



THE EFFECT OF SCHOOL BULLYING ON SCIENCE ACHIEVEMENT AND COGNITIVE APPRAISALS

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Abstract

Despite the social and technological advancements of the 21st century, school bullying remains a significant problem in education systems. Beyond the psychological distress, school bullying affects the mind's core cognitive appraisals and creates an unfair academic disadvantage to victims. The moral dilemma of random assignment impedes experimental research on bullying, thereby making it difficult to gain insights into the detrimental effects of bullying on victims' cognitive appraisals and academic outcomes. Propensity score analysis can simulate a quasi-experimental design with balanced groups to overcome this challenge. This study seeks to analyse the prevalence of bullying across nations and to employ propensity score matching (PSM) on a nationally representative TIMSS 2019 dataset to mitigate selection bias in evaluating the effect of bullying on science performance and cognitive appraisals. Descriptive statistics were obtained from 162,365 eighth-grade students in 24 countries. PSM analyses were performed on the Türkiye dataset (4,077 students). Generally, the percentage of high-frequency bullying was associated with lower science achievement across countries. PSM results showed that bullying victimization significantly decreased students' science achievement and perceived control in learning science. Additionally, a marginally significant positive effect of bullying on perceived value of learning science was found. Similar results from OLS regression and sensitivity analyses provided evidence for the robustness of the estimated effects. Overall, the findings show that bullied students experience cognitive disadvantages. The contributions of these domain-specific findings to control-value theory and its implications for anti-bullying initiatives were discussed.

Keywords: cognitive appraisals, propensity score analysis, school bullying, science achievement

Introduction

Bullying in schools is not merely an interpersonal issue; it is a significant educational problem that threatens students' development and the effectiveness of educational systems. Bullying is commonly perceived to negatively affect individuals' psychological and emotional well-being and academic achievement. In this sense, bullying can be considered a structural barrier to students' overall educational experience. This socially unacceptable behaviour has significant long-term costs for individuals, families, and society (Wolke & Lereya, 2015). Nonetheless, it remains a prevalent and significant issue globally. On average, one in five students in OECD countries were bullied at least several times a month and 8% were bullied regularly (OECD, 2023). Specifically, science achievement of students is lower in schools where bullying is more frequent (OECD, 2017). Yet, the existing literature lacks evidence on the relationship between bullying and science achievement across different contexts at the student level. Not only is peer bullying understudied in the literature from an educational perspective, but there is also a lack of evidence regarding the pathway from bullying victimization to perceived control and value in science, domain-specific cognitive appraisals in control-value theory (CVT).

CVT is a prominent theory that offers a multidimensional perspective in explaining the effects of environmental, cognitive, and emotional factors on achievement outcomes.

According to this theory, achievement emotions that students experience during academic tasks are regulated by two basic cognitive appraisals: control and value appraisals (Pekrun, 2006; Pekrun et al., 2002; Pekrun, 2024). While students' perceived control and value in science education correlate with their achievement through various emotions (Tze et al., 2016), to the best of our knowledge, the influence of school bullying on these cognitive appraisals remains unexamined in the literature. The tenets of CVT imply that bullying as a social-environmental stressor may negatively influence cognitive appraisals, which may trigger negative emotions such as anxiety, frustration, shame, and hopelessness that have negative effects on academic achievement (Pekrun, 2024; Pekrun & Perry, 2014).

This study, which examines how bullying affects science achievement as well as perceived value and perceived control, is intended to contribute significantly to the literature by addressing the environmental and cognitive appraisal factors that determine success in science education within the CVT framework. Should the treatment effects—conditional on balanced covariates—exist, this could inform education policymakers and school administrators that policies aimed at improving student achievement should not be limited solely to cognitive learning processes, rather more emphasis should be placed on preventing bullying to create a safe school climate. In this study, treatment effect refers to the average difference in science achievement between bullied students and matched students with comparable background who were not bullied. Similarly, the findings aim to encourage teachers of classroom practices that foster positive peer relationships, give students a sense of control over their success, and demonstrate the value of science lessons. Furthermore, this study is aimed at providing robust empirical evidence incorporating bullying as an environmental factor within the CVT framework by employing a methodology that is infrequently implemented in the field of educational research.

Furthermore, science discipline provides a particularly suitable context for examining the effects of bullying on academic and cognitive processes. International assessments show that bullying is consistently associated with science achievement, and that science scores are lower in schools where high-frequency bullying occurs (OECD, 2017). Science lessons involve high cognitive demands such as problem solving, experimental work, and scientific reasoning, and are therefore directly linked to the student's perceived sense of control and value. CVT (Pekrun, 2006; Pekrun, 2024) argues that the fundamental cognitive appraisals that shape feelings of success become more pronounced in areas such as science, which involve high cognitive load. Therefore, bullying as a social-environmental stressor, is expected to have a stronger impact on science achievement by reducing perceived control and disrupting value judgments in science learning. Furthermore, studies examining (conditionally) causal links between bullying and science achievement are quite limited in the literature; existing research has mostly focused on mathematics or general academic achievement (e.g., Carrasco et al., 2022; Juvonen et al., 2011; Nakamoto & Schwartz, 2010). This study examines the environmental determinants of CVT within science discipline, revealing the estimated effects of bullying on perceived control, perceived value, and science achievement, and provides concrete implications for practice, thereby making a significant contribution to the literature.

Theoretical Background

Control–Value Theory of Achievement Emotions

In CVT, cognitive appraisals in academic context are influenced by environmental factors. Subsequently, the subjective cognitive appraisals play a predictive role in emotions and learning outcomes (Pekrun, 2006). The theory explains this process through four main components: environment, cognitive appraisals, emotions, and achievement outcome (Pekrun, 2024). According to CVT, environmental factors (e.g., autonomy support, teaching style, family

expectations) provide external inputs that influence the individual's perception of control and value. Environmental antecedents of cognitive appraisals can be characterized as cultural context and social environments (Pekrun, 2024). Perceived control refers to an individual's belief in being able to successfully perform a learning task or influence an outcome, while perceived value refers to the extent to which the task or outcome in question is important, useful or interesting to the individual (Pekrun, 2006). Perceived control and value impact the learning experiences and academic achievement either directly or indirectly through these emotions (Pekrun et al., 2002; Pekrun & Perry, 2014). In other words, perceived control and value are functional elements within the framework that links contextual inputs to emotional and achievement-related outcomes.

Bullying and Its Consequences on Achievement and Cognitive Appraisal

Bullying is defined as aggressive behaviour emboldened by a power imbalance with the intent to repeatedly harm another individual verbally, physically, or in a virtual environment (Olweus, 2003). The person or group that engages in bullying behaviour is called the bully; the person who is subjected to bullying is called a victim; and the ones who are both bully perpetrators and bullying victims are called bully-victims (Perren & Alsaker, 2006). Bullying includes physical aggression (kicking, hitting, damaging someone's property, etc.), verbal aggression (threatening, name-calling, etc.), social/relational aggression (spreading rumours, social exclusion, etc.), and the most recent form of aggression, which is aggression through the Internet and new technologies (cyberbullying) (Menesini & Salmivalli, 2017; Monks & Smith, 2006; Smith, 2014). Nevertheless, due to their substantial overlap, some researchers do not differentiate between traditional bullying and cyberbullying as distinct phenomena (Mitchell et al., 2016). In this paper, we use bullying, bullying/cyberbullying, and bully victimization interchangeably to refer to the experience of being bullied.

Peer bullying affects children's academic achievement. A meta-analysis of 16 quasi-experimental studies indicated that bullying has short-term (within a year) effects, including diminished academic performance (Schoeler et al., 2018). Bullied students' academic achievement (Juvonen et al., 2011; Liu et al., 2014; Nakamoto, & Schwartz, 2010; Strøm et al., 2013) and particularly science achievement (Coşkun & Karadağ, 2023) decreases.

In addition to the reduced academic achievement, negative social experiences in the school environment, such as peer bullying, may weaken students' positive feelings towards learning, consequently lowering their cognitive evaluations (Espelage & Swearer, 2010). Studies showed that bullying victimization is related to lower self-efficacy in elementary school (Kokkinos & Kipritsi, 2012) and during adolescence (Samara et al., 2021), which may reflect diminished perceived control. Moreover, an unsafe environment was associated with diminished perceived value of experiences in youth sports programs (Ellis et al., 2017). According to CVT, inasmuch as students' perceived control is decreased due to bullying—a social-environmental stressor, negative activating emotions like anxiety and anger, and deactivating emotions like hopelessness can be triggered as a result of decreased control (Pekrun, 2024). Additionally, the perceived value of learning can be distorted by social distress and rejection as a result of bullying. The toxic combination of these appraisals may create conditions for heightened anxiety, shame, hopelessness, and frustration that have direct negative effects on academic achievement (Pekrun, 2024; Pekrun & Perry, 2014). Consequently, bullying may negatively affect students' perceived control and value in learning science and result in lower achievement in science through the effects of achievement emotions regulated by perceived control and value, or through other mechanisms not accounted for by the CVT framework.

Research Aim and Research Questions

The exploration of factors that influence students' academic performance is crucial for enhancing educational policy effectiveness. This study aimed to determine the prevalence of bullying and its association with science achievement across countries. Furthermore, research employing the CVT framework has primarily focused on the connections between cognitive appraisals, emotions, and achievement outcomes. Nonetheless, the literature lacks studies exploring the effect of environmental factors (e.g., bullying) on science achievement and cognitive appraisals in learning science. Although Coşkun and Karadağ (2023) examined the effect of bullying on science achievement using the TIMSS 2015 dataset, the results of the current study contribute to the literature by more precisely estimating the effect through the use of PSM, which provides a less biased estimated effect on balanced cohorts. Hence, this study aimed to elucidate the role of bullying as an environmental factor in CVT by examining its effects on science achievement, and science-related perceived control and value. The answers to the following research questions were sought:

1. How prevalent is bullying victimization across nations? Is there an association between science achievement and bullying victimization?
2. Does bullying victimization decrease science achievement?
3. Does bullying victimization decrease perceived control in learning science?
4. Does bullying victimization decrease perceived value in learning science?

Research Methodology

General Background

This study used a quantitative methodology to analyse cross-sectional data from the eighth-grade cohort in the 2019 Trends in International Mathematics and Science Study (TIMSS) survey. This data was collected by the International Association for the Evaluation of Educational Achievement (IEA) between October and December 2018 in the Southern Hemisphere, and between March and June 2019 in the Northern Hemisphere (Martin et al., 2020). The goal of the study was to determine the prevalence of bullying across nations. Furthermore, the dataset from Turkey was used to estimate the effect of peer bullying on science achievement, perceived control, and perceived value in learning science within the framework of CVT using the PSM method in Stata 14 statistical software. PSM was employed as a quasi-experimental research methodology on this secondary data to infer causal estimates from observational data. PSM addresses the challenge of non-random assignment of treatment in observational datasets by creating a statistically comparable control group using observed covariates, thus simulating the counterfactual scenario—that is, how the outcome would have changed if the control group was exposed to the treatment condition (Guo & Fraser, 2015). By aligning characteristics (i.e., balancing covariates) across treatment and control groups, PSM reduced selection bias and enhanced the reliability of treatment effect estimations. Robustness of the results was evaluated using OLS regression results, and sensitivity analyses were performed to measure the sensitivity of the results to omitted confounders. Because the study used the fully anonymized, publicly available TIMSS dataset, which does not contain any identifiable personal data, ethical approval was not required.

Sample

The international TIMSS 2019 survey is aimed at measuring fourth and eighth-grade students' science and mathematics achievement along with student, teacher, and school-level

background variables through valid and reliable comparative data (Martin et al., 2020). The research design of this assessment was a stratified two-stage cluster sampling design that collected data from students, teachers and school administrators (for more technical details about the research design, see TIMSS 2019 Technical Report by Martin et al., 2020). Initially, analytical data for the current study were gathered from all the TIMSS 2019 eighth-grade cohort data of 38 countries (227,345 students from 7636 schools). However, Kazakhstan was excluded from the analyses because of the detection of insoluble problems related to the translation of bullying items (Wagemaker & Mirazchiyski, 2023). Moreover, Cyprus, Finland, Sweden, France, Georgia, Hungary, Korean Republic, Lebanon, Israel, Lithuania, Morocco, Portugal, Romania, and Russian Federation were also excluded because they had complete sets of missing data on either science achievement or bullying. In this way, we prevented bias that may arise from non-random missing data. Descriptive statistics for the first research question were obtained from the remaining 24 countries from different continents and cultural backgrounds (Refer to Table 2 for the list of these countries). The final sample included 162,365 students (50.12% girls and 49.88% boys) from 5085 schools. To answer other research questions, Türkiye data was used. This dataset consisted of 4077 students (49.62% girls and 50.37% boys) from 181 schools. This context was selected because it does not have anti-bullying legislation. In countries with strong anti-bullying legislation, the true effect may be underestimated. Additionally, analysing data from under-examined countries can provide meaningful interpretations of the results.

Variables and Measures

Science Achievement

The TIMSS 2019 dataset includes five plausible values of individual science achievement. Although the possible range of individuals' TIMSS 2019 science achievement score was between 0 and 1,000 with 500 as the scale centerpoint, most of average achievement scores were between 300 and 700 (Irwin et al., 2021; Martin et al., 2020). Because students were not tested on all available items measuring the achievement, their responses to a subset of items were used to generate imputed values through a 'latent regression (or population) model' using item response theory to accurately measure students' unbiased performance by accounting for contextual data (Martin et al., 2020). Their weighted pooled average scores across imputed values of the initial analytical sample were 489.12, and for the final sample, they were 518.00, with Chinese Taipei/Taiwan having the highest (573.26) and Jordan having the lowest pooled average (450.23). Since these are imputed values, in the following PSM analyses, we simultaneously analysed all five datasets of Türkiye, each containing a plausible value, to properly account for the uncertainty introduced by the missing data.

Bullying/Cyberbullying

A bullying/cyberbullying scale was extracted from the TIMSS 2019 assessment framework, which consisted of 14 items. Each item corresponded to one of the eight items of "Scale A: Being victimized" of the Revised Olweus Bully/Victim Questionnaire in Kyriakides et al. (2006, p. 793). This scale consisted of eight items, and each of the 14 bullying behaviours that were reported by students in the TIMSS dataset matched to one of the items of Scale A: Being victimized. For example, TIMSS 2019 student questionnaire items 'refused to talk to me' and 'excluded me from their group' matched to the item 'left out of things, excluded, or ignored' in 'Scale A: Being victimized' or another TIMSS item 'spread lies about me' was matched to 'other students told lies about me or tried to make others dislike me' in the cited scale. The bullying/cyberbullying scale was very reliable with a Cronbach's alpha coefficient of .90. These items were used to depict the prevalence of bullying victimization across nations. Moreover,

for PSM analysis, a composite variable (BSDGSB) constructed by IEA was used. This 3-point Likert-type ‘student bullying’ variable was recoded into a binary treatment variable of 0 (No) and 1 (Yes) to demonstrate students’ frequent (weekly or monthly) exposure to bullying.

Perceived Control and Value in Science

Tze and Li’s (2021) operationalization of three items to conceptualize perceived control and three items to conceptualize perceived value appraisals in learning science (See Table 1) were used. The Cronbach’s alpha coefficients for science related perceived control and perceived value scales were .82 and .78. For the Türkiye data set, perceived control scale had good reliability ($\alpha = .81$) while perceived value had acceptable level of reliability ($\alpha = .65$).

Table 1
Descriptions of Main Variables and Their Items

Variable TIMSS Item Code	Items Descriptions	Response Range**
Science Achievement		
BSSSCI01	1st Plausible Value Science	Min=5.00, Max=863.03
BSSSCI02	2nd Plausible Value Science	Min=5.00, Max=873.40
BSSSCI03	3rd Plausible Value Science	Min=11.50, Max=858.35
BSSSCI04	4th Plausible Value Science	Min=5.00, Max=851.31
BSSSCI05	5th Plausible Value Science	Min=5.00, Max=865.72
Bullying		
BSBG14A*	Said mean things about my physical appearance (e.g., my hair, my size)	1= Never 2=A few times a year 3=Once or twice a month 4=At least once a week
BSBG14B*	Spread lies about me	
BSBG14C*	Shared my secrets with others	
BSBG14D*	Refused to talk to me	
BSBG14E*	Insulted a member of my family	
BSBG14F*	Stole something from me	
BSBG14G*	Made me do things I didn’t want to do	
BSBG14H*	Sent me nasty or hurtful messages online	
BSBG14I*	Shared nasty or hurtful things about me online	
BSBG14J*	Shared embarrassing photos of me online	
BSBG14K*	Threatened me	
BSBG14L*	Physically hurt me	
BSBG14M*	Excluded me from their group (e.g., parties, messaging)	
BSBG14N*	Damaged something of mine on purpose	

Cognitive appraisals*Perceived Low Control*

BSBS24B*	Science is more difficult for me than for many of my classmates	1=Disagree a lot 2=Disagree a little
BSBS24C*	Science is not one of my strengths	3=Agree a little 4=Agree a lot
BSBS24G*	Science is harder for me than any other subject	

Perceived Value

BSBS22D*	I learn many interesting things in science
BSBS22F*	I look forward to learning science in school
BSBS22H*	I like to conduct science experiments

Note. All item descriptions are direct quotes from Fishbein et al. (2021) Supplement 1; *Reverse coded items

**These response ranges were calculated using datasets of the 24 countries.

Potential Confounders for Balancing

In PSM analysis, it is essential to control for alternative explanations that might bias treatment selection. To obtain credible causal estimates, factors influencing the likelihood of student bullying victimization must be controlled to mimic a randomization procedure. Numerous factors are associated with bullying. This include being a male (Rigby, 2005; Wang et al., 2009), age (Carrasco et al., 2022), socioeconomic status and disadvantaged schools (Badger et al., 2023; Johansson et al., 2022; Tippet & Wolke, 2014), belonging to school (Badger et al., 2023) and low cognitive skills (Sarsoza, 2024). In PSM, alternative explanations for outcomes must also be controlled. Student perceived control and/or perceived value was reported to be affected by teacher support, instructional clarity and supportive feedback (e.g., Ellis et al., 2017; Lazarides & Buchholz, 2019; Skinner et al., 2008), and parental value of subject-matter (Eccles, 2009; Jacobs & Bleeker, 2004). Moreover, student science achievement is reported to be affected by previous achievement, SES (Blums et al., 2016; Tan, 2022), sense of school belonging (Carrasco et al., 2022; Huang, 2020), gender (Frenzel et al., 2007), school safety, instructional clarity, and confidence in learning science (Coşkun & Karadağ, 2023). In addition to these plausibly fixed-effect variables, student report of ‘generally doing well in science’ was used as a proxy, which conceptually may partly represent student self-concept (confidence in learning science) and previous science achievement. Additionally, school region, male proportion within the classroom, and feeling safe at school were used in the PSM model.

Data Analysis

To answer the first research question, descriptive statistics were obtained from 24 countries spanning different continents and cultural backgrounds. The cross-tabulation of bullying and science achievement across nations was calculated. In the TIMSS dataset, schools were organized into jackknife zones (JKZs) based on background characteristics, and item responses were aggregated within each JKZ (Camilli & Dossey, 2019). In accordance with IEA guidelines, the jackknife repeated replication method was used to estimate the appropriate sampling errors (Fishbein et al., 2021) for the effect of bullying.

PSM analyses on covariates with missing values can bias treatment effect estimation (D’Agostino & Rubin, 2000). Examination of the Türkiye data revealed that 45 cases had missing values for the treatment variable, bullying victimization. Because the treatment assignment is considered to be part of the design, these cases were removed. Additionally, four cases had missing values on more than half of the covariates and were subsequently removed.

Examining the missing data pattern of the remaining 4,028 students revealed that the missing data mechanism was missing at random. The variables ‘parents’ highest level of education’ and ‘school location’ exhibited 7.2% and 2.11% missing data, respectively. The remaining covariates either had no missing data or had less than or equal to 1% missing data (when rounded to the tenth digit). The missing values in these variables, which exhibited negligible amounts of missing data, were replaced by their means. The missing values for the other two categorical variables were imputed using the multiple-imputation chained equation (MICE) method, implemented within the Stata software. MICE method employs univariate models that utilize posterior predictive distributions of imputed data on a variable-by-variable basis without necessitating a multivariate normal distribution when imputing categorical values (Bouhlila & Sellaouti, 2013). The production of five imputed datasets was successfully executed with 10 iterations. Each plausible value of science achievement was kept in an imputed dataset.

Propensity score analysis comprises statistical methods designed to infer causal treatment effects from nonexperimental data via counterfactuals (Guo & Fraser, 2015), to analyse extensive nonexperimental datasets to evaluate the causal estimates of an intervention under a treatment condition (Rubin, 1997). Because in non-experimental designs the probability of receiving a treatment is unknown (Rubin, 2001), the specified covariates were used to calculate propensity scores using logistic regression weighted by the student weight variable in TIMSS 2019 as suggested by Ridgeway et al. (2015). The PSM matching process helped eliminate sample selection bias to estimate causal inferences—conditional on an extensive number of potential confounders—using these propensity scores (Guo & Fraser, 2015). The validity of the inferences obtained from PSM output depends on two general assumptions: stable unit treatment value assumption (SUTVA) and strong ignorability of treatment assignment condition (Guo & Fraser, 2015; Powell et al., 2019; Rosenbaum & Rubin, 1983). These assumptions were assessed by the examination of covariate balance before and after matching process via standardized mean differences, adequate overlap of propensity score distributions between treated and control groups, and diagnostic sensitivity analysis. The criteria for acceptable covariate balance involved i) mean bias under 5% post-matching, ii) individual standardized mean differences below 10% post-matching, and iii) significant reduction in variance explaining the selection into treatment (pseudo- R^2). Despite the established evidence indicating that greedy matching methods of caliper matching and kernel matching yielded outcomes comparable to those derived from optimal matching techniques in instances of large sample sizes (Austin, 2013), due to a slightly better covariate balance, the kernel matching method with Epanechnikov kernel framework was employed using `psmatch2` command (Leuven & Sianesi, 2003) in Stata to estimate the average treatment effect on the treated (ATT). To assess the robustness of the treatment effect estimates, the same model (with covariates as independent variables) was performed in OLS regression (with student weight and school ID variable to take cluster effect into account), and the results were compared to those of PSM. Furthermore, sensitivity analysis using the `sensatt` package with `attk` command (Nannicini, 2006) was performed. This counterfactual simulation-oriented analysis evaluates the sensitivity of the baseline model estimations in relation to a simulated scenario. The analysis calculated the selection and outcome effects of an omitted binary confounder, U , on both the outcomes and the treatment, bullying. The four parameters of this variable are delineated by p_{ij} for $i, j \in \{0, 1\}$. These parameters “give the probability that $U=1$ in each of the four groups defined by the treatment status and the outcome value” (Nannicini, 2007). The moderate to high probability parameters (p_{ij}) of U were specified at $p_{00}=0.20$, $p_{01}=0.30$, $p_{10}=0.30$, and $p_{11}=0.40$. These parameters were considered to be justifiable for the purpose of estimating the simulated effect of U . Following the suggestion by Nannicini (2007), the percentage changes in treatment effect estimates were scrutinized for a possible sensitivity to unobserved bias.

Research Results

Descriptive Results

The first research question concerned the cross-country variation in bullying and science achievement, and any discernible patterns among them. Overall, the results showed that 80.97% of eight-grade students had experienced a form of bullying at least ‘a few times a year’. The results for the average aggregated bullying experience indicated that, on average, 66.18% of students did not experience bullying ($N = 97,615$), 27.26% experienced bullying a few times a year ($N = 40,210$), 5.69% experienced bullying once or twice a month ($N = 8,395$) and 0.86% experienced bullying at least once a week ($N = 1,269$).

Despite the convergence of intended science curricula in terms of the number and types of topics covered (Stacey et al., 2018), there was a notable discrepancy in the weighted average eighth-grade science achievement between countries. Table 2 shows that while average bullying does not clearly distinguish high-achieving countries from the rest, the percentage of high-frequency bullying indicates an association with science achievement. In general, high achieving countries tend to have a lower percentage of high-frequency bullying and vice versa.

Table 2

Descriptive Statistics on Science Achievement and Bullying Across Countries

Country	Science Achievement	Bullying/ Cyberbullying	% Bullied at least once a week
Egypt	389.33 (5.24)	1.52 (0.02)	2.61
Qatar	474.53 (4.19)	1.53 (0.02)	2.47
United Arab Emirates	472.98 (4.16)	1.54 (0.01)	2.24
Jordan	452.01 (4.30)	1.39 (0.01)	2.17
Bahrain	486.04 (5.17)	1.53 (0.02)	1.52
Hong Kong SAR	503.52 (5.07)	1.46 (0.02)	1.48
Kuwait	444.21 (5.49)	1.43 (0.01)	1.37
Australia	528.34 (3.09)	1.52 (0.01)	1.25
South Africa	369.97 (2.56)	1.85 (0.01)	1.15
Saudi Arabia	431.47 (2.37)	1.38 (0.01)	0.99
Oman	457.18 (2.65)	1.49 (0.01)	0.97
England	516.68 (4.74)	1.45 (0.01)	0.94
United States	522.34 (4.60)	1.45 (0.01)	0.76
New Zealand	498.88 (3.33)	1.50 (0.01)	0.74
Malaysia	460.24 (3.37)	1.83 (0.01)	0.70
Singapore	607.55 (3.80)	1.49 (0.01)	0.68
Chile	462.35 (2.68)	1.40 (0.01)	0.56
Turkey	515.49 (3.58)	1.41 (0.01)	0.48
Ireland	523.10 (2.81)	1.39 (0.01)	0.46
Norway	495.45 (2.73)	1.31 (0.01)	0.43
Iran	449.41 (3.46)	1.37 (0.01)	0.37
Italy	500.48 (2.50)	1.35 (0.01)	0.13
Chinese Taipei/Taiwan	574.33 (1.83)	1.21 (0.01)	0.03
Japan	569.51 (2.05)	1.15 (0.00)	0.00

Notes. These values were calculated using Stata's 'svy' feature with jackknife repeated replication method. The statistics of countries are ordered based on the percentage of highest frequency bullying experience.

The frequency of bullying victimization indicator derived by IEA (BSDGSB) showed that about weekly or monthly bullied students consisted of 28.6% of students ($n = 1,152$; 176 bullied weekly and 976 bullied monthly), while 2,876 students reported they were never or almost never bullied in Türkiye.

Propensity Score Matching Estimates

The results of PSM analysis using kernel matching demonstrate (See Table 3) that bullying victimization decreases student science achievement and perceived control significantly. Although bullying victimization did not significantly affect perceived value in science at the conventional threshold at the $\alpha = .05$ level, it increased perceived value in science significantly for $\alpha = .10$ level ($\tau = 0.046$, $SE = 0.026$, $p < .1$) with a 90% confidence interval of (0.003, 0.089). To check the robustness of the results, the same variables were run on an ordinary-least square regression with student weight and school ID as the cluster variable. OLS treatment effect estimates were similar in magnitude to that of kernel matching; however, standard errors were notably smaller. This can be anticipated due to the reliance of OLS on functional form assumptions and the utilization of the complete sample, in contrast to the matching, which confines comparisons to comparable units, thereby mitigating bias while concurrently amplifying sampling variability.

Table 3
Pooled Treatment Effects of Bullying Victimization

Outcomes	Kernel matching		OLS	
	ATT	SE	β	SE
Science Achievement	-17.944***	3.763	-17.667***	3.405
Perceived control in science	-0.222***	0.034	-0.237***	0.032
Perceived value in science	0.046+	0.026	0.068**	0.021

Notes. *** $p < .001$; ** $p < .01$; * $p < .5$; + $p < .1$

Table 4 shows that after the PSM procedure, students who experienced bullying exhibit lower science achievement in comparison to their matched counterparts who were not subjected to bullying; this matching procedure shows a decrease of the unadjusted group discrepancy from -26.71 (i.e., the difference between 492.456 and 519.161) to -17.95 , approximately 32.8% reduction. The observed reduction is 17.03% for perceived control and 45.24% for perceived value.

Table 4
Average Values Before and After Matching

Matching Status	Science achievement		Perceived control		Perceived value	
	Bullied	Not-Bullied	Bullied	Not-Bullied	Bullied	Not-Bullied
Unmatched	492.456	519.161	2.824	3.140	3.295	3.379
Matched (ATT)	492.366	510.311	2.826	3.048	3.297	3.251

Notes. $n_{\text{bullied}} = 1152$, $n_{\text{non-bullied}} = 2862$

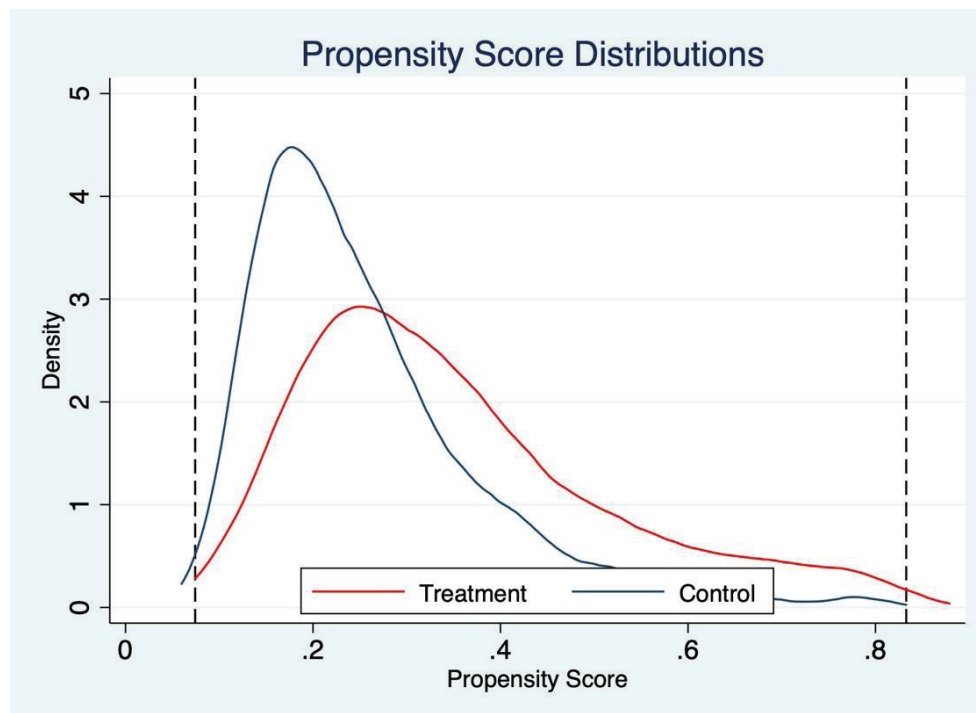
Balance Diagnostics

The validity of average treatment effect estimates is predicated upon the fulfilment of the PSM assumptions (Guo & Fraser, 2015). A substantial overlap between the propensity score distributions of the treatment and control cohorts in both nations is observed (See Figure 1).

The quality of the kernel matching analysis was assessed through the statistical examination of observations situated within the common support region, standardized mean differences, and mean bias. The results showed that 99.6% of the cases were located within the common support region for all three outcome variables, thereby affirming the similarity of confounders between the treatment and control cohorts. In each analysis, the percentage of bias (standardized mean differences) for each item was significantly less than 10%. The mean bias was reduced from 10.38% to 1.58%. In other words, the covariate matching process removed 84.78% of bias in the distribution of covariates due to their imbalance between treatment and control groups. Pseudo R^2 values, which reflect the covariate imbalance before and after matching and assess the degree to which the confounders predict the treatment assignment, were reduced from 0.078 to 0.003. These three diagnostic indicators confirmed the satisfactory balance of the covariates after matching and almost complete elimination of treatment selection bias in specified covariates.

Figure 1

The Distribution of Propensity Scores of Treatment and Control Groups



Notes. This graph was derived from the first imputed datasets. The distributions of propensity scores of other imputed datasets are almost the same with the same percentage of off-support cases.

Sensitivity Analysis

The results of the sensitivity analyses suggested that the ATT estimates demonstrated an acceptable degree of sensitivity in the face of unmeasured confounding variables. The sensitivity

analysis utilizing a simulated binary unobserved confounder U revealed that the estimated ATT was characterized by a small level of sensitivity to omitted latent variables, as indicated by the relatively minor fluctuations in treatment effect estimates of science achievement and perceived control (4.20% and 4.31%, respectively), thereby reinforcing the interpretation of the derived results. The ATT pertaining to science achievement demonstrated a variation of 4.20% when the confounder augmented the odds of treatment (Γ) to 1.75 and enhanced the odds of the outcome (Λ) to 1.56; in contrast, the perceived control exhibited a change of 4.31% ($\Gamma = 1.72$, $\Lambda = 1.57$), whereas the perceived value demonstrated a relatively greater sensitivity with a change of 17.07% ($\Gamma = 1.74$, $\Lambda = 1.67$). Although a relatively higher ATT change in perceived value in the presence of U may partly be attributed to its small treatment effect size and its marginal significant effect on the outcome, these results imply that a singular moderate unobserved confounder of this magnitude would exert a negligible impact on the estimates related to science achievement and perceived control, yet could potentially induce a relatively higher change in the small-sized perceived-value estimate.

Discussion

Using the TIMSS 2019 data from multiple countries and cultures, this study examined the prevalence of school bullying/cyberbullying and its descriptive association with science achievement. Furthermore, the effect of bullying on science achievement, perceived control and perceived value in learning science provided evidence for the role of bullying in CVT as an environmental factor. By finding causal estimates—conditional on selected covariates, this study aims to encourage and inform reform initiatives in reducing bullying/cyberbullying to improve students' well-being and science achievement. While a substantial body of research has examined school bullying in relation to students' mental well-being, social relationships, school engagement, and overall academic achievement, considerably less attention has been paid to its association with achievement in specific subject domains. In this respect, the present study adopts an exploratory approach by focusing on science achievement and cognitive appraisals as a theoretically relevant, yet empirically underexplored, outcomes. Guided by prior theoretical frameworks linking bullying experiences to students' cognitive processes, the PSM analyses should be interpreted as testing theory-driven and context-dependent hypotheses rather than confirming a well-established empirical relationship between bullying and science performance.

Bullying and Science Achievement Across Countries

Inspection of the 14 bullying items revealed that the vast majority of eighth-graders reported experiencing at least one type of bullying at least a few times a year. Although their average response to all bullying items varied, it is clear that bullying is a significant issue among this age group. Although average bullying does not clearly distinguish high-performing countries from others, the percentage of high-frequency bullying suggests a relationship between bullying and science achievement. Previous studies have reported a higher frequency of bullying among this grade cohort (Nansel et al., 2001; Thomsen et al., 2024), an increasingly negative association between the frequency of bullying and academic performance (Canales & Webb, 2024), and an increasing global trend in bullying across countries (Center for Global Development, 2025). The findings of the current study imply that anti-bullying initiatives can mitigate the negative effects of less widespread and less frequent bullying on science achievement. However, the prevalence of repeated and prolonged bullying may render anti-bullying interventions and policies less effective in counteracting their detrimental effects on science achievement.

The Effect of Bullying on Science Achievement and Science-Related Cognitive Appraisals

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PSM results indicated that bullying victimization had a significant negative direct effect on science achievement in Türkiye. The negative effect (-17.94) was larger than that of a recent study (-14.59) that analysed TIMSS 2015 Türkiye data (Coşkun & Karadağ, 2023). In other words, the negative effect of bullying on science achievement shows a slight upward trend in this context. According to the literature, the relationship between bullying and academic performance can be mediated by school motivation (Fan & Dempsey, 2016), student sense of school belonging (Carrasco et al., 2022; Huang, 2020), and psychological difficulties (Murphy et al., 2022). Additionally, encouraging student participation, respecting students, and having clear school rules were found to reduce school bullying behaviours and victimization (Welsh, 2000). Although it was not within the scope of this study, in accordance with the CVT framework, bullying may affect science achievement indirectly through perceived control and perceived value or their indirect effect through achievement emotions such as science anxiety. Bullied/cyberbullied students feel a lower level of control over their academic performance (i.e., negative control appraisals) due to the contextual distress and disturbance caused by bullying (Solas-Martínez et al., 2025). This lowered sense of control or feeling of lowered competence may manifest itself in the form of fear of failure that leads to the avoidance of science-related tasks. In turn, these negative experiences may also negatively affect intrinsic or extrinsic value appraisals, such as task value (Solas-Martínez et al., 2025), leading to a devaluation of school activities and academic achievement in the presence of existing distress. Students who are distanced from bullying experience a positive shift in emotional well-being (Ragusa et al., 2023) and an improvement in academic performance (Kyriakides, 2008). Furthermore, the negative effects of bullying tend to diminish over time (Hunter & Boyle, 2002), particularly when anti-bullying initiatives are implemented. Interventions that focus on enhancing students' resilience and addressing their pre-existing vulnerabilities, especially among those who have been victims of bullying, may prove beneficial (Schoeler et al., 2018) on improving science achievement. Therefore, it is imperative that international and national initiatives to prevent bullying through evidence-based interventions in educational settings receive increased priority and commitment, both from a moral and pragmatic standpoint.

Bullying victimization had a negative effect on perceived control in science, but it had a positive effect on perceived value in science, albeit with a small effect size. This finding is partly similar to a recent study conducted in a closely related domain that found that bullying significantly reduced eighth-grade Turkish students' perceived control and perceived value in mathematics (Kaplan, 2026). In the cited study, the effect on perceived value in mathematics was positive and significant but very small. The diminished perceived control in learning science among bullied students can be elucidated by earlier studies highlighting its adverse impact on academic efficacy beliefs and attention (Boulton et al., 2008; Juvonen et al., 2000). This is consistent with the predictions of control-value theory (Pekrun, 2006). Although it may seem surprising that bullying is positively associated with perceived value of science in this sample, bullying behaviour may be perceived by students as a threat to the classroom environment and peer relationships. This threat may lead students to value certain subjects, such as science, more highly. This is because achievement in science can give students a sense of power gain or visibility, and thus, increase perceived value (Pekrun et al., 2002) of science. Additionally, value appraisals comprise intrinsic and extrinsic components. School bullying was reported to be negatively associated with the intrinsic motivation of secondary school students, while it was positively associated with their extrinsic motivation (Bütün Ayhan et al., 2019; Caputo, 2014). In the face of stressful social contexts, such as frequent bullying, the extrinsic value assigned to science may increase if achievement in science is perceived as a self-protective or compensatory value that may restore social status. This, in turn, may heighten students' perceptions of its

importance. Therefore, the possibility of bullying victims having a higher perceived value of science is plausible if bullying increases the extrinsic value of science proportionally more than the decrease in the intrinsic value of science. This mechanism may offer a partial explanation for the minor yet positive impact of bullying on perceived value in science.

The interaction between perceived value and perceived control may affect science achievement indirectly through various emotions (Pekrun, 2006). According to CVT, when perceived control decreases and perceived value increases slightly, negative achievement emotions are likely to intensify. Specifically, the “toxic combination of lack of confidence and high importance” intensifies anxiety (Pekrun, 2024, p. 82). If perceived control decreases to the level where failure seems inevitable, hopelessness may ensue (Pekrun, 2024). Additionally, low perceived control increases anger, particularly when valued goals are obstructed (Pekrun, 2024) by factors such as social-environmental stressors, bullying, or its relevant outcomes. Similarly, shame and frustration can intensify when the task is valued but coupled with a lack of control (Pekrun, 2024; Pekrun & Perry, 2014). Overall, CVT predicts that a decrease in perceived control in learning science, coupled with a slight increase in perceived value in learning science, predominantly exacerbates negative activating and deactivating emotions that can negatively influence science achievement. Therefore, in contrast to the tendency of some practitioners to regard bullying as isolated incidents unrelated to academic success, the findings and the theoretical discussion suggest that bullying should be regarded as an environmental factor that impacts science achievement through cognitive appraisals and the resulting various achievement emotions.

Limitations and Future Recommendations

The main objective of this study was to examine the relationship between bullying, cognitive appraisals and academic achievement within the framework of CVT. The model did not include the exact measurement of widely researched motivational variables or previous achievement. The observed positive relationship between bullying and perceived value of learning science was small in magnitude and only marginally statistically significant. Accordingly, this finding should be interpreted with caution. Any interpretation in terms of potential compensatory mechanisms—such as valuing academic success as a means of regaining control, visibility, or status—remains speculative and cannot be conclusively inferred from the present data. Rather than constituting a robust empirical conclusion, this result should be viewed primarily as a tentative indication that may serve as a stimulus for further theory-driven and empirical research. Another important limitation of the present study pertains to the absence of direct measurement of achievement emotions, which could have served as potential dependent variables. While the analyses focused on cognitive appraisals of control and value in learning science, CVT explicitly posits achievement emotions as mediators linking these appraisals to academic achievement through emotions (Pekrun, 2024; Pekrun & Perry, 2014). Accordingly, the absence of emotional variables precludes a direct test of the full theoretical pathway proposed by CVT. The mediation effect of cognitive appraisals on the path from bullying to achievement was not examined since a causal pathway from cognitive appraisals to science achievement cannot be asserted due to the cross-sectional nature of the current data of these variables. Despite its frequent use in psychological studies, mediation analysis using cross-sectional data can produce biased estimates because mediation is an inherently temporal causal process (Maxwell & Cole, 2007). Subsequent studies should incorporate measures of science-related achievement emotions, such as anxiety, enjoyment, hopelessness, or anger, in order to more comprehensively examine the mediating mechanisms through which bullying experiences influence academic achievement. Employing longitudinal or experimental designs would further enable researchers to test these mediation processes more rigorously and to clarify

the temporal ordering of cognitive appraisals, emotions, and achievement outcomes. Future research should also examine whether similar patterns emerge across other subject domains and their educational outcomes in different contexts.

Our treatment effects were obtained from a nationally representative dataset. However, due to omitted variables that are unaccounted for in the model, the interpretation of the directional association should be tentative, even though the use of an extensive number of time-invariant covariates reduced selection bias into treatment. While student reports of previous bullying experiences can satisfy temporal ordering of a hypothetical intervention, the findings should be confirmed with replication studies using longitudinal datasets. Furthermore, the present study employed student self-report data which is susceptible to self-report bias (Cohen et al., 2007). Other types of data sources can inform CVT with more comprehensive and valid data. Unfortunately, bullying has been understudied in the literature and has not perceived sufficient attention by policymakers. Because of the exogenous nature of bullying (and parental value of science), applying randomized controlled studies, which is mostly considered the golden standard in research and policy-making, is not feasible because of ethical principles. Econometric models such as difference-in-difference, propensity score analysis, or regression discontinuity design methods can help provide pseudo-experimental findings to strengthen the theoretical underpinnings of this behaviour and its consequences, which can help create more effective strategies for educators, researchers, and policymakers to tackle this worldwide issue.

Conclusions and Implications

This research found important links between bullying/cyberbullying victimization, domain-specific cognitive appraisals, and science achievement. This study found the negative effect of bullying on science achievement, with a less biased estimated effect using PSM methodology. Additionally, empirical evidence regarding the negative effect of bullying on perceived control and a small but positive effect of bullying on perceived value, which had not been examined previously, contributes to the CVT by providing evidence of this environmental factor (i.e., bullying) within the framework. The findings should not be interpreted as uniquely specific to science achievement, but rather as indicative of broader school-related mechanisms through which experiences of bullying may influence students' academic functioning through cognitive appraisals. Although the effect of bullying victimization on the cognitive appraisals provides partial evidence for the inclusion of this factor as an environmental variable in CVT in the context of Türkiye, further causal evidence is necessary to evaluate its direct and indirect effects on academic outcomes through various emotions. Moreover, our results emphasize the necessity for increased efforts to combat bullying in schools with greater attention towards the societal normalization or trivialization of student bullying behaviours, given the significant effect of bullying on academic performance and emotion regulating cognitive appraisals. Taken together, the findings indicate that the academic consequences of bullying may extend beyond emotional well-being to include cognitive processes that are directly implicated in learning and performance. At the same time, the absence of direct measures of achievement emotions and the cross-sectional design limit the extent to which the full CVT pathway can be empirically tested. Future research employing longitudinal designs and incorporating achievement emotions is therefore essential to more rigorously examine the mechanisms through which bullying experiences relate to academic achievement across subject domains.

Declaration of Interest

The authors declare no competing interests.

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