disagree to 4 = strongly agree	Students	I like going to school
Experienced bullying*	1 = never to 4 = at least once a week	Students	Made fun of me or called me names
Perceived teacher support*	1 = strongly disagree to 4 = strongly agree	Students	Our German teacher praises me when I do something right
Demographic information (DI)			
Female	0 = male, 1 = female	Administrative data	-
Age	Age in years and months	Administrative data	-
Books at home	1 = none or very few (0–10 books) to 5 = three or more bookshelves (over 200 books)	Students	3419
HISEI	Values between 10 and 90	Students	Own calculation
Foreign-born	0 = German-born, 1 = foreign-born	Students	Were you born in Germany?
One foreign-born parent	0 = no, 1 = yes	Parents	In which country were you born?
At least one foreign-born parent	0 = no, 1 = yes	Parents	In which country were you born?
Two foreign-born parents	0 = no, 1 = yes	Parents	In which country were you born?
Siblings (in household)	Number of siblings in household	Students	Which persons live together in your household? – Siblings of the child or other children
Single parent	0 = no, 1 = yes	Students	Are you a single parent?
At least one stepparent	0 = no, 1 = one stepparent	Students	Which persons live together in your household? At least one of – Stepmother, father's partner or – Stepfather, mother's partner

Table 5 (continued)

Variable	Values	Survey	Survey question
Adopted	0 = no, 1 = is adopted	Students	Which persons live together in your household? Only – Stepmother, father's partner and/or – Stepfather, mother's partner
Cognitive prerequisites (COG)			
Cognitive skill test score	Test score results	Administrative data	-
Early childhood education under three	0 = no, 1 = yes	Students	2552
Preschool	0 = no, 1 = yes	Students	2813
Enrichment activities*	1 = no, never; 2 = yes, occasionally; 3 = yes, regularly	Parents	Has your child received extracurricular support in recent years to improve his/her academic performance or develop his/her talents? – In reading Read stories or texts on the internet Read stories or texts in books or magazines Watch television [including videos and DVDs] Play video or computer games [including Nintendo, Gameboy, or PlayStation]
Reading for entertainment*	1 = no time to 5 = 5 h or longer	Students	
Digital devices for entertainment*	1 = no time to 5 = 5 h or longer	Students	
Self-regulated learning (SRL)			
Concentration ability*	1 = strongly disagree to 4 = strongly agree	Parents	My child is focused and persistent
Teacher feedback on homework in class*	1 = never or rarely to 3 = always or almost always	Teachers	Discuss homework in class
Use of teacher feedback: Correcting assignments and giving feedback*	1 = never or rarely to 3 = always or almost always	Teachers	Correct assignments and give feedback to the students
Emphasis on inquiry in schools*	1 = strongly disagree to 4 = strongly agree	School principal	At what grade level is particular emphasis first placed on the following reading skills and reading strategies in instruction at your school? – Finding information in-text
Digital inquiry experience*	1 = not at all to 3 = longer than 30 min	Students	How long do you use a computer or tablet on a normal school day for these activities? – Search for and read information

Table 5 (continued)

Variable	Values	Survey	Survey question
Use of self-evaluation*	1 = never to 3 = once or twice a week	Teachers	How often do you do the following things in reading class? – Give students opportunities to self-monitor what they write
Motivation (MOT)			
Extracurricular reading for fun*	1 = never or rarely to 4 = every day or almost every day	Students	How often do you do these things outside of school? – I read outside of school because I enjoy it
Extracurricular reading to learn*	1 = never or rarely to 4 = every day or almost every day	Students	How often do you do these things outside of school? – I read to learn about things I like learning about
Reading self-concept*	1 = strongly disagree to 4 = strongly agree	Students	– Reading is very easy for me
Reading interest*	1 = strongly disagree to 4 = strongly agree	Students	– I like to read

*Latent variables. For the latent variables, the survey questions only include one example item. The full list of items can be seen in the scale manual for PIRLS 2016 (Häußmann et al., 2020)

Table 6 Variables grouped by the taxonomy of PIRLS 2016

Variable groups	Number of survey questions	Examples of variables per group	Number of PCs
Student data			
Demographic data	3	Gender, year of birth	2
Social background	7	Persons in household, possession of books and other goods indicative of wealth, income	2
Cultural background	4	Country of origin of the student and parents, German as native language	1
Parental support behavior	2	Parents' interest in the child's activities (My parents always know where I go after school.)	1
Extracurricular activities	1	Activities outside school	2
Individual learning conditions	6	Absenteeism at school, library usage, extracurricular reading activities, reading self-concept	1
Subject-specific teaching in the classroom	14	Reading activities in class, perceived class management, perceived support from the teacher	2
School-related attitudes and perceptions	1	Sense of safety at school	1
Tutoring	1	Private tutoring	1
Participation in all-day activities	1	Participation in all-day school activities	1
Computer and Internet use	3	Computer use: location, frequency, and duration	2
Student-specific information from the student participation list	13	Grades, Learning and social behavior	2
Skills	2	Cognitive skills test, receives special education support	2
Parent data			
Reference person	1	Person filling in the survey	2
Cultural background	26	Germany as the child's country of birth, language(s) in early childhood, parents' cultural practices, educational expectations	2
Social background	22	Reading habits of parents, number of books at home, parental education background and occupation, economic and cultural capital	3
Digital media at home	2	Number of digital devices in the household	2

Table 6 (continued)

Variable groups	Number of survey questions	Examples of variables per group	Number of PCs
Preschool years	4	Learning to read: preparatory activities at home, early childhood education, child's reading skills at school entry	2
Elementary school years	5	Parental support activities at home, parents' interest in the child's friendships	3
Parents and schools	4	Parents' satisfaction with the school and child's school performance, contact between home and school	3
Teacher data			
Demographic and educational biographical information	7	Gender, age, highest educational attainment, professional qualifications	1
Professional education and attitudes toward the teaching profession	8	Teaching experience, university major	3
School structure and organizational characteristics	6	School atmosphere, communication with fellow teachers, willingness to innovate among the teaching staff	3
Structure, process, and organizational characteristics of subject teaching	17	Classroom disturbances, constructivist beliefs, cognitive activation	5
Spelling instruction	3	Spelling lessons (time to practice, materials, and methods)	3
Use of phonics tables in teaching	5	Use of phonics tables (time, form, frequency, and own opinion)	1
Collaborative teaching	8	Students with and without special educational needs (preparation, change in teaching)	1
Resources	7	Time for reading instruction/reading activities, computer use in reading instruction, classroom library, reading specialist(s) on staff	3
Design of reading instruction	23	Differentiation in reading lessons, text types in reading instruction, methods in reading instruction, teaching reading strategies, support for weak and strong readers	3
School principal data			
School spirit	3	School spirit among teachers, parents, and students	1
Structure and organizational characteristics of schools and teaching	7	Number of teaching days per year/week, performance orientation of the school, classroom management: organization of learning groups	3

Table 6 (continued)

Variable groups	Number of survey questions	Examples of variables per group	Number of PCs
Resources and equipment	11	Free meals at the school ^a , homework supervision, number of computers/e-books available, problems with the school's personnel and material equipment, all-day school	3
Additional support services at the school	1	School support and care services	3
Measures for promoting reading	3	Systematic development of reading skills/strategies, Measures to promote reading	3
Special education	14	"Inklusionsschule," e.g. schools that include both students with and without special needs (implementation, year, number of students, specialized support without diagnoses, type of support needs, persons involved, framework)	2
Immigration	5	First-generation immigrants and refugees (number of students, organization, challenges)	2
School profile and profile classes	6	School profile (type, goals), profile classes (type and goals)	3
Information about students	7	Number of students, Social backgrounds, German as native language	3
Information about teachers	6	Problematic behavior by teachers, age composition, teacher cooperation	4
Information about school principal	12	Gender, experience, areas of activity of school administration	2

^aWhile in the USA, only schools with a high-poverty student body have free meals available to students (due to a federal funding stream), free meals in German schools are not just provided in high-poverty regions and are often more of a "perk" in high-resource schools

The table presents the PRILS taxonomy as well as the number of principle components determined in each category which were used for the analysis in this paper. PC, Number of principal components after conducting a principal component analysis

Table 7 Selection of additional control variables in Model 3

Variables	ATR	EOS	EB	PTS	Sum
Demographic information (DI)					
Female					0
Age	•				1
Books at home	•				1
HISEI	•				1
Foreign-born					0
One foreign-born parent					0
At least one foreign-born parent				•	1
Two foreign-born parents				•	1
Siblings (in household)					0
Single parent					0
One stepparent					0
Adopted					0
Sum	3	0	0	2	
Cognitive prerequisites (COP)					
Cognitive skill test score	•			•	2
Early childhood education under three					0
Preschool					0
Enrichment activities					0
Non-digital reading for entertainment			•	•	2
Digital devices for entertainment	•	•	•	•	4
Sum	2	1	2	3	
21st century skills (CES)					
Use of communication: Talks about what students read		•			1
Use of communication: Explaining one's answers		•		•	2
Use of collaborative reading: Pairing up stronger and weaker readers	•		•		2
Use of collaborative reading strategies		•		•	2
Promotion of critical thinking					0
Promotion of creativity					0
Computer usage for texts and presentations	•		•		2
Sum	2	3	2	2	
Self-regulated learning (SRL)					
Concentration ability	•	•	•	•	4
Teacher feedback on homework in class		•			1
Use of teacher feedback: Correcting assignments and giving feedback	•	•		•	3
Emphasis on inquiry in the school					0
Digital inquiry experience		•			1
Use of self-evaluation					0
Sum	2	4	1	2	
Motivation (MOT)					
Extracurricular reading for fun		•		•	2
Extracurricular reading to learn		•		•	2
Reading self-concept	•	•	•	•	4
Sum	1	3	1	3	

Dependent variables: *ATR* academic track recommendation (dichotomous), *EOS* enjoyment of school (standardized). Independent variables: *EB* experienced bullying (standardized), *PTS* perceived teacher support (standardized). The table reveals which additional control variables were selected for the respective outcomes ATR, EOS, and TA, as well as the two social resource factors EB and PTS. The last column gives the sum of how often each variable was selected. The sums in the last row of each set of control variables show how often a variable from that set was selected for the respective outcome variable

Regarding cognitive prerequisites, skill test scores were important for academic track recommendation and perceived teacher support. At the same time, using digital devices for entertainment was an important predictor of academic track recommendation, enjoyment of school, bullying experience, and perceived teacher support. Furthermore, non-digital reading for pleasure was selected when explaining the social resource factors of bullying experience and perceived teacher support. Looking at the self-regulated learning variables, we see that the ability to concentrate was selected five times, while emphasis on inquiry at the school and use of self-evaluation were not selected. Lastly, reading self-concept was an essential predictor for each of our three outcomes and the two resource antecedents, while extracurricular reading for fun and to learn were only selected for enjoyment of school and perceived teacher support. Thus, only ability to concentrate and reading self-concept were important in every selection procedure.

Funding Open Access funding enabled and organized by Projekt DEAL. The project “From Prediction to Agile Interventions in the Social Sciences (FAIR)” has received/is receiving funding from the program “Profilbildung 2020,” an initiative of the Ministry of Culture and Science of the State of North Rhine-Westphalia. The sole responsibility for the content of this publication lies with the authors.

Data Availability The authors do not have permission to share the analyzed data. However, these data are available via the IQB (https://www.iqb.hu-berlin.de/fdz/studies/IGLU_2016).

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Current themes of research:

Jakob Schwerter is a postdoctoral researcher at the Center for Research on Education and School Development (IFS) and at the chair Statistical Methods in Social Sciences, Faculty of Statistics, both at the TU Dortmund University. He earned his Ph.D. in Economics in 2020. His research lies at the intersection of psychology, education, statistics, data science, and economics. In a core strand of

research with a particular focus on data-driven and evidence-based intervention research in the field of digital educational psychology, he investigates how digital educational environments impact student learning. His other core strands of research focusses on educational choices and effectiveness as well as educational data sciences.

Most Relevant Publications:

- Goldberg, P., Schwerter, J., Seidel, T., Müller, K., & Stürmer, K. (2021). How does learners' behavior attract preservice teachers' attention during teaching? *Teaching and Teacher Education*, 97, 103213. <https://doi.org/10.1016/j.tate.2020.103213>.
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Current themes of research:

Justine Stang-Rabrig is a postdoctoral researcher at the Center for Research on Education and School Development (IFS) at TU Dortmund University. She earned her Ph.D. in Psychology in 2017. Her recent work focuses on themes like well-being, attitudes, stereotype threat, and instructional quality.

Most Relevant Publications:

- Kleinkorres, R., Stang-Rabrig, J., & McElvany, N. (2023). Comparing parental and school pressure in terms of their relations with students' well-being. *Learning and Individual Differences*, 104, Article 102288. <https://doi.org/10.1016/j.lindif.2023.102288>.
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Current themes of research:

Ruben Kleinkorres is a postdoctoral researcher at the Center for Research on Education and School Development (IFS) at TU Dortmund University. He earned his Ph.D. in Psychology in 2023. His recent work focuses mainly on antecedents and outcomes of the well-being and academic achievement of students.

Most Relevant Publications:

- Ludewig, U., Kleinkorres, R., Schaufelberger, R., Schlitter, T., Lorenz, R., König, C., Frey, A., & McElvany, N. (2022). COVID-19 Pandemic and Student Reading Achievement: Findings From a School Panel Study. *Frontiers in Psychology*, 13(May). <https://doi.org/10.3389/fpsyg.2022.876485>.
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Current themes of research:

Johannes Bleher is a postdoctoral researcher at the University of Hohenheim. He earned his Ph.D. in Economics and Finance in 2021. His work focuses on econometrics, data science and machine learning methods with a special focus on asset pricing.

Most Relevant Publications:

- Schwerter, J., Bleher, J., Doeblér, P., & McElvany, N. (2023). Metropolitan, urban, and rural regions – How regional differences affect elementary school students' academic achievement, well-being, and motivation. *SSRN Electronic Journal*, 1–55.
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Current themes of research:

Philipp Doeblér is a full professor for Statistical Methods in Social Sciences at the Department of Statistics at TU Dortmund University. His recent work focuses on themes like Machine Learning in Measurement, Meta-Analysis, and, more recently, Educational Data Science.

Most Relevant Publications:

- DeVries, J. M., Szardenings, C., Doeblér, P., & Gebhardt, M. (2020). Individualized Assignments, Group Work and Discussions: How They Interact With Class Size, Low Socioeconomic Status, and Second Language Learners. *Frontiers in Education*, 5(May), 1–13. <https://doi.org/10.3389/feduc.2020.00065>.
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- Schwerter, J., Bleher, J., Doeblér, P., & McElvany, N. (2023). Metropolitan, urban, and rural regions – How regional differences affect elementary school students' academic achievement, well-being, and motivation. *SSRN Electronic Journal*, 1–55. <https://doi.org/10.2139/ssrn.4368170>

Current themes of research:

Nele McElvany is the executive director of the Center for Research on Education and School Development (IFS) and vice-president for research at TU Dortmund University. As Professor of Empirical Educational Research, she focuses on educational processes from psychological and pedagogical perspectives. As psychologist by training, her work comprises research on individual, social and institutional conditions of educational processes and outcomes.

Most Relevant Publications:

- Becker, M., & McElvany, N. (2018). The interplay of gender and social background: a longitudinal study of interaction effects in reading attitudes and behaviour. *British Journal of Education Psychology*, 88(4), 529–549. <https://doi.org/10.1111/bjep.12199>
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- Vogel, S. N. T., Stang-Rabrig, J., & McElvany, N. (2023). The importance of parents for key outcomes among socio-economically disadvantaged students: Parents' role in emergency remote education. *Social Psychology of Education*. <https://doi.org/10.1007/s11218-023-09801-2>.

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