Achievement Emotions and Science Performance in PISA 2015: Multilevel Analysis of the Seven Eastern & Western Top Performers

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Abstract

This study investigates the relationship between emotional factors, specifically, students' enjoyment of science and test anxiety and science performance across seven top-performing education systems (Hong Kong, China (B-S-G-J), Singapore, Korea, Australia, Canada, and Finland) using data from Program for International Student Assessment (PISA) 2015. Drawing on the Control-Value Theory of achievement emotions (Pekrun, 2006), the study examines how these emotional variables predict students' science achievement while controlling for individual and school-level socioeconomic status and other background factors through hierarchical linear modeling (HLM). Findings show that students' enjoyment of science is positively associated with performance across all economies, though the strength of this relationship varies. Test anxiety generally has a negative effect on students' academic performance, with Finland showing the strongest detrimental impact and Korea showing no significant relationship. The analysis reveals pronounced school-level stratification, with Eastern economies like China, Singapore, and Korea showing higher between-school variance in science performance, suggesting more segregated systems. Western systems such as Finland and Canada display lower stratification, reflecting greater equity. Stratification may heighten competition, boosting enjoyment for top performers but increasing anxiety for lower achievers. Yet, this is not universal; in Korea, test anxiety does not significantly predict science performance, possibly due to cultural coping norms. Substantial between-school socioeconomic disparities are also found, especially in Eastern economies. Gender differences emerge in both emotional variables and science performance. These results highlight the need to address emotional well-being and structural inequality to improve science outcomes in high-performing education systems.

Keywords: enjoyment of science, test anxiety, science performance, science achievement, HLM, stratification

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Introduction

Emotions are increasingly recognized as central to the learning process, influencing students' motivation, engagement, and academic achievement. Among these, enjoyment of learning and test anxiety represent two key emotional variables that shape how students experience and perform in academic settings. The Control-Value Theory (CVT) of achievement emotions (Pekrun, 2006) offers a useful framework to understand these emotional experiences by emphasizing the role of perceived control and task value in eliciting emotions related to achievement.

In the field of science education, international assessments such as the Programme for International Student Assessment (PISA) have made it possible to examine how students' emotional engagement relates to their academic performance across different cultural and national contexts. However, while previous research has documented the general importance of emotions, few studies have systematically compared the strength and nature of these associations across high-performing education systems. In particular, it remains unclear whether the effects of enjoyment and anxiety are consistent across countries with differing educational structures, cultural norms, and socioeconomic conditions.

This study seeks to address this gap by analyzing PISA 2015 data from seven top-performing economies—Australia, Canada, Finland, Hong Kong, Korea, Singapore, and China (B-S-J-G)—to investigate how enjoyment of science and test anxiety relate to students' science performance. By applying multilevel modeling and including both student-level and school-level socioeconomic variables, the study aims to explore not only how these emotions affect achievement, but also how these relationships may vary across systems. In doing so, the research contributes to a more nuanced understanding of emotional influences on learning across diverse educational landscapes.

Literature Review

While cognitive skills are essential for success in science, such skills cannot fully explain students' outcomes. Using PISA 2018 data from 71 countries, Arastaman et al., (2024) found reading-related cognitive constructs accounted for 63% of variance, leaving much unexplained Similarly, Malanchini et al. (2024) showed that noncognitive skills, including motivation and self-regulation, predict achievement beyond cognitive ability and gain strength with age. These findings underscore the importance of examining noncognitive abilities, with particular attention to emotional factors such as students' enjoyment of science and test anxiety in science learning because such factors directly shape engagement, persistence, and performance in science learning.

Prior research has highlighted the significance of emotional factors in shaping student achievement. For instance, analyses from PISA (Program for International Student Assessment) 2006 indicate a positive correlation between students' enjoyment of science and science performance (OECD, 2007). This relationship was found to be especially strong among high-achieving students across 57 countries, using PISA 2006 data (Perez & Cromley, 2009). Similarly, K.-C. Lau & Ho, (2022), using PISA 2015 data, identified enjoyment of science as the most robust predictor of science performance than other attitudes towards science, for instance, instrumental motivation, science self-efficacy, and science activities, and teaching practices, such as perceived feedback, adaptive instruction, teacher-directed and inquiry-based instruction, among four high-performing economies — Hong Kong (China),

China (B-S-J-G[1]), Canada, and Finland. Notably, their analysis statistically controlled for gender, student-level economic, social, and cultural status (ESCS), school-average ESCS, and school gender composition (percentage of girls), which strengthens the claim that enjoyment independently predicts achievement. They reported that a one standard deviation increases in the enjoyment of science score corresponded to a gain of 16 to 20 points in science achievement, which represents approximately 0.16 to 0.20 of a standard deviation in science performance, which is considered a small to moderate effect in educational research.

In contrast to the beneficial effects of enjoyment, test anxiety has consistently shown a negative association with educational outcomes. A comprehensive meta-analysis spanning three decades (1988–2018) confirmed that test anxiety significantly and negatively associated with a wide range of educational outcomes, such as standardized tests, university entrance exams, and grade point average (von der Embse et al., 2018). Using PISA 2015 data, Grabau et al. (2024) explored the relationship between test anxiety and science literacy across twelve education systems — six in Southeast Asia (e.g., Hong Kong, Japan, Korea, Macao, Singapore, and Taiwan) and six in Northwest Europe (e.g., Belgium, Estonia, Finland, Iceland, Ireland, and the Netherlands). Their findings revealed distinct patterns such as negative linear and reverse U-shaped relationships. The reverse U-shaped means students with either low or high academic performance reported lower levels of anxiety compared to those with average or mid-range scores (Grabau et al., 2024).

Culture context, which has been shown to play a role in science learning (Lemke, 2001), adds another important layer to this discussion. Prior work has identified broad cultural models within high-performing systems, with Western countries such as Finland, Canada, and Australia often exhibiting more individualistic approaches to learning, and Eastern systems such as China, Korea, Singapore, and Hong Kong characterized by more paternalistic and collectivist traditions (Meyer & Schiller, 2013). These contrasting models may influence how emotional factors such as enjoyment of science and test anxiety interact with student performance. While prior research has often examined enjoyment and anxiety separately or compared with them within regional groupings (Grabau et al., 2024), fewer have investigated their combined effects across top science performing systems using a performance-based classification. This present study addresses this gap by comparing four Eastern high science performers (Singapore, Hong Kong, Korea, and China-B-S-J-G) with three Western high science performers (Finland, Canada, and Australia), all of which ranked in the global top 14 for science performance in PISA 2015. This approach provides a novel and empirically grounded perspective on how emotional engagement influences science achievement across top-performing educational systems.

Accordingly, this study addresses the following research questions:

1. What are the patterns of students' emotions across the seven top-performing economies in PISA 2015: Australia, Finland, Canada, Hong Kong, China, Korea, and Singapore?
2. How are these emotions, particularly science enjoyment and test anxiety related to the science performance in these economies in PISA 2015?

[1] B-S-J-G (China): the four PISA-participating China provinces: Beijing, Shanghai, Jiangsu and Guangdong.

Conceptual Framework

This study is grounded in the Control-Value Theory (CVT) of achievement emotions, which provides a theoretical foundation for understanding the emergence, measurement, and impact of emotions in academic settings (Pekrun, 2006). According to CVT, students' perceptions of control (i.e., their perceived ability to succeed) and value (i.e., the importance they assign to a task or outcome) are central determinants of their achievement emotions. These emotions are categorized as follows: positive activating emotions, including enjoyment, hope, and pride; positive deactivating emotions, such as relief, relaxation following success, and contentment; negative activating emotions, including anxiety, shame, and anger; and negative deactivating emotions, such as boredom and hopelessness (Pekrun et al., 2002). Emotions are of central importance in education not only because they affect students' engagement, performance, and classroom climate (Pekrun et al., 2002a), but also because they are essential to students' mental health and well-being, so they should be seen as valuable learning goals on their own, not just because they help with school success (Pekrun, 2006).

One pathway for fostering students' emotional development involves helping them regulate their perceptions of control and value, which in turn shapes their emotional experiences. Teachers can help students learn these skills, which can improve how they handle emotions and support their overall emotional development (Goetz et al., 2005).

To operationalize the construct of academic emotions, Pekrun and colleagues developed the Academic Emotions Questionnaire (AEQ), a multidimensional self-report instrument that measures a wide range of emotions in academic contexts. The AEQ has demonstrated strong reliability and validity across various age groups and settings and has become a widely used tool in educational research. Findings from studies using the AEQ show that academic emotions are significantly associated with students' motivation, learning strategies, cognitive resources, self-regulation, academic performance, personality traits, and classroom environment (Pekrun et al., 2002).

Although this study utilizes data from the Programme for International Student Assessment (PISA), which does not employ the AEQ, the PISA framework includes several emotion-related constructs, such as enjoyment of science and test anxiety — that conceptually align with the dimensions proposed in CVT and measured by the AEQ. Therefore, this study draws upon CVT as a guiding framework to interpret these PISA measures, despite differences in instrumentation.

Methods

Samples

PISA uses a two-stage stratified sampling approach. In the first stage, schools are selected based on factors such as school type and regional demographics. In the second stage, 15-year-old students are randomly chosen from the selected schools (OECD, 2016). This analysis uses samples of PISA 2015 dataset from the seven high performing economies featured in (Meyer & Schiller, 2013): Finland (N = 5,882), Canada (N = 20,058), Australia (N = 14,530), Korea (N = 5,581), Singapore (N = 6,115), Hong Kong (N = 5,359), and China (B-S-J-G) (N = 9,841), with a total sample size of 67,366 participants. To ensure the representativeness of estimates and the validity of cross-national comparisons, appropriate sampling weights were applied throughout the analysis. Specifically, the student-level final weight (w_fstuwt)

provided by the OECD in the PISA 2015 dataset was used. This weight adjusts for the probability of selection of each student, as well as non-response and post-stratification corrections. It is essential when analyzing large-scale assessment data like PISA, where complex survey designs are employed. All descriptive statistics and multilevel models were conducted using Stata's svyset function with w_fstuwt to account for the stratified sampling design and ensure unbiased population-level estimates across countries. Chinese participants come from four regions: Beijing, Shanghai, Jiangsu, and Guangdong (B-S-J-G), which are among the most developed in China, therefore the findings should not be considered representative of the entire country.

Independent Variables

Emotions consist of multi-component, coordinated process of psychological subsystems, (Damasio, 2004; Scherer, 1982). Within academic contexts, achievement emotions are emotions specifically connected to either achievement-related activities or the outcomes of those achievements. Enjoyment, boredom, frustration, and anger are examples of achievement activity-related emotions. Hope, anxiety, pride, and shame are part of the outcomes of achievement emotions (Pekrun et al., 2002, 2006). Two specific achievement emotions were developed in PISA 2015: enjoyment of science and test anxiety. Due to limited variables in the 2015 dataset, this study is focusing on the enjoyment of science and test anxiety.

Enjoyment of Science (JOYSCIE) is drawn from the ST094 series in the PISA 2015 questionnaire. Enjoyment is categorized as a positive, activating emotion which is associated with intrinsic motivation, that is, engaging in learning for its own sake or personal interest—as well as increase effort, deeper engagement with learning materials, and effective self-regulation in an achievement task (Pekrun et al., 2011). The enjoyment experienced during learning is an example of achievement emotions linked to the activity itself (Pekrun, 2006). In PISA 2015, the Enjoyment of science is a single-dimensional concept, statistically derived using Weighted Likelihood Estimation (WLE) (OECD, 2016). It defined as the intrinsic motivation to participate in science learning activities (Ainley & Ainley, 2011; Krapp & Prenzel, 2011). In PISA 2015, students' enjoyment of science is measured using their reports of how they "feel" when engaged in learning activities. The Enjoyment of Science scale includes items that were also used in previous PISA cycles, making it a trend item or indicator that enables comparison of student attitudes over time. Students rated their agreement with various statements using a four-point Likert scale: "strongly agree", "agree", "disagree", and "strongly disagree". The specific statements included in this measure are listed in Table 1.

Test anxiety (ANXTEST). The question number is ST118 series in the PISA 2015. It refers to the subjective experience of heightened physiological, cognitive, and/or behavioral symptoms of anxiety in test-taking situations, which can influence test performance (Sawka-Miller, 2011). Items were introduced in PISA 2015 to measure test anxiety. Students responded to a series of self-descriptive statements about how they feel about taking tests using a four-point Likert scale, selecting from "strongly agree", "agree", "disagree", or "strongly disagree" (OECD, 2016). It should be noted that "enjoyment" is specific to science while "anxiety" is more general about any test.

Table 1
Item Parameters for Enjoyment of Science (JOYSCIE) & Test Anxiety (ANXTEST) (OECD, 2016)

Item	How much do you disagree or agree with the statements about yourself below?
ST094Q01NA	I generally have fun when learning <broad science> topics.
ST094Q02NA	I like reading about <broad science>.
ST094Q03NA	I am happy working on <broad science> topics.
ST094Q04NA	I enjoy acquiring new knowledge in <broad science>. Learning-related emotions .
ST094Q05NA	I am interested in learning about <broad science>.
	To what extent do you disagree or agree with the following statements about yourself?
ST118Q01NA	I often worry that it will be difficult for me taking a test.
ST118Q02NA	I worry that I will get poor <grades> at school.
ST118Q03NA	Even if I am well prepared for a test I feel very anxious.
ST118Q04NA	I get very tense when I study for a test.
ST118Q05NA	I get nervous when I don't know how to solve a task at school.

Control Variables

In this study, several student and school-related factors were included as control variables to account for their potential influence on the outcome. Student background factors are ESCS (an index of economic, social and cultural status and gender. The ESCS is statistically derived using Weighted Likelihood Estimation (WLE), and calculated using principal component analysis based on parental education, highest parental occupation, and household possessions (including books), with possessions serving as a proxy for income (OECD, 2016). The school backgrounds include school mean socioeconomic status, which reflects the average background of the student population, and school location, which identifies school's community type based on population size, ranging from rural areas under 3,000 people to large cities with over 1 million. These variables help isolate the effect of the primary independent variables by accounting for structural and contextual differences across schools.

Dependent Variable

You et al., (2021) utilized the averages of the 10 plausible values (imputed from students' responses) for each science achievement subscale provided by PISA as the dependent variable. This study used the same method.

Hierarchical Linear Modeling

Hierarchical linear modeling (Bryk & Raudenbush, 1992) was employed to examine the relationships between students' emotions and their science performance using PISA 2015 dataset, while controlling some student and school background factors. The final model was developed in the following steps:

(1) Null model used to partition the variance of scientific performance into within- and between-school components.
(2) Model analyzing the associations between student background characteristics and school contextual factors with science achievement.

(3) A model investigating the effects of students' academic emotions on science performance, controlling for student- and school-related background variables.

Each set of analyses was conducted separately for each country, with students (level 1) nested within schools (level 2).

Results

Enjoyment of Science and Test Anxiety

The relationship between enjoyment of science and test anxiety was examined across seven economies using simple correlations (Table 2). In all cases, enjoyment of science was negatively correlated with test anxiety, indicating that students who reported greater enjoyment of science tended to experience lower levels of test anxiety. Although the strength of these correlations was generally small, they were statistically significant in all contexts except Korea. Singapore exhibited the strongest negative correlation (r = –0.1067, $p < 0.001$), followed closely by Canada (r = –0.0733, $p < 0.001$). Moderate negative correlations were observed in Finland (r = –0.0700, $p < 0.001$) and China (B–S–J–G) (r = –0.0670, $p < 0.001$). Slightly weaker, yet significant, associations were found in Hong Kong (r = –0.0503, p < 0.001) and Australia (r = –0.0494, $p < 0.001$). Korea demonstrated the weakest correlation (r = –0.0179, $p > 0.05$), indicating that the relationship between enjoyment of science and test anxiety was negligible and not statistically significant. This suggests that, in the Korean context, these two emotional constructs may operate more independently, possibly influenced by distinct cultural or educational factors. Therefore, no clear patterns between eastern and western economies.

Table 2

Correlations of Enjoyment of Science With Test Anxiety

	Hong Kong	China(B-S-J-G)	Singapore	Korea	Australia	Canada	Finland
Test Anxiety	-0.0503***	-0.0670 ***	-0.1067 ***	-0.0179	-0.0494***	-0.0733***	-0.0700***

*** p < 0.001, ** p < 0.001, * p < 0.01

Singapore showed the most negative correlation, while Korea's association was negligible and not statistically significant. However, no formal tests were conducted to determine whether these correlations significantly differed from each other, so such comparisons should be interpreted with caution.

Gender Differences in Emotions Across 7 Economies

In most of these high-performing economies, gender disparities exist in science enjoyment. The pattern is that girls show lower enjoyment and higher anxiety than boys in all 7 economies (Table 3). The only exception was Finland, where girls reported slightly higher enjoyment of science than boys, with a gap of just 0.005 with no statistical significance. Among the seven economies, Korea exhibited the largest observed gender difference in science enjoyment (–0.282), while Canada showed the largest observed gender difference in test anxiety (0.558). However, no formal statistical tests were conducted to determine whether these gaps were significantly larger than those in other economies.

Table 3

Gender Differences in Emotions (Enjoyment of Science and Test Anxiety) Across Seven Economies

	Enjoyment of science				Test Anxiety			
	Girls	Boys	Combined	G–B (Sig)	Girls	Boys	Combined	G–B (Sig)
Hong Kong	0.118	0.332	0.450	-0.214***	0.500	0.145	0.645	0.354***
China (B-S-J-G)	0.301	0.402	0.703	-0.101***	0.289	0.176	0.465	0.113***
Singapore	0.423	0.557	0.980	-0.133***	0.736	0.471	1.207	0.266***
Korea	-0.294	-0.012	-0.306	-0.282***	0.218	-0.014	0.205	0.232***
Australia	-.0327	0.055	0.023	-0.088***	0.482	0.029	0.511	0.452***
Canada	0.192	0.245	0.437	-0.052***	0.454	-0.104	0.350	0.558***
Finland	-0.071	-0.076	-0.146	0.005(ns)	-0.164	-0.468	-0.632	0.304***

G-B = mean(female) - mean(male)

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

HLM Analysis

Hierarchical linear models (HLMs) were conducted separately for each economy to examine the relationships between enjoyment of science, test anxiety, and science performance, while controlling for gender, family ESCS, school-level ESCS, and the school location (Table 5). The reported coefficients represent the change in the mean science score (with the OECD mean scaled to 493) associated with a one-unit increase in each variable. Asterisks indicate the statistical significance of these associations.

Null models were estimated without including student- or school-level predictors. The intraclass correlation coefficients (ICCs) — reflecting the proportion of variance in science performance attributable to differences between schools — varied across the seven economies. Among the Eastern economies, ICCs were highest in China (B-S-J-G: 0.555), followed by Singapore (0.415), Hong Kong (0.398), and Korea (0.312). For Western economies, ICCs were 0.363 in Australia, 0.271 in Canada, and 0.196 in Finland (Table 4). While Eastern systems like China and Singapore demonstrated relatively high between-school variation, Australia showed a higher ICC than Korea, indicating that between-school differences are not strictly patterned by the East-West distinction. These results indicated that there are significant and substantial variations in performance among schools in all these 7 economies. Therefore, HLM was employed in the subsequent analyses to account for key school-level contextual factors.

Table 4

Mixed-Effects Analysis of Science Performance Across Seven Regions (PISA 2015)

	Science Performance		
	Coeff.	SE	ICC
Hong Kong	518.8637***	4.253	0.398
B-S-J-G China	519.6801***	4.599	0.555
Singapore	538.4649***	5.213	0.415
Korea	510.7822***	4.182	0.312
Australia	487.7254***	2.307	0.363
Canada	500.5072***	1.475	0.271
Finland	509.8525***	3.523	0.196

***p < 0.001

Student and School Background Factors

Genders

To examine gender disparities in science performance, this study included a gender indicator variable in the full multilevel models across seven education systems.

The results showed that gender differences vary substantially by country. In Finland**,** boys scored significantly lower than girls by 26.4 points on average ($p < 0.001$), the largest gender gap among all economies analyzed. Canada**,** Australia, and Korea also showed statistically significant disadvantages for boys, ranging from 5.1 to 12.7 points. In contrast, In China (B-S-J-G), boys scored significantly higher than girls by 9.4 points ($p < 0.001$), while in Hong Kong, the gender gap was smaller but still in favor of boys (+4.5 points, $p < 0.05$), highlighting a consistent advantage for boys in these two Chinese contexts, in contrast to the female advantage observed in most other systems (Table 5).

Table 5

HLM Analysis of the Relationships of the Emotions (Enjoyment of Science & Test Anxiety) With Science after Controlling for the Student and School Background Variables of the Seven Economies in PISA 2015

	HK		China		Singapore		Korea		Australia		Canada		Finland	
	Coeff.	SE	Coeff.	SE	Coeff.	SE	Coeff.	SE	Coeff.	SE	Coeff.	SE	Coeff.	SE
Student background factors														
Intercept	554.7***	4.9	578.5***	10.1	540.5***	3.3	548.9***	17.7	495.8***	5.6	487.6***	3.2	534.3***	4.9
Boy	4.5*	1.8	9.4***	1.3	2.7	2.2	-12.7***	2.5	-5.1**	1.5	-7.6***	1.2	-26.4***	2.1
ESCS	1.8	1.0	5.9***	0.8	22.6***	1.3	15.6***	1.7	21.6***	1.0	16.9***	0.8	27.2***	1.5
Emotions														
Enjoyment of Science	17.8***	0.8	11.6***	0.7	23.3***	1.1	24.7***	0.9	26.8***	0.7	22.3***	0.5	22.9***	1.1
Test Anxiety	-7.2***	0.8	-8.2***	0.7	-8.2***	1.1	-1.0	1.1	-10.0***	0.8	-11.8***	0.6	-23.4***	1.2
School environment														
School average ESCS	58.6***	6.7	63.2***	4.6	70.8***	6.5	85.0***	7.3	58.8***	3.1	42.2***	3.5	40.3***	7.0
School location - A village														
A small town			-1.0	9.2			10.4	22.7	-7.7	6.7	-0.7	4.2	-13.2*	6.0
A town			2.8	10.1			7.1	18.4	-11.4	6.3	-1.0	4.3	-15.5**	5.8
A city			8.7	10.9			-5.0	17.7	-7.9	6.2	-0.7	4.0	-18.3**	6.4
A large city	0	(omitted)	2.2	11.3	0	(omitted)	-3.9	17.7	-4.3	6.1	1.0	5.0		
ICC	26%		31%		18%		11%		10%		11%		5%	
Variance explained														
Between school (%)	49.7%		68.4%		74.8%		76.1%		81.3%		70.4%		83.6%	
Within school (%)	7.3%		12.1%		17.4%		14.2%		5.3%		12.9%		22.1%	
Total variance (%)	24.2%		43.4%		41.2%		33.5%		32.9%		28.5%		34.2%	

****p < 0.001; **p < 0.01; *p < 0.05*

ESCS (Individual-Level ESCS)

To understand how socioeconomic status (ESCS) influences science achievement, both individual-level ESCS and school-average ESCS were included in the multilevel models across seven economies.

By centering both the individual and school-level ESCS around the grand mean, the model cleanly separated how much science performance was influenced by a student's family background versus their school's average SES. This also made the model's intercept meaningful: it showed the expected science score for an "average" student in an "average" school.

The effects of individual ESCS, which reflected each student's family economic, social, and cultural status were positive and statistically significant in all economies except Hong Kong, where the effect was small and not significant (1.8, $p > 0.05$). The largest effects were observed in Finland (27.2) and Singapore (22.6), suggesting that students from more advantaged families tend to score substantially higher in science, even after controlling for

school context and other factors. China**,** Korea**,** Australia, and Canada also showed moderate, positive effects (ranging from 5.9 to 21.8), indicating that family background remains a consistent predictor of student performance in most systems.

ESCS (School Average ESCS)

Korea, Singapore, and China showed very strong school-level ESCS effects, indicating high stratification of science performance between schools. Finland again showed a smaller school-level effect, consistent with its reputation for more equitable education (Sahlberg, 2012).

Table 6

Comparison of Family ESCS and School Average ESCS CI Across 7 Economies

Economy	Individual ESCS Coefficient (95% CI)	School ESCS Coefficient (95% CI)
Hong Kong	1.8 [-0.1, 3.7]	58.6 [45.6, 71.7]
China (B-S-J-G)	5.9 [4.3, 7.4]	63.2 [54.2, 72.2]
Singapore	22.6 [20.0, 25.1]	70.8 [58.1, 83.6]
Korea	15.6 [12.4, 18.9]	86.0 [71.8, 100.3]
Australia	20.6 [18.6, 22.6]	58.8 [52.7, 64.9]
Canada	16.9 [15.4, 18.5]	42.3 [35.5, 49.2]
Finland	27.2 [24.2, 30.1]	40.3 [26.7, 53.9]

Figure 1

Comparison of School SES Effects Across Economies (CI Overlap Analysis)

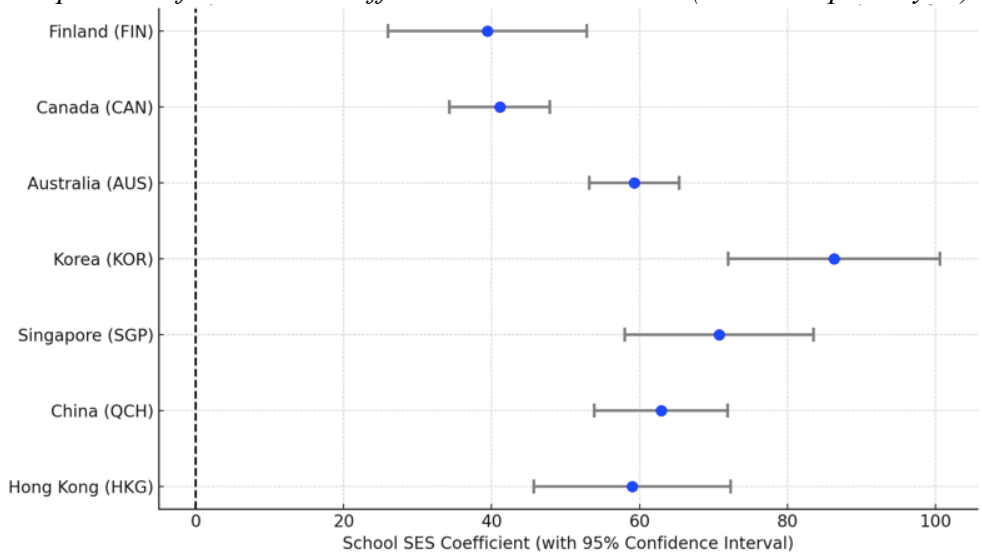


Figure 1 illustrated the school average ESCS coefficients and their 95% confidence intervals on science performance across economies. The confidence intervals for Korea, Singapore and China did not overlap with those for Finland and Canada (see Table 6). This suggested statistically significant differences in the strength of the association between school-level socioeconomic composition and science performance across these economies. These non-overlapping intervals supported the conclusion that school average socioeconomic advantage has a stronger impact on science achievement in Korea, Singapore, and China, implying greater school-based stratification of science performance in those systems.

This pattern is also reflected in the higher ICCs for science performance reported in Table 7, where China (55%), Singapore (41%), and Korea (31%) showed the largest proportions of between-school variance, further supporting the presence of system-level stratification.

In contrast, the confidence intervals for Hong Kong overlapped with all other economies, indicating that differences in school-level ESCS effects in Hong Kong may not be statistically significant and should be interpreted cautiously. This overlap implied more uncertainty in estimating the extent of school-based stratification in Hong Kong.

In comparison, Canada and Finland showed weaker associations between school average ESCS and science scores, pointing to more equitable school systems where student outcomes were less dependent on school-level socioeconomic composition.

Table 7

Comparison Between the ESCS ICC & Science Performance ICC

	ESCS ICC	Science Performance ICC (Null Model)
Hong Kong	40%	40%
China (B-S-J-G)	45%	55%
Singapore	23%	41%
Korea	21%	31%
Australia	25%	36%
Canada	16%	27%
Finland	13%	20%

According to Table 6, China has the greatest percentage of variance in ESCS (45%) between rather than within schools, suggesting that schools tend to be more internally homogenous (or stratified by ESCS). In contrast, Finland has the lowest percentage of variation in ESCS (13%) across compared to within schools, indicating that schools are more internally heterogenous (or not stratified by ESCS). Notably, a similar pattern is seen in the relative variation across schools in science performance, which the greatest between school for China (55%) and the lowest between schools for Finland (20%). The similar patterns for these two variables suggest that variation across schools in mean ESCS is also strongly related to variation across schools in Science Performance. That hypothesis is supported by the effect of school ESCS being stronger in China than for Finland (indicated by the confidence intervals not overlapping) (Table 6 & Figure 1).

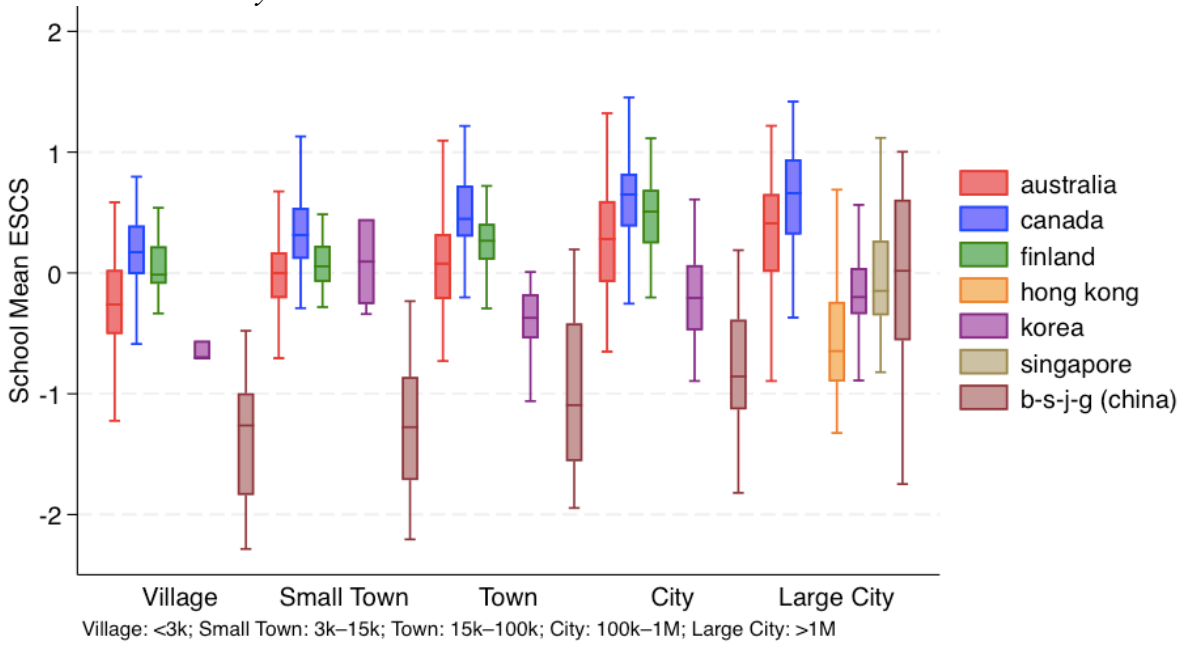
Although China exhibited the highest science performance ICC (55%) and ESCS ICC (45%), the corresponding school ESCS coefficient for China was marginally lower than Korea's, with their 95% confidence intervals only slightly overlapping, indicating a modest but potentially significant difference. This suggested that while between-school variation in science performance in China was substantial, it may be driven by a combination of factors beyond socioeconomic composition, such as educational tracking systems (Lo, 1984). In contrast, Korea displayed a more moderate science ICC (31%) and ESCS ICC (21%) but the highest school ESCS coefficient (β = 85.0), indicating that school socioeconomic composition played a particularly dominant role in explaining achievement differences between schools.

School Location

Interestingly, Figure 2 showed that although regression results indicate non-significant differences in science performance by school location in most countries (Table 5), school average ESCS often varies notably by location type, particularly in China. This supported the idea that urban schools tend to serve more advantaged populations, even if that advantage does not always translate into significant performance gains after controlling for covariates.

Figure 2

School Mean ESCS by School Location Across 7 Economies



Emotions (Enjoyment of Science & Test Anxiety)

Enjoyment of Science

Across all economies, higher enjoyment of science is strongly associated with better science performance. The coefficients range from about +11.6 (China) to +26.8 (Australia), meaning that a one standard deviation increase in science enjoyment is associated with about 11 to 27 points increase in students' science scores. Enjoyment of science showed a significantly stronger association with science performance in Singapore, Korea, and the Western economies of Australia, Canada, and Finland compared to China and Hong Kong. This is evidenced by non-overlapping 95% confidence intervals, indicating statistically meaningful differences in the impact of enjoyment across systems (Table 8).

Although one might expect regional clustering, the data show no clear East–West divide in the effect of science enjoyment. Instead, both Western economies and certain East Asian systems like Singapore and Korea exhibit significantly stronger enjoyment effects, suggesting system-level or cultural differences in how emotional engagement contributes to academic performance.

Table 8

Enjoyment of Science and Test Anxiety

Economy	Enjoylment of Science Coefficient (95% CI)	Test Anxiety Coefficient (95% CI)
Hong Kong	17.8 [16.3, 19.4]	-7.2 [-8.8, -5.5]
China (B-S-J-G)	11.6 [10.2, 13.1]	-8.2 [-9.6, -6.8]
Singapore	23.3 [21.2, 25.3]	-8.2 [-10.4, -6.0]
Korea	24.7 [22.9, 26.4]	-1.1 [-3.2, 1.0]
Australia	26.8 [25.5, 28.1]	-9.9 [-11.5, -8.4]
Canada	22.3 [21.3, 23.3]	-11.8 [-12.9, -10.7]
Finland	22.9 [20.7, 25.1]	-23.4 [-25.8, -21.0]

Test Anxiety

In most economies, higher test anxiety is significantly associated with lower science achievement. The coefficients range from about -7 to -23, meaning that a one standard deviation increase in test anxiety is linked to 7 to 23 points decrease in students' science scores. Finland shows the largest negative effect (-23), suggesting that anxiety is particularly damaging there. Korea is an exception. The effect is small (-1.1) and not statistically significant, meaning test anxiety may not predict science performance there.

For test anxiety, Finland shows a uniquely strong negative effect on science performance, with a coefficient of –23.4 and a 95% confidence interval of [–25.8, –21.0], which does not overlap with any other economy. This suggests that in Finland, higher levels of test anxiety are particularly detrimental to student outcomes. In contrast, Korea stands out with a non-significant coefficient of –1.1 [–3.2, 1.0], indicating minimal impact of test anxiety on science performance in that context.

Across the remaining economies, Western countries such as Canada (–11.8), Australia (–9.9), and Singapore (–8.2) show strong and statistically significant negative associations between test anxiety and science scores, with confidence intervals that do not overlap with Korea or Hong Kong, suggesting greater susceptibility to anxiety-related performance declines. China and Hong Kong also show negative effects (–8.2 and –7.2, respectively), but these are less pronounced compared to Western economies and partially overlap with Singapore and each other, suggesting moderate and relatively similar anxiety impacts.

Overall, these results indicate that while test anxiety negatively affects science achievement in most economies, the magnitude of this effect varies considerably, with Finland and Western countries showing the strongest impacts, East Asian regions like China and Hong Kong showing moderate effects, and Korea showing virtually no significant effect.

Table 9

Test Anxiety Standard Deviation and Mean for 7 Economies

	Standard Deviation	Mean
Korea	0.97	0.09
China (B-S-J-G)	0.92	0.23
Hong Kong	1.01	0.31
Singapore	0.95	0.60
Australia	0.97	0.24
Canada	1.07	0.15
Finland	0.93	-0.33

Although Korea showed no significant relationship between test anxiety and science performance (with a small coefficient of –1.1), I examined the distribution of Korea's test anxiety data to check whether the responses were too flat or lacked variability. As shown in Table 9, Korea's standard deviation (0.97) was similar to that of the other economies and indicated a normal degree of variation among students. The relatively low mean (0.09) simply suggested that most Korean students are clustered around the average level of test anxiety, rather than experiencing extremely high or low anxiety. Therefore, the lack of significance is not due to a lack of variation in the data.

Conclusion

In Finland, overall test anxiety is low, yet its negative impact on science performance is the highest among the studied economies: a one-unit increase corresponds to a 24-point drop. This may stem from students' limited exposure to high-stakes exams, with the Matriculation Examination as the only such test. Rare exposure may heighten anxiety (Pollari, 2016; Sahlberg, 2006), underscoring the need for school-based mental health and stress-reduction strategies. Finland also shows the largest gender gap, favoring girls by 28 points. Addressing this disparity by supporting boys' academic engagement and performance should also be a key policy consideration.

In Korea, despite a highly stratified system and intense hagwon culture (Lim, 2025), test anxiety is not significant, possibly due to normalized stress and strong academic support. Science enjoyment strongly predicts performance (+24.8***), highlighting its importance.

The analysis also reveals stark differences in school-level stratification, with Eastern economies such as China, Singapore, and Korea displaying higher between-school variance in students' science performance, indicating more segregated systems. In contrast, Western systems like Finland and Canada demonstrate lower stratification in student's science performance, reflecting more equitable education environments. These institutional features may shape students' emotional responses. For instance, highly stratified systems may increase competition and performance pressure, intensifying both enjoyment for top performers and anxiety for lower-performing students. However, this pattern does not apply uniformly: in Korea, despite a highly stratified system, test anxiety does not significantly predict science performance, suggesting that cultural norms around academic stress or coping mechanisms may buffer its negative effects. Consequently, the interplay between students' emotions and science performance may be stronger or weaker depending on the broader institutional and cultural context.

Additionally, substantial between-school variance in school-level socioeconomic stratification is observed, particularly in Eastern economies. Gender differences in both students' emotional variables and science performance are also identified, highlighting areas for targeted policy intervention. The findings underscore the importance of addressing both students' emotional well-being and structural inequality to enhance science performance in science high-performing education systems.

China and Hong Kong exhibit bigger gender gap in science performance, favoring boys. Targeted policies are needed to support girls' achievement in science through inclusive pedagogy, mentorship, and confidence-building strategies. Improving science enjoyment and reducing test anxiety especially among girls should be central to education reform efforts.

A few limitations should be acknowledged for future research. First, the generalizability of the findings to other regions is limited due to these are only high science performing economies. Second, the total variance in science performance explained by the model (R^2 ranging from 21% to 38% (see Table 6) suggests that many other influential factors remain unaccounted for. Lastly, Korea stands out as the only case where test anxiety is not a significant predictor of science performance, making it a compelling context for further investigation into the underlying mechanisms.

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