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The mediating role of student–teacher relationships, assertiveness, and curiosity in science achievement

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Teacher–student relationships, assertiveness, and curiosity are socio-emotional constructs that influence science achievement. Assertiveness is associated with self-confidence and clear expression, while curiosity fosters exploration and a desire to learn. Investigating their mediating role is important because they represent modifiable factors that teachers and schools can promote to improve science achievement. This study aims to examine the mediating role of student–teacher relationship, assertiveness and curiosity of science achievement. The quality of the student–teacher relationship (RELATST) was assessed through students’ evaluations of seven statements that measured the perceptions of respect and interest from the teachers. Assertiveness (ASSERAGR) measured students’ perceptions through statements indicating self-confidence. The degree of curiosity (CURIOAGR) assessed students’ inclination towards curiosity by evaluating their agreements with statements reflecting a desire to learn and understand, based on data from PISA (2022) in the OECD Report (2024). Whereas PVSCI represents the results achieved in science from testing conducted in the same year. The data were analyzed through the following statistical analysis: confirmatory factorial analysis and second confirmatory factorial analysis, correlation analysis and mediation analysis for the studied variables. The findings reveal that the quality of the student–teacher relationship (QST) has a positive and significant relationship to self-confidence and curiosity, having an indirect impact on achievement in science (PVSCI). QST also has a positive and strong impact on assertiveness ($\beta = 0.176$, $p < 0.001$) and curiosity ($\beta = 0.331$, $p < 0.001$), while assertiveness impacts curiosity ($\beta = 0.239$, $p < 0.001$) which consequently impacts science achievement ($\beta = 0.221$, $p < 0.001$). These results indicate that a good relationship with the teacher fosters the development of the student’s assertiveness and curiosity, which contributes to improving science achievement.

KEYWORDS

assertiveness, curiosity, mediation analysis, PISA, science achievement, student–teacher relationship

Introduction

The influence of socio-emotional and motivational factors on academic achievement has aroused the interest of researchers in contemporary education. Student–teacher relationships, assertiveness and curiosity are considered key elements that can influence student achievement, especially in the field of science (OECD, 2024, ch. 4). The Program for International Student Assessment (PISA), implemented by the Organization for Economic Co-operation and Development (OECD), provides detailed data on the knowledge, skills and behavior of

15-year-old students in subjects such as mathematics, reading and science, as well as on the factors that influence how they learn and use their knowledge in real-world situations (OECD, 2024, ch. 1). PISA 2022, besides measuring academic knowledge and skills, also encompasses socio-emotional and motivational dimensions, including student–teacher relationships, curiosity, and assertive behavior of students. PISA data show that the quality of relationships with teachers can increase student engagement and performance, while assertiveness and curiosity help deepen understanding and active participation in the learning process (OECD, 2024, ch. 4–5). In this context, this paper aims to explore the mediating role of student–teacher relationships, assertiveness, and curiosity in science achievement, using data from PISA 2022. This study aims to contribute to the understanding of how these factors interact and help increase students' academic success in science.

Theoretical background

Student–teacher relationship, assertiveness, and curiosity framework

This study draws on a conceptual framework that links student–teacher relationships, assertiveness, and curiosity to science achievement. In recent literature and in the PISA 2022 conceptual framework, these three socio-emotional and motivational constructs have been identified as essential dimensions that help explain student performance in science (OECD, 2024, ch. 4–5). The PISA 2022 framework emphasizes that positive interactions with teachers characterized by support, appropriate feedback, and effective communication are fundamental to student engagement and learning. Quality relationships with teachers are associated with higher motivation, self-regulation, and better academic achievement, while poor relationships can have hindering effects (OECD, 2024, ch. 4). Assertiveness is described as the ability of students to express opinions, ask questions, and actively participate in discussions. PISA considers assertiveness as a factor that promotes active engagement and deeper understanding of scientific concepts, thus linking the quality of teaching to student achievement (OECD, 2024, ch. 5). Curiosity, conceptualized as the willingness to explore and ask questions beyond the curriculum, is associated with higher engagement in inquiry practices, seeking explanations, and persistence in problem-solving. This dimension, in interaction with student–teacher relationships and assertiveness, helps to strengthen engagement with science content and improve achievement (OECD, 2024, ch. 4). Science achievement in PISA 2022 Academic achievement in educational institutions, including schools, colleges, and universities, refers to the measurable results that indicate the level of development individuals have made in specific educational objectives or activities (Suleiman, 2023).

In this way, the theoretical framework of the study positions student–teacher relationships, assertiveness, and curiosity as important mediators of achievement in science, thus providing a clear basis for the formulation of hypotheses and empirical verification in this paper.

Student–teacher relationships and science achievement

The student–teacher relationship plays an important role in enhancing science achievement, particularly in fostering assertiveness

and curiosity. It has been highlighted by various authors, such as Hughes (2011), who claim that the positive relationship between teacher and student significantly influences improvements in science subject results. Moreover, the students' assertiveness in understanding science positively impacts their active involvement and success in the subject (Britner and Pajares, 2006), and assertiveness in science has a positive impact on academic achievements (Liu and Koirala, 2009). The teacher–student relationship is a crucial factor for students' engagement and their academic achievements (Roorda et al., 2011). The teacher–student relationship is the most basic and important interpersonal relationship in school education (Zeng et al., 2024). Moreover, according to the analysis of the study by Jiang et al. (2025), the student–teacher relationship affects the self-concept of students' academic activities in science, thus explaining the potential difference in the mediation of emotional activities. Göktaş and Kaya (2023) found that positive teacher–student relationships have a medium-sized positive effect on academic achievement, underscoring the importance of both intrapersonal and interpersonal relationships. Ali et al. (2024) confirm that the quality of the relationship between student and teacher positively affects achievement in science, through the mediation of intellectual curiosity, the findings show that the more supportive and positive the relationship with the teacher, the more students display curiosity about learning, which directly affects their results in science.

H1: The quality of the student–teacher relationship has a positive impact on students' science achievement.

Assertiveness and science achievement

Furthermore, Kim and Lee (2021) also confirmed that teacher emotional support improves assertiveness and learning satisfaction, which significantly mediate reading and science outcomes. The concept of curiosity as a motivator extends to hands-on activities in chemistry, where Kibga et al. (2021) established that teacher–student mentorship positively affects students' collaborative learning efforts, fostering curiosity-driven inquiry.

These studies emphasize the necessity of supporting curiosity in educational structures as it is consistent with improving academic performance and engagement in science. Neurologically based studies also prove that curiosity helps in learning (Gruber et al., 2014). Moreover, the mediating role of assertiveness influences the relationship between teacher–student relationships and academic achievement (Xu and Qi, 2019). This also aligns with Oraon's (2024) findings, which highlight the significant relationship between assertiveness and academic achievement among school students. They advocate for strategies aimed at enhancing assertiveness in educational environments to boost performance. Also, Cui et al. (2020) in their study of teacher–student relationships and assertiveness in learning, which were measured using questionnaires adapted from PISA 2012, the results showed that teacher–student relationships, assertiveness in learning, and related academic achievements were all statistically significantly related to each other. In addition, other studies prove that assertiveness can play a pivotal role in better academic performance (Putwain et al., 2013). Assertiveness ability improves psychological-social skills, academic achievement, and self-confidence. Emotional self-regulation helps people identify their emotions and helps them succeed in academic achievement and social interactions. Student–teacher relationship

quality has a major role in regulating emotions and improving academic achievement and social interactions (Khalooei et al., 2022).

H2: The quality of the student–teacher relationship positively influences students’ assertiveness.

H4: The assertiveness of students positively influences their curiosity.

H6: Assertiveness mediates the relationship between the quality of the student–teacher relationship and curiosity.

Curiosity and science achievement

Curiosity is the inner drive for learning or “hunger for learning” which is among the twenty-first-century learning competencies (Kibga et al., 2021), and curiosity has a significant positive relationship with interest in learning science (Gitatenia and Lasmawan, 2022). Engel (2011) highlights the importance of maintaining curiosity in the classroom as a key factor for engaging the students in learning science and recent work has argued that curiosity can improve learning (Wade and Kidd, 2019). Science requires curiosity, which motivates active learning and spontaneous discovery (Oudeyer et al., 2016). In science achievement, curiosity is essential for driving the inquiry process, prompting students to investigate, formulate hypotheses, and seek solutions (Gottfried et al., 2016; Whitesides, 2018; Abu Khurma and El Zein, 2024). Additionally, as Valle et al. (2022) highlighted, active learning methodologies that stimulate curiosity significantly improve engagement in science achievement. Also, curiosity is intricately tied to students’ assertiveness and motivation, which are crucial for adaptive learning behaviors (Amponsah, 2023; Kim et al., 2019). Research consistently demonstrates that curiosity aids in enhancing science learning by promoting an openness to exploration and a critical approach to evidence evaluation (Casey, 2014; Spektor-Levy et al., 2013). Curiosity in the educational context is emphasized as an intrinsic motivator that fosters a deeper connection with learning materials and fosters inquiry-based learning experiences, particularly in science (Kang, 2023; Karacan-Ozdemir and Ayaz, 2022; Tsai and Zheng, 2021). Creativity and curiosity are important variables to support the science achievement (Ramdani et al., 2022) and curiosity predicts teacher–student relationships (Amorim Neto et al., 2022). Kang (2023) asserts that student engagement in science is closely linked to their science assertiveness, which triggers state curiosity when students encounter obstacles in their learning process. Mahama et al. (2023) also examined how students’ innate abilities like curiosity, affects their achievement in science and found that students who become curious in their learning situation can improve their academic performance and achieve their academic goals, especially in science.

H3: The quality of the student–teacher relationship positively influences students’ curiosity.

H5: Students’ curiosity positively influences their science achievement.

Many studies have been undertaken to assess and analyze science achievement in the PISA test (Fonseca et al., 2011; Lau and Lam,

2017; Bidegain and Mujika, 2020; Zhang, 2021; Lau and Ho, 2022; Odell et al., 2020). This research has shed light on various factors that influence student performance, including cognitive abilities, socioeconomic status, and institutional factors. However, research to date has not sufficiently addressed the impact that social–emotional and interpersonal variables have on science outcomes.

This study aims to fill this gap by examining the mediating roles of the student–teacher relationship, assertiveness, and curiosity in science achievement. The nature of the student–teacher relationship can directly influence students’ emotional engagement and motivation to learn, thus creating a safe and supportive environment for scientific exploration. A stable relationship with the teacher can strengthen assertiveness, as well as foster intellectual curiosity – both of which are closely linked to improved academic outcomes. In this context, the current research aims to examine how quality teacher relationships can foster assertiveness and curiosity in students, and how these two qualities mediate the impact of teacher relationships on science outcomes. Drawing on PISA 2022 data, this study provides an in-depth analysis that can contribute to the design of educational policies and the improvement of pedagogical practices that strengthen social and personal factors in students’ science achievements. This study is mainly focused on student–teacher relationships, assertiveness, and curiosity, as these emotional and motivational factors are identified as crucial mediators in achievements in science subjects. In comparison with immutable factors like intelligence and socio-economic status, these three factors are impactful through pedagogical interventions; therefore, they have particular importance for educational practices and school policies (Roorda et al., 2011; Oudeyer et al., 2016; Abu Khurma and El Zein, 2024).

H7: Assertiveness and curiosity mediate the relationship between the quality of the student–teacher relationship and science achievement.

Methodology

PISA 2022 covered member countries of the Organization for Economic Co-operation and Development (OECD) and several partner countries outside the organization. The program assesses the skills of 15-year-old students in three key areas: science, mathematics, and reading. Science education systems vary from country to country, including different curriculum structures, teaching approaches, teaching hours, and levels of laboratory equipment. This diverse context allows for the interpretation of student results in relation to teaching practice and factors influencing science learning. This study employs quantitative methodology using the secondary data from the OECD Report (2024) to statistically analyze the relationship between quality of student–teacher relationships (RELATST), assertiveness (ASSERAGR), curiosity (CURIOAGR) of students, and PVSCI (science achievement). A brief description of each variable, along with the items used to measure it and the rating scale is included below.

Quality of student–teacher relationships (RELATST)—students’ ratings of their agreement with the eight statements (e.g., “The teachers at my school are respectful towards me,” “When my teachers ask how I am doing, they are interested in my answer.”) in question ST267 were scaled into the index of “Quality of student–teacher relationships” (OECD, 2024, p. 437). Each of the eight items included

in this scale had four response options (“Strongly disagree,” “Disagree,” “Agree,” “Strongly agree”). The data is taken from Table 19.A.22 titled “Items in the RELATST scale” presented in the OECD Report (2024).

Assertiveness (ASSERAGR) students’ ratings of their agreement with statements about a range of behaviors indicative of assertiveness (e.g., “I take initiative when working with my classmates,” “I find it hard to influence people.”) in question ST305 were scaled into the index of “Assertiveness.” Each of the 10 items included in this scale had five response options (“Strongly disagree,” “Disagree,” “Neither agree nor disagree,” “Agree,” “Strongly agree”) (OECD, 2024, p. 439). The data is taken from Table 19.A.32 titled “Items in the ASSERAGR scale” presented in the OECD Report (2024).

Curiosity (CURIOAGR) students’ ratings of their agreement with statements about a range of behaviors indicative of curiosity (e.g., “I like to know how things work,” “I am more curious than most people I know.”) in question ST301 were scaled into the index of “Curiosity.” Each of the 10 items included in this scale had five response options (“Strongly disagree,” “Disagree,” “Neither agree nor disagree,” “Agree,” “Strongly agree”) (OECD, 2024, p. 439). The data is taken from Table 19.A.35 titled “Items in the CURIOAGR scale” presented in the OECD Report (2024). Tables 1–3 show the different items for these variables.

quality of student–teacher relationships, assertiveness, and science achievement without manipulating the environment or conditions of the participants. The model constructed in this study (Figure 1) includes four main variables, categorized according to their role in the conceptual and statistical structure of the analysis. Quality of student–teacher relationship (RELATST) represents the independent variable, which is assumed to directly and indirectly influence science achievement. On the other hand, assertiveness (ASSERAGR) and curiosity (CURIOAGR) function as mediating variables, mediating the links between student–teacher relationships and science achievement. Specifically, the model examines how assertiveness influences the growth of curiosity and how these two factors together sequentially influence student science achievement (see Tables 4–7).

The final variable of the model is science achievement (SCI), which serves as the dependent variable. It is measured through the plausible values (PVSCI) reported in the PISA 2022 data and represents the result that is affected by all the factors included in the model. This structure allows testing hypotheses that include both direct and mediating effects, providing a broad framework for understanding the interrelationships between social, personal, and cognitive factors in academic achievement in science.

Research design

The research design for the study is a non-experimental, correlational design utilizing secondary data from the 2022 Program for International Student Assessment (PISA). This design is appropriate for investigating the proposed relationships between

Sample

The analyses conducted in this study are based on data from the PISA 2022 application. The used sample was formed utilizing a double stratified sampling method and consisted of approximately 690,000 students aged 15 years, attending formal education from the seventh grade onwards,

TABLE 1 Teacher–student relationship quality items with codings.

Construct	Items and codes	Response
RELATST	ST267Q01JA—The teachers at my school are respectful towards me	1 = Strongly disagree, 2 = Disagree, 3 = Neither agree nor disagree, 4 = Agree, 5 = Strongly agree
	ST267Q02JA—If I walked into my classes upset, my teachers would be concerned about me	
	ST267Q03JA—If I came back to visit my school 3 years from now, my teachers would be excited to see me	
	ST267Q04JA—I feel intimidated by the teachers at my school	
	ST267Q05JA—When my teachers ask how I am doing, they are really interested in my answer	
	ST267Q06JA—The teachers at my school are friendly towards me	
	ST267Q07JA—The teachers at my school are interested in students’ well-being	
	ST267Q08JA—The teachers at my school are mean towards me	

TABLE 2 Assertiveness items with coding.

Construct	Items and codes	Response
ASSERT	ST268Q01JA—I feel safe when expressing my opinions	1 = Strongly disagree, 2 = Disagree, 3 = Neither agree nor disagree, 4 = Agree, 5 = Strongly agree
	ST268Q02JA—I’m not afraid to ask about things I do not understand	
	ST268Q03JA—I like to give my opinion in class	
	ST268Q04JA—I can express my opinion even when others disagree	
	ST268Q05JA—I feel comfortable speaking in front of a group of students	
	ST268Q06JA—I can ask for help when I need it	
	ST268Q07JA—Does not avoid confrontation when necessary	
	ST268Q08JA—I am willing to try new things in class	

TABLE 3 Curiosity items with codings.

Construct	Items and codes	Response
CURIOS	ST269Q01JA—I like to learn new things	1 = Strongly disagree, 2 = Disagree, 3 = Neither agree nor disagree, 4 = Agree, 5 = Strongly agree
	ST269Q02JA—Express interest in topics I do not know about	
	ST269Q03JA—I often ask about things that seem unclear to me	
	ST269Q04JA—I like to explore different ideas	
	ST269Q05JA—When I encounter difficulties, I try to find solutions	
	ST269Q06JA—I feel motivated to learn something outside of the classroom	
	ST269Q07JA—I experiment with different ways of understanding something	
	ST269Q08JA—Show interest in projects that challenge me	

including full-time and part-time students, those in vocational programs, as well as students from foreign schools within the country (OECD, 2024, p. 103). The international target population included students aged 15 years and 3 months to 16 years and 2 months at the start of the testing period, allowing for a variation of up to 1 month for countries that tested outside the standard period (OECD, 2024, p. 103). The number of incomplete responses on science tests ranged from 1.2 to 8.5%, reflecting variations in student participation and question completion (OECD, 2024). The analyses were conducted using a multilevel model to account for student clustering within schools. To ensure representativeness of the results, PISA sampling weights were applied throughout the analyses, correcting for non-response and differences in sample structure (OECD, 2024). This procedure ensured that the assessment of the role of student–teacher relationships, assertiveness, and curiosity in science achievement was statistically robust and reliable. This study includes students from countries and regions participating in PISA 2022. Besides age and grade, characteristics of the science education systems of different countries were taken into account, including curriculum, teaching methods, class hours, and laboratory resources.

- H1: The quality of the student–teacher relationship has a positive impact on students’ science achievement.
- H2: The quality of the student–teacher relationship positively influences students’ assertiveness.
- H3: The quality of the student–teacher relationship positively influences students’ curiosity.
- H4: The assertiveness of students positively influences their curiosity.
- H5: Students’ curiosity positively influences their science achievement.
- H6: Assertiveness mediates the relationship between the quality of the student–teacher relationship and curiosity.
- H7: Assertiveness and curiosity mediate the relationship between the quality of the student–teacher relationship and science achievement.

The above hypotheses are built on the basis of the literature and theories presented above. It is evident from the studies mentioned that

teacher–student relationships, assertiveness, and curiosity are interrelated factors that can directly and indirectly influence scientific achievement (Figure 1).

Findings

Initial factor analysis and elimination of inappropriate items

For the analysis of the data obtained from the OECD Report (2024) on quality of student–teacher relationships (RELATST), assertiveness (ASSERAGR) and curiosity (CURIOAGR) of students, the initial factor analysis was run, followed by Pearson correlation and analysis of intermediation.

In the initial factor analysis, not all the elements were considered appropriate for the model, so those that did not fit the expected structure were removed. Two of items have been eliminated for the latent variable “Quality of student–teacher relationships,” because of their low factor loading. These included Item 4: ST267Q04JA (0.123)—*I feel intimidated by the teachers at my school*; and Item 8: ST267Q08JA (0.111)—*The teachers at my school are mean towards me*. Regarding a latent variable “Perseverance,” Item 4: ST307Q04JA (0.130)—*I stop when work becomes too difficult*; Item 6: ST307Q06JA (0.171)—*I give up after making mistakes*; Item 7: ST307Q07JA (−0.063)—*I quit doing homework if it is too long*; and Item 10 ST307Q10JA (−0.123)—*I give up easily* was removed as they did not sufficiently fit the model. Furthermore, for the latent variable “Curiosity” three items were removed due to poor model fit: Item 3: ST301Q03JA (−0.314)—*I get frustrated when I have to learn the details of a topic*; Item 7: ST301Q07JA (0.566)—*I like to develop hypotheses and check them based on what I observe*; and Item 8: ST301Q08JA (0.054)—*I find learning new things to be boring*.

Confirmatory factor analysis results

Table 1 displays the findings from the confirmatory factor analyses. The first analysis yielded a χ^2 of 2974.697 with 347 degrees of freedom, a χ^2 /df ratio of 8.572, a CFI of 0.862, a TLI of 0.850 an SRMR of 0.068, and an RMSEA of 0.038. After removing poorly fitting items, the second confirmatory factor analysis (CFA) demonstrated substantial improvements in fit indices: χ^2 of 818.665 with 149 degrees of freedom, χ^2 /df = 5.494, CFI = 0.958, TLI = 0.952, SRMR = 0.036,

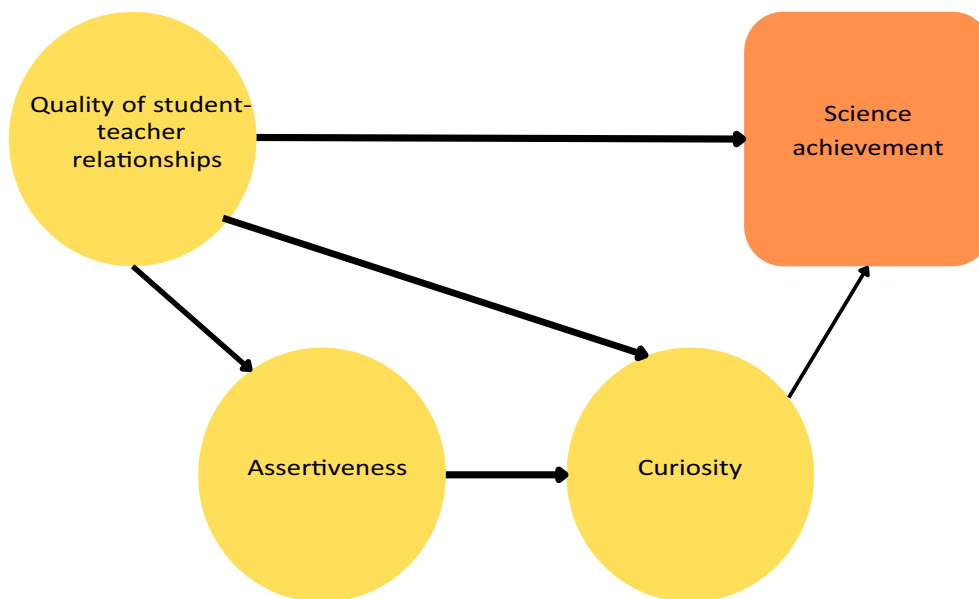


FIGURE 1
The structural model.

TABLE 4 Plausible values in science (PVSCI).

Code	Description
PV1SCIE	Plausible value 1 in science
PV2SCIE	Plausible value 2 in science
PV3SCIE	Plausible value 3 in science
PV4SCIE	Plausible value 4 in science
PV5SCIE	Plausible value 5 in science
PV6SCIE	Plausible value 6 in science
PV7SCIE	Plausible value 7 in science
PV8SCIE	Plausible value 8 in science
PV9SCIE	Plausible value 9 in science
PV10SCIE	Plausible value 10 in science

and RMSEA = 0.030. The CFI and TLI values exceeded the recommended threshold of 0.95, indicating a strong model fit. Moreover, the RMSEA and SRMR values were well within acceptable limits, further confirming the improved model fit.

Factor analysis 1 resulted in the removal of some of the variables from the latent variables. After conducting exploratory factor analysis for the three latent constructs, the remaining variables and loadings are as follows:

The latent constructs include:

- latent qualitative (teacher–student relationships): qst1 (0.518), qst2 (0.582), qst3 (0.578), qst5 (0.604), qst6 (0.432), qst7 (0.483). The internal loadings of the corresponding factors are: 0.694 (0.013), 0.647 (0.014), 0.649 (0.013), 0.629 (0.014), 0.754 (0.012), 0.719 (0.012). These variables show moderate to strong relationships with the latent construct, suggesting that they represent the dimension of teacher–student relationships well.

- latent_self (student assertiveness): as1 (0.606), as3 (0.442), as6 (0.595), as9 (0.447), as10 (0.492). The internal loadings of the corresponding factors are: 0.628 (0.019), 0.747 (0.016), 0.636 (0.019), 0.744 (0.017), 0.713 (0.018). The variables contribute moderately to the assertiveness index, while the removed variables did not contribute consistently to this factor.
- latent_curious (student curiosity): cu1 (0.485), cu2 (0.505), cu4 (0.320), cu5 (0.363), cu6 (0.531), cu9 (0.525), cu10 (0.472). The internal loadings of the corresponding factors are: 0.718 (0.013), 0.703 (0.014), 0.825 (0.010), 0.798 (0.011), 0.685 (0.014), 0.689 (0.014), 0.727 (0.013). Although the remaining variables accurately represent curiosity, some loadings are lower (for instance, cu4 = 0.320), which suggests that this indicator is less robust compared to the others.

The relationships between the latent constructs are also shown in the figure: the correlation between latent_qualitative and latent_self is 0.174 (0.021), between latent_qualitative and latent_curious 0.351 (0.019), and between latent_self and latent_curious 0.379 (0.017). The stability and interpretability of the latent constructs can be improved by removing non-contributing variables, which makes the model clearer and more reliable for further analysis (Figure 2).

The relationship between student–teacher relationships, assertiveness, curiosity, and achievement in science

Correlations are between latent variables estimated through structural equation modeling (SEM).

Analyses were conducted using structural equation modeling (SEM) to assess the relationships between latent variables: quality of student–teacher relationships (RELATST), assertiveness (ASSERAGR), curiosity (CURIOAGR), and science achievement (PVSCI). SEM was

TABLE 5 Model suitability indicators for confirmatory factor analysis (CFA).

	χ^2	df	χ^2/df	CFI	TLI	SRMR	RMSEA
First confirmatory factorial analysis	2974.697	347	8.572	0.862	0.850	0.068	0.038
Second confirmatory factorial analysis	818.665	149	5.494	0.958	0.952	0.036	0.030

TABLE 6 The Pearson correlations between RELATST, assertiveness, curiosity and PVSCI.

	RELATST	Assertiveness	Curiosity
1. RELATST	1		
2. Assertiveness	0.176**	1	
3. Curiosity	0.382**	0.351**	1
4. PVSCI	0.137**	0.093**	0.240**

** $p < 0.01$.

TABLE 7 The analysis of the intermediation of assertiveness and curiosity in the relationship between the quality of the student–teacher relationship and science achievement.

H:	Hypotheses test	Estimate	Lower bound	Upper bound	p -value
H1:	RELATST → PVSCI	0.052	0.012	0.115	0.034
H2:	RELATST → Assertiveness	0.176	0.142	0.228	0.000
H3:	RELATST → Curiosity	0.331	0.302	0.375	0.000
H4:	Assertiveness → Curiosity	0.239	0.262	0.342	0.000
H5:	Curiosity → PVSCI	0.221	0.185	0.276	0.000
H6:	RELATST → Assertiveness → Curiosity	0.053	0.064	0.112	0.000
H7:	RELATST → Assertiveness → Curiosity → PVSCI	0.014	0.918	1.79	0.000

$p < 0.001$.

chosen due to its ability to test direct and cross-sectional relationships between variables. Moreover, it confirms that relationship quality and student personal factors interact to influence science achievement.

Table 2 presents the correlation among four study variables: quality of student–teacher relationship (RELATST), assertiveness, curiosity, and science achievement (PVSCI). The correlations presented are positive and statistically significant for the value ($p < 0.01$). The quality of the student–teacher relationship (RELATST) has a weak positive correlation with assertiveness ($r = 0.176$), a moderate correlation with curiosity ($r = 0.382$) and a weak correlation with success in science ($r = 0.137$). Assertiveness is positively related to curiosity ($r = 0.351$) and, to a lower extent, to success in science ($r = 0.093$), while Curiosity has a stronger relationship with achievement in science ($r = 0.240$). These results support the theoretical model of the study, indicating that a close and high-quality relationship with the teacher can positively influence the development of self-confidence and the promotion of curiosity, which in turn contribute to students’ science achievement.

Intermediation of assertiveness and curiosity in the relationship between the quality of the student–teacher relationship and science achievement

The quality of the student–teacher relationship (RELATST) has a positive and statistically significant effect on achievement in science (PVSCI) ($\beta = 0.052$, $p = 0.034$). QST has a strong positive impact on

assertiveness ($\beta = 0.176$, $p < 0.001$), indicating that a good relationship with the teacher supports students in developing more assertiveness and the ability to express their opinions. RELATST also positively impacts curiosity ($\beta = 0.331$, $p < 0.001$), which shows that a great relationship with the teacher enables students to be more curious and motivated to learn. Further, the results show that assertiveness positively impacts curiosity ($\beta = 0.239$, $p < 0.001$), suggesting that students who are more confident and engaged are more likely to be curious. Curiosity positively impacts the PVSCI ($\beta = 0.221$, $p < 0.001$), which reveals that more curious students perform better at science. In addition, QST impacts curiosity through assertiveness ($\beta = 0.053$, $p < 0.001$). It shows that a good relationship between teacher and student supports students becoming more confident, which in turn increases their curiosity to learn. Overall, RELATST impacts PVSCI through assertiveness and curiosity ($\beta = 0.014$, $p < 0.001$). These results confirm that the impact of the student–teacher relationship on science achievement is not directly stated, but it is also achieved through the development of assertiveness and curiosity.

Discussion and conclusion

The role of student–teacher relationships in science achievement

This study explored the impact of quality student–teacher relationships on science achievement, focusing on the mediating role of assertiveness and curiosity. Data analyzed from the OECD (2024) report show that a good relationship with the teacher not only directly

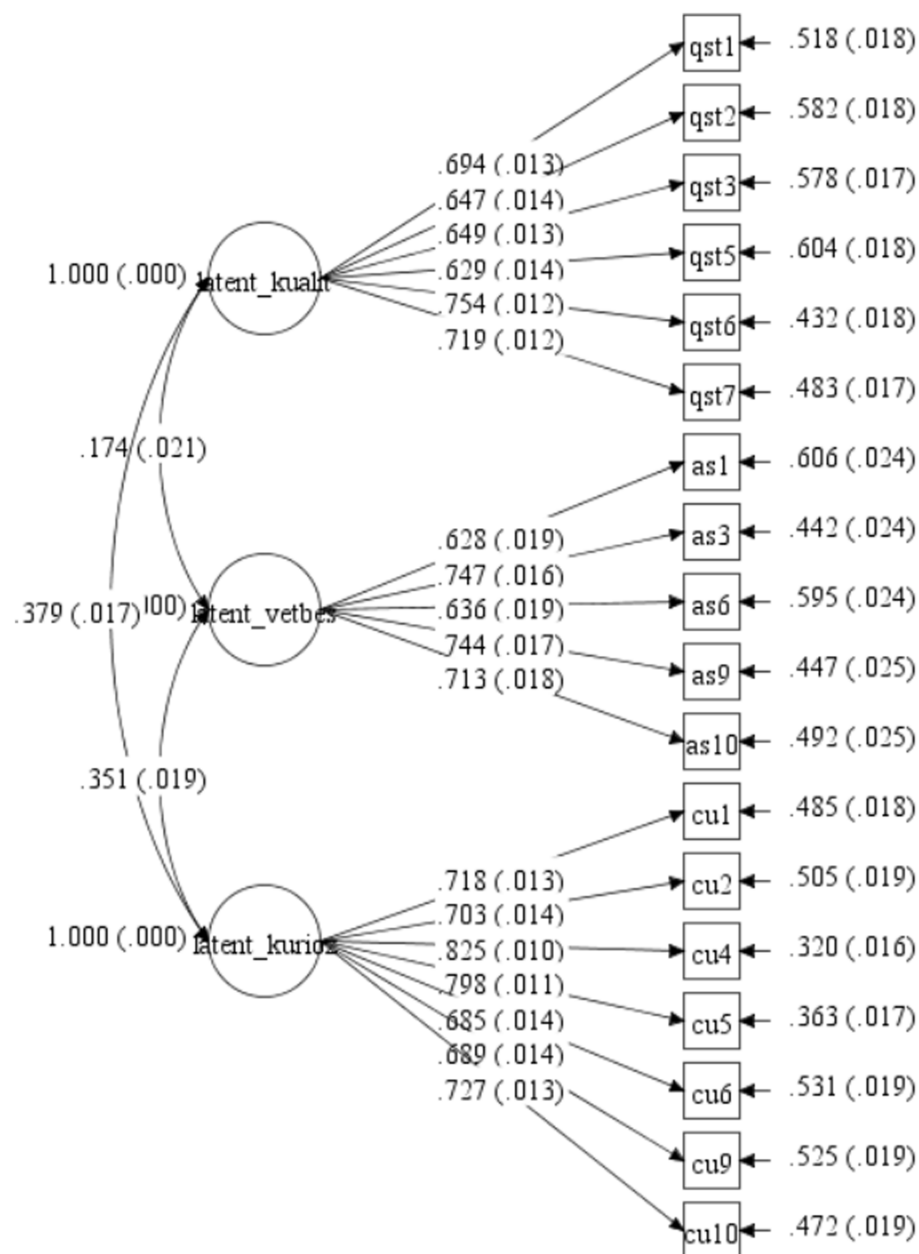


FIGURE 2
Results of the exploratory factor analysis after removing non-significant variables.

affects science achievement, but also has a huge impact in the development of students' assertiveness and curiosity. The findings confirmed that the quality of student-teacher relationships has a direct positive effect on science achievement. This aligns with previous studies showing that supportive relationships foster motivation, engagement, and ultimately academic performance (Hughes, 2011; OECD, 2024).

The mediating role of assertiveness

The results demonstrated that assertiveness significantly mediates the relationship between teacher-student relationships

and science achievement. Assertiveness helps students feel more confident, while curiosity encourages deeper engagement in the learning process and exploration of scientific concepts. The analysis confirms that the quality of the relationship with the teacher has a direct and an indirect impact on scientific achievement through the mediation of assertiveness and curiosity. A good relationship with the teacher increases the level of assertiveness of students ($\beta = 0.176$), which in turn affects the increase in curiosity ($\beta = 0.239$), which then directly affects the results in science ($\beta = 0.221$). This mediation process testifies to the importance of creating a supportive climate in the classroom, where students feel valued, listened to, and encouraged to explore new knowledge.

The mediating role of curiosity

The findings align with the current existing literature, as proven by the studies of Hamre and Pianta (2006), Kurbanoglu et al. (2023), as well as Abu Khurma and El Zein (2024), who highlight that curiosity and intellectual perspective play a pivotal role in academic achievement. In science education, this study provides a deeper understanding of how social factors (student–teacher relationship) and personal factors (assertiveness and curiosity) interact between each other. The results show that curiosity has a bigger affect than assertiveness in science achievements. Moreover, this supports the literature that considers curiosity as the main driver of learning in exploratory subjects (Oudeyer et al., 2016; Engel, 2011). The analysis also revealed that curiosity serves as a mediator between student–teacher relationships and science achievement.

The finding suggests that the improvement of student–teacher relationships is not just an emotional issue, but it is directly related to scientific results through strengthening self-confidence and stimulating curiosity. This supports the need for further training for teachers in building positive relationships and the usage of “project-based learning” or “inquiry-based learning” methods. The study confirms that quality student–teacher relationships have an important impact on student achievement in science, both directly and through building assertiveness and fostering curiosity. Assertiveness builds self-confidence and encourages active engagement, while curiosity pushes students to explore science concepts in depth. The data show that the higher the level of curiosity, the higher the results in science. These findings highlight the importance of creating healthy relationships between students and teachers and cultivating assertiveness and curiosity in the school environment. It is recommended that teachers develop strong and supportive relationships with students, promote assertiveness, and stimulate curiosity.

In conclusion, this research provides empirical evidence that socio-emotional factors like the quality of the student–teacher relationship, assertiveness, and curiosity are not secondary but primary in science subjects. The findings support the idea that the improvement of academic results does not depend only on the way the content is delivered, but on creating an emotionally safe and intellectually stimulating environment. The mediating role of assertiveness and curiosity emphasizes the transformative potential of student–centered pedagogies. Further studies should examine deeper how these factors are developed over time and how they react to targeted interventions, while education systems should give priority to the development of positive relationships and motivation in learning, alongside cognitive content.

This study aimed to examine the role of teacher–student relationships on science achievement and the mediating effects of assertiveness and curiosity. The results confirmed all the hypotheses put forward: teacher–student relationships have a direct positive impact on science achievement (H1, H2), while both assertiveness (H3, H4) and curiosity (H5, H6) act as significant mediators. The full model (H7) showed that these socio-emotional factors amplify the impact of relationships, with stronger mediating effects than the direct effect.

Overall, the findings highlight that the path from supportive teacher–student relationships to better academic outcomes operates primarily through students’ self-confidence and curiosity. This suggests that developing socio-emotional skills is not an optional

supplement, but a central component of effective science education. By prioritizing teaching practices and educational policies that strengthen the quality of relationships and socio-emotional development, education systems can create conditions where students not only achieve higher outcomes, but also become more engaged and motivated to learn.

Study limitations and future studies

The use of secondary data is a significant limitation of this study, which limits the ability to fully control for variables and to collect data directly relevant to the research objectives. Furthermore, there is cross-cultural variability within PISA, as education systems, teaching practices, and social norms differ from country to country, which may influence student perceptions and responses. The study also has a cross-sectional design, which limits the ability to draw causal conclusions about student–teacher relationships, assertiveness, and curiosity.

Additionally, the measurement of student–teacher relationships, assertiveness, and curiosity relies on self-reporting, which may result in biased or distorted participation by students’ subjective perceptions. For future studies, it is recommended to utilize longitudinal designs and experimental interventions, which can enhance the assessment how student–teacher relationships influence the development of assertiveness and curiosity. Experimental or intervention studies could test specific strategies to improve teacher–student interactions, strengthen assertiveness, and stimulate curiosity, providing stronger evidence of causal effects.

Implications for practice

The results of this study have clear implications for curriculum design, teaching strategies, and teacher professional development:

1. **Fostering positive student–teacher relationships:** Teachers should focus on building supportive and respectful relationships with students. Practical strategies include regular check-ins, acknowledging student ideas, providing constructive feedback, and creating a climate where students feel valued and heard. Strong relationships help develop curiosity and assertiveness in students.
2. **Promoting assertiveness:** Teachers can create structured opportunities for students to express their opinions, lead discussions, or present results in science activities. Role-playing, debates, and group work promote students’ assertiveness and communication skills, which has a positive on engagement and achievement in science.
3. **Fostering curiosity:** Embracing learning approaches such as inquiry-based learning and project-based learning should be used more systematically. Allowing students to explore questions, design experiments, and seek solutions on their own fosters intellectual curiosity. Hands-on activities, problem-solving from real-world situations, and open-ended explorations deepen students’ conceptual understanding and engagement.
4. **Teacher professional development:** Training programs should focus on equipping teachers with strategies to strengthen

students' socio-emotional skills. Trainings may include techniques for improving student–teacher relationships, fostering assertiveness, and guiding curiosity in the classroom. Teachers should be able to identify and support students' motivational and emotional needs alongside academic content.

5. Curriculum integration: Science curricula should include activities that build both content knowledge and socio-emotional skills simultaneously. For example, a project-based unit where students explore a scientific question in a group can increase engagement, curiosity, and self-confidence. Curricula should provide support for students in gradually taking responsibility for their own learning.

By implementing these strategies, schools can create learning environments that not only convey scientific content, but also support the socio-emotional and motivational factors that contribute to student achievement in science.

Data availability statement

The datasets presented in this study can be found in online repositories. The names of the repository/repositories and accession number(s) can be found at: <https://doi.org/10.1787/01820d6d-en>.

Ethics statement

This study involved the secondary analysis of publicly available data from the OECD PISA 2022 dataset. As such, no new data was collected directly from human participants, and ethical approval was not required. The use of this data complies with all relevant data usage policies and ethical guidelines set by the OECD.

Author contributions

FR: Conceptualization, Data curation, Formal analysis, Project administration, Writing – original draft. DK: Software, Validation,

Writing – review & editing. MP-S: Resources, Supervision, Validation, Writing – review & editing. BÇ: Resources, Software, Visualization, Writing – review & editing.

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Conflict of interest

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Appendix A

TABLE A1 Variables used in the analysis and their PISA codes.

Variable name	Description	PISA 2022 codes
RELATST	Student–teacher relationship index	ST267Q01–ST267Q08
ASSERAGR	Student assertiveness index	ST263Q01–ST263Q10
CURIOAGR	Student curiosity index	ST264Q01–ST264Q10
PVSCI	Values for science achievement	PV1SCI–PV10SCI