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Research Paper

Analysis of Teaching Methods and Adolescents' Motivation in Science Study

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This study investigates adolescents' motivation to engage in science education and the extent to which teaching methods influence their motivation across 40 countries. Drawing upon data from the 2022Programme for International Student Assessment (PISA), we examined responses from over 100,000 fifteen-year-old students. Motivation was assessed in terms of interest, perceived importance for future careers, and daily involvement in science-related activities. Using principal component analysis, three distinct dimensions of motivation were identified. Subsequent regression analyses revealed that teaching strategies promoting critical thinking, creativity, and student autonomy were positively associated with higher motivation scores. Notably, significant variations in motivation were observed across gender, parental education levels, and national contexts. These findings underscore the pivotal role of pedagogical approaches in shaping students' engagement with science and offer insights for international educational policy reform aimed at fostering scientific literacy and enthusiasm among youth.

Keywords
Science Education; Student Motivation; Teaching Methods; Critical Thinking
PISA 2022; Cross-National Comparison; Adolescent Learning; Educational Equity

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I. Background

In contemporary knowledge-based economies, science and technology education plays an increasingly vital role in shaping future generations capable of addressing global challenges such as climate change, public health crises, energy transitions, and technological innovation. Despite this recognized importance, a persistent concern in science education is the observed decline in adolescents' motivation and engagement with scientific subjects, particularly as students transition from primary to secondary schooling. A growing body of literature highlights that while younger children often display natural curiosity about scientific phenomena, this enthusiasm tends to diminish during adolescence—a critical period for shaping educational aspirations and future career trajectories.

This decline in motivation has serious implications for the development of a scientifically literate population and the cultivation of a future workforce equipped with essential STEM (Science, Technology, Engineering, and Mathematics) competencies. Numerous studies have pointed to various interrelated factors that contribute to this trend, including students' perceived relevance of science to everyday life, their self-efficacy in science learning, sociocultural influences, and notably, the pedagogical approaches employed in science classrooms.

Among these determinants, teaching methods are particularly influential and modifiable. Pedagogical practices that prioritize rote memorization and teacher-centered instruction have often been associated with student disengagement. In contrast, instructional strategies that emphasize inquiry-based learning, collaborative problem solving, real-world applications, and opportunities for critical and creative thinking have demonstrated more promising outcomes in fostering student interest and long-term commitment to science education. Effective teaching methods not only transmit scientific knowledge but also have the potential to shape students' attitudes, motivations, and beliefs about the nature and value of science.

Furthermore, motivation in science learning is increasingly viewed as a multidimensional construct, encompassing cognitive, affective, and behavioral components such as intrinsic interest, perceived utility, and active participation in science-related activities. Understanding how different teaching practices influence these dimensions of motivation is essential for the development of evidence-based educational policies and classroom interventions.

Against this backdrop, the present study aims to contribute to the existing literature by adopting a cross-national perspective to examine adolescents' motivation in science and the role of teaching methods in shaping it. Using data from the 2022 cycle of the Programme for International Student Assessment (PISA)[1], this research investigates not only the overall motivational patterns among adolescents but also how pedagogical strategies vary in their effectiveness across diverse sociocultural and educational contexts.

II. Study objectives

The primary objective of this study is to examine adolescents' motivation in learning science from a global perspective, using data from the 2022Programme for International Student Assessment (PISA). Specifically, the study seeks to (1) identify and quantify key components of motivation—namely, interest, perceived importance, and daily involvement in science-related activities; (2) analyze how these components vary across demographic factors such as gender, parental education, and national context; and (3) evaluate the extent to which different teaching methods are associated with students' motivation. The ultimate aim is to inform evidence-based pedagogical practices that promote meaningful engagement in science education.

III. Materials and Methods

3.1. Data source and Study sample

This study used data from the 2022Programme for International Student Assessment (PISA, website: http://www.oecd.org/pisa/) [2]. PISA is the survey of adolescent students around the world, conducted by the Organization for Economic Co-operation and Development (OECD). It is conducted every three years to tests 15-year-old students in reading, mathematics and science. PISA choose the age of 15 because it is believed that students at this age can decide whether or not they want to continue their education.
The 2022 data is the most recent available PISA data by the time of this study. It (https://www.oecd.org/en/data/datasets/pisa-2022-database.html) includes five main data files: a student-questionnaire data file, a school-questionnaire data file, a teacher-questionnaire data file, a cognitive item data file and a file with questionnaire timing data. We used the student-questionnaire data.

3.2 Variables

The data includes 928 variables in total. Below are list of variables used and variable coding:
3.2.1 outcome
The following "clusters" of questions were asked to students on their interest/perception in broad sciences:

- *How much do you disagree or agree with the statements about yourself below?*

ST094Q01NA	I have fun when I am learning <broad science>
ST094Q02NA	I like reading about <broad science> topics.
ST094Q03NA	I am happy working on <broad science> topics.
ST094Q04NA	I enjoy acquiring new knowledge in <broad science>.
ST094Q05NA	I am interested in learning about <broad science>.

Responses are:

1	Strongly disagree
2	Disagree
3	Agree
4	Strongly agree

- *How much do you agree with the statements below?*

ST113Q01TA	Making an effort in my <school science> subject(s) is worth it because this will help me in the work I want to do later
ST113Q02TA	What I learn in my <school science> subject(s) is important for me because I need this for what I want to do later on
ST113Q03TA	Studying my <school science> subject(s) is worthwhile for me because what I learn will improve my career prospects.
ST113Q04TA	Many things I learn in my <school science> subject(s) will help me to get a job.

Responses are:

1	Strongly disagree
2	Disagree
3	Agree
4	Strongly agree

- *How often do you do these things?*

ST146Q01TA	Watch TV programs about <broad science>
ST146Q02TA	Borrow or buy books on <broad science> topics
ST146Q03TA	Visit web sites about <broad science> topics
ST146Q04TA	Read <broad science> magazines or science articles in newspapers
ST146Q05TA	Attend a <science club>
ST146Q06NA	Simulate natural phenomena in computer programs\virtual labs
ST146Q07NA	Simulate technical processes in computer programs\virtual labs
ST146Q08NA	Visit web sites of ecology organisations
ST146Q09NA	Follow news via blogs and microblogging

Responses are:

1	Very often
2	Regularly
3	Sometimes
4	Never or hardly ever

3.2.2 Teaching methods

This was based on the following question:
"When learning topics at school, how often do the following activities occur?"

ST098Q01TA	Students are given opportunities to explain their ideas.
ST098Q02TA	Students spend time in the laboratory doing practical experiments.
ST098Q03NA	Students are required to argue about science questions.
ST098Q05TA	Students are asked to draw conclusions from an experiment they have conducted.
ST098Q06TA	The teacher explains <school science> idea can be applied
ST098Q07TA	Students are allowed to design their own experiments.
ST098Q08NA	There is a class debate about investigations.
ST098Q09TA	The teacher clearly explains relevance <broad science> concepts to our lives.
ST098Q10NA	Students are asked to do an investigation to test ideas.

Responses are:

1	In all lessons
2	In most lessons
3	In some lessons
4	Never or hardly ever

A score is created based on each question. A higher score indicates lower degree of critical thinking/creativity encouraged by the teaching methods.

3.2.3 Other variables:

CNTRYID	Country Identifier

This is a variable indicating the source country.

#ST001D01T	Student International Grade (Derived)
#ST003D03T	Student (Standardized) Birth -Year
#ST004D01T	Student (Standardized) Gender

Variables of grade, age, and gender are based on the above questions.

ST005Q01TA	What is the <highest level of schooling> completed by your mother?
ST007Q01TA	What is the <highest level of schooling> completed by your father?

A variable indicating "parent's highest education" was created, based on the higher one of mother's or father's. Responses include: ISCED level 1, ISCED level 2, ISCED level 3B/3C, ISCED level 3A, ISCED level 4, ISCED level 5B, ISCED level 5A, ISCED level 6

3.3 data analysis

We first examined the components of adolescents' motivation in science study, by using principal components analysis (PCA). PCA is a popular statistical procedure in variable reduction. It converts a set of (possibly) correlated variables into a set of components. As a result, it is particularly useful in situations where the dimensionality/component structure of data is to be studied.[3]

Then, we looked at adolescents' motivation across countries, gender, and parental education.

Lastly, we used linear regression to evaluate if teaching methods are related with adolescents' motivation in science study. Linear regression is for studying continuous outcome variables, and its general formula is:

$$y = b0 + b1*X1 + b2*X2 + ...+ bn*Xn$$

The major output is regression coefficient (b) for all variables in the model, as well as their P-values. If a coefficient has a P-value of below 0.05, it means that this variable has statistically significant association with the outcome. In this case, we further look at the direction of its regression coefficient (b). If b is above 0, the variable is *positively* associated with the outcome. If b is below 0, the variable is *negatively* associated with the outcome.

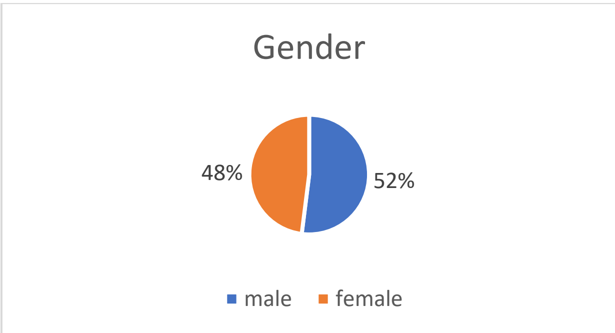
On the other hand, if the P-value is above 0.05, it means the association is not statistically significant.

In the model, we included age, gender, grade, parental education, and country. These are potentially important variables confounding the relationship between teaching methods and students' motivation. Therefore, by including them in the model, their effect is controlled for.

IV. RESULTS

There are 134,436 participants with complete information of the variables in section 3. They are from 40 countries.

age	proportion
16 years	10%
17 years	90%



Grade	proportion
7	0.5%
8	3.4%
9	33.3%
10	50.7%
11	11.6%

12	0.5%
13	0.0%

Most students are in grade 9 and 10.

4.1 Correlation among all the motivation questions.

Results showed that the questions within each "cluster" question are highly correlated.

	ST094Q01NA	ST094Q02NA	ST094Q03NA	ST094Q04NA	ST094Q05NA	ST113Q01TA	ST113Q02TA	ST113Q03TA	ST113Q04TA	ST146Q01TA	ST146Q02TA	ST146Q03TA	ST146Q04TA	ST146Q05TA	ST146Q06NA	ST146Q07NA	ST146Q08NA	ST146Q09NA
ST094Q01NA	1.00	0.70	0.72	0.72	0.74	-0.33	-0.35	-0.35	-0.32	-0.28	-0.27	-0.34	-0.31	-0.11	-0.15	-0.14	-0.19	-0.24
ST094Q02NA	0.70	1.00	0.73	0.72	0.72	-0.32	-0.34	-0.34	-0.31	-0.36	-0.37	-0.42	-0.41	-0.16	-0.20	-0.19	-0.25	-0.30
ST094Q03NA	0.72	0.73	1.00	0.75	0.74	-0.34	-0.36	-0.36	-0.33	-0.31	-0.32	-0.38	-0.34	-0.16	-0.20	-0.19	-0.23	-0.28
ST094Q04NA	0.72	0.72	0.75	1.00	0.80	-0.34	-0.35	-0.35	-0.31	-0.32	-0.30	-0.37	-0.33	-0.12	-0.16	-0.15	-0.21	-0.27
ST094Q05NA	0.74	0.72	0.74	0.80	1.00	-0.37	-0.38	-0.38	-0.34	-0.32	-0.31	-0.38	-0.34	-0.13	-0.17	-0.17	-0.22	-0.27
ST113Q01TA	-0.33	-0.32	-0.34	-0.34	-0.37	1.00	0.79	0.74	0.67	0.22	0.25	0.27	0.24	0.15	0.16	0.16	0.17	0.21
ST113Q02TA	-0.35	-0.34	-0.36	-0.35	-0.38	0.79	1.00	0.78	0.73	0.23	0.26	0.28	0.26	0.16	0.18	0.18	0.19	0.22
ST113Q03TA	-0.35	-0.34	-0.36	-0.35	-0.38	0.74	0.78	1.00	0.76	0.22	0.24	0.27	0.24	0.14	0.16	0.16	0.18	0.22
ST113Q04TA	-0.32	-0.31	-0.33	-0.31	-0.34	0.67	0.73	0.76	1.00	0.21	0.25	0.26	0.24	0.16	0.18	0.18	0.19	0.22
ST146Q01TA	-0.28	-0.36	-0.31	-0.32	-0.32	0.22	0.23	0.22	0.21	1.00	0.54	0.55	0.55	0.35	0.40	0.40	0.43	0.45
ST146Q02TA	-0.27	-0.37	-0.32	-0.30	-0.31	0.25	0.26	0.24	0.25	0.54	1.00	0.63	0.64	0.53	0.53	0.53	0.54	0.54
ST146Q03TA	-0.34	-0.42	-0.38	-0.37	-0.38	0.27	0.28	0.27	0.26	0.55	0.63	1.00	0.66	0.43	0.48	0.48	0.55	0.56
ST146Q04TA	-0.31	-0.41	-0.34	-0.33	-0.34	0.24	0.26	0.24	0.24	0.55	0.64	0.66	1.00	0.47	0.50	0.48	0.54	0.55
ST146Q05TA	-0.11	-0.16	-0.16	-0.12	-0.13	0.15	0.16	0.14	0.16	0.35	0.53	0.43	0.47	1.00	0.63	0.62	0.54	0.49
ST146Q06NA	-0.15	-0.20	-0.20	-0.16	-0.17	0.16	0.18	0.16	0.18	0.40	0.53	0.48	0.50	0.63	1.00	0.86	0.60	0.54
ST146Q07NA	-0.14	-0.19	-0.19	-0.15	-0.17	0.16	0.18	0.16	0.18	0.40	0.53	0.48	0.48	0.62	0.86	1.00	0.60	0.55
ST146Q08NA	-0.19	-0.25	-0.23	-0.21	-0.22	0.17	0.19	0.18	0.19	0.43	0.54	0.55	0.54	0.54	0.60	0.60	1.00	0.65
ST146Q09NA	-0.24	-0.30	-0.28	-0.27	-0.27	0.21	0.22	0.22	0.22	0.45	0.54	0.56	0.55	0.49	0.54	0.55	0.65	1.00

PCA analysis showed that the 3-component structure works well. Questions within each "cluster" question are highly loaded on one of the 3 components.

	RC1	RC2	RC3	h2	u2	com
ST094Q01NA	0.08	0.90	-0.01	0.77	0.23	1.0
ST094Q02NA	-0.04	0.88	0.03	0.79	0.21	1.0
ST094Q03NA	0.00	0.89	-0.01	0.80	0.20	1.0
ST094Q04NA	0.05	0.93	0.01	0.82	0.18	1.0
ST094Q05NA	0.04	0.91	-0.03	0.82	0.18	1.0
ST113Q01TA	0.00	0.00	0.90	0.80	0.20	1.0
ST113Q02TA	0.01	-0.01	0.92	0.85	0.15	1.0
ST113Q03TA	-0.01	-0.02	0.91	0.84	0.16	1.0
ST113Q04TA	0.01	0.02	0.88	0.78	0.22	1.0
ST146Q01TA	0.62	-0.17	-0.01	0.48	0.52	1.2
ST146Q02TA	0.77	-0.07	0.02	0.65	0.35	1.0
ST146Q03TA	0.70	-0.19	0.02	0.63	0.37	1.2
ST146Q04TA	0.73	-0.15	-0.01	0.63	0.37	1.1
ST146Q05TA	0.80	0.16	0.01	0.59	0.41	1.1
ST146Q06NA	0.88	0.14	0.00	0.71	0.29	1.1
ST146Q07NA	0.88	0.15	0.00	0.70	0.30	1.1
ST146Q08NA	0.84	0.05	-0.02	0.67	0.33	1.0
ST146Q09NA	0.76	-0.05	-0.01	0.60	0.40	1.0

Based on the "cluster" questions, we created the following three motivation component variables:

- interest = ST094Q01NA+ ST094Q02NA+ ST094Q03NA+ ST094Q04NA+ ST094Q05NA
- importance = 20- (ST113Q01TA + ST113Q02TA + ST113Q03TA + ST113Q04TA)
- daily_involvement = 45- (ST146Q01TA + ST146Q02TA + ST146Q03TA + ST146Q04TA + ST146Q05TA + ST146Q06NA + ST146Q07NA + ST146Q08NA + ST146Q09NA)

they are created so that higher scores indicate higher motivation in each component.

4.2 Scores by gender, parents' highest education, and country

	Motivation		
	interest	importance	daily involvement
female	13.78	11.65	14.33
male	14.1	11.66	16.18

Parent's highest education level	Motivation		
	interest	importance	daily involvement
did not complete <ISCED level 1>	14.01	11.82	15.77
ISCED level 1	13.89	11.75	15.35
ISCED level 2	13.88	11.78	15.56
ISCED level 3B, 3C	13.21	11.12	14.41
ISCED level 3A	13.63	11.45	14.94
ISCED level 4	13.85	11.58	15.16
ISCED level 5B	13.86	11.62	14.89
ISCED level 5A	14.27	11.78	15.12
ISCED level 6	14.26	11.96	16.55

Comparison across 40 countries

			score			**Ranking**		
country code	**country name**	**# of participants**	**interest**	**importance**	**daily involvement**	**intere st**	**importa nce**	**daily involvement**
970	B-S-J-G (China)	7,007	14.66	12.37	16.81	9	7	9
858	Uruguay	1,882	13.07	11.53	14.92	32	22	21
840	United States	2,968	14.04	11.77	14.27	19	18	26
826	United Kingdom	5,739	14.04	12.1	13.43	18	12	34
788	Tunisia	1,665	15.29	12.9	20.9	1	1	1
784	United Arab Emirates	6,067	14.97	12.7	18.78	5	3	2
756	Switzerland	2,443	13.45	10.02	13.75	28	38	29
703	Slovak Republic	3,263	12.41	10.72	14.44	37	33	25
702	Singapore	4,070	15.21	12.4	15.05	2	6	16
643	Russian Federation	2,875	13.3	11.48	17.26	29	23	7
634	Qatar	4,354	14.72	12.59	18.65	7	4	3
620	Portugal	3,032	15.05	12.86	16.15	4	2	11
616	Poland	3,434	13.21	11.06	15.7	31	30	13
604	Peru	3,237	14.7	12.33	17.57	8	8	6
554	New Zealand	1,861	14.3	12.2	13.47	13	10	33
446	Macao	3,252	14.04	11.53	14.96	17	21	20
442	Luxembourg	2,202	13.73	10.68	14.55	25	34	24
440	Lithuania	3,308	14.32	11.94	15.72	12	16	12
428	Latvia	2,458	13.54	10.89	14.62	27	32	23

410	Korea	3,354	12.76	10.9	13.36	35	31	36
376	Israel	3,248	13.82	11.95	15.46	24	15	15
372	Ireland	2,736	14.18	12.02	12.63	16	14	39
352	Iceland	1,514	13.84	11.47	13.54	23	24	31
348	Hungary	2,546	12.26	10.34	15.05	40	36	18
344	Hong Kong	2,861	14.74	12.05	16.43	6	13	10
300	Greece	2,596	13.9	11.54	15.03	21	20	19
276	Germany	1,338	12.67	9.77	13.68	36	40	30
246	Finland	3,249	12.95	11.24	11.91	34	27	40
233	Estonia	3,265	13.89	11.34	15.05	22	26	17
214	Dominican Republic	1,144	15.08	12.45	18.42	3	5	4
203	Czech Republic	3,742	12.36	10.32	13.35	38	37	37
191	Croatia	3,018	12.96	11.15	14.08	33	28	28
188	Costa Rica	2,498	14.37	11.93	15.64	11	17	14
152	Chile	3,091	13.54	11.77	14.68	26	19	22
124	Canada	9,622	14.58	12.29	14.15	10	9	27
100	Bulgaria	2,344	14.19	11.13	18.23	15	29	5
76	Brazil	5,336	14.22	12.19	16.86	14	11	8
56	Belgium	4,487	13.28	10.53	13.51	30	35	32
40	Austria	2,968	12.31	9.8	13.39	39	39	35
36	Australia	4,362	13.92	11.4	13.24	20	25	38
	Total	134,436						

4.3 Results from Linear regression analysis

Coefficients:	interest			importance			daily involvement		
	coefficient estimate	Std. Error	P-value	coefficient estimate	Std. Error	P-value	coefficient estimate	Std. Error	P-value
(Intercept)	10.88	0.70	<0.0001	12.98	0.57	<0.0001	20.03	1.04	<0.0001
age	0.10	0.04	0.02	-0.03	0.03	0.32	0.06	0.06	0.37
gendermale	0.30	0.02	<0.0001	-0.04	0.02	0.01	1.55	0.03	<0.0001
parental education	0.12	0.01	<0.0001	0.05	0.01	<0.0001	0.13	0.01	<0.0001
grade	0.32	0.02	<0.0001	0.11	0.01	<0.0001	-0.14	0.03	<0.0001
ST098Q01TA	-0.20	0.01	<0.0001	-0.17	0.01	<0.0001	0.10	0.02	<0.0001
ST098Q02TA	-0.04	0.02	0.02	-0.11	0.01	<0.0001	-0.47	0.02	<0.0001
ST098Q03NA	-0.08	0.01	<0.0001	-0.08	0.01	<0.0001	-0.32	0.02	<0.0001
ST098Q05TA	-0.14	0.01	<0.0001	-0.04	0.01	<0.0001	0.02	0.02	0.47
ST098Q06TA	-0.38	0.01	<0.0001	-0.14	0.01	<0.0001	-0.03	0.02	0.11
ST098Q07TA	0.17	0.02	<0.0001	-0.02	0.01	0.06	-0.75	0.02	<0.0001
ST098Q08NA	0.07	0.02	<0.0001	0.01	0.01	0.31	-0.42	0.02	<0.0001

ST098Q09TA	-0.56	0.01	<0.0001	-0.29	0.01	<0.0001	-0.17	0.02	<0.0001
ST098Q10NA	-0.02	0.01	0.27	-0.12	0.01	<0.0001	-0.45	0.02	<0.0001
country ID: referene 36									
40	-1.01	0.09	<0.0001	-1.22	0.07	<0.0001	0.92	0.13	<0.0001
56	-0.19	0.08	0.01	-0.49	0.06	<0.0001	0.95	0.12	<0.0001
76	0.46	0.08	<0.0001	0.94	0.06	<0.0001	3.62	0.11	<0.0001
100	0.69	0.10	<0.0001	-0.06	0.08	0.47	4.72	0.14	<0.0001
124	0.57	0.07	<0.0001	0.86	0.06	<0.0001	0.78	0.10	<0.0001
152	-0.29	0.09	<0.0001	0.43	0.07	<0.0001	1.66	0.13	<0.0001
188	0.78	0.09	<0.0001	0.77	0.08	<0.0001	2.83	0.14	<0.0001
191	-0.31	0.09	<0.0001	0.15	0.07	0.04	1.30	0.13	<0.0001
203	-1.22	0.08	<0.0001	-0.85	0.07	<0.0001	0.51	0.12	<0.0001
214	0.84	0.12	<0.0001	0.75	0.10	<0.0001	4.03	0.18	<0.0001
233	0.51	0.09	<0.0001	0.28	0.07	<0.0001	2.14	0.13	<0.0001
246	-0.40	0.09	<0.0001	0.23	0.07	0.00	-0.52	0.13	<0.0001
276	-0.70	0.11	<0.0001	-1.30	0.09	<0.0001	0.64	0.17	<0.0001
300	0.31	0.09	<0.0001	0.40	0.07	<0.0001	2.37	0.13	<0.0001
344	1.38	0.09	<0.0001	0.89	0.07	<0.0001	2.97	0.13	<0.0001
348	-1.12	0.09	<0.0001	-0.68	0.08	<0.0001	2.41	0.14	<0.0001
352	0.14	0.11	0.19	0.25	0.09	0.01	0.67	0.16	<0.0001
372	0.50	0.09	<0.0001	0.78	0.07	<0.0001	-0.36	0.13	0.01
376	0.26	0.09	0.00	0.74	0.07	<0.0001	2.10	0.13	<0.0001
410	-0.49	0.08	<0.0001	0.01	0.07	0.92	1.04	0.12	<0.0001
428	0.00	0.09	0.98	-0.31	0.08	<0.0001	1.31	0.14	<0.0001
440	0.57	0.09	<0.0001	0.62	0.07	<0.0001	2.40	0.13	<0.0001
442	0.15	0.10	0.13	-0.53	0.08	<0.0001	1.34	0.14	<0.0001
446	0.80	0.09	<0.0001	0.54	0.07	<0.0001	2.13	0.13	<0.0001
554	0.04	0.10	0.71	0.69	0.08	<0.0001	0.50	0.15	<0.0001
604	0.50	0.08	<0.0001	0.62	0.07	<0.0001	3.10	0.12	<0.0001
616	-0.07	0.09	0.42	0.07	0.07	0.30	2.78	0.13	<0.0001
620	1.29	0.09	<0.0001	1.50	0.07	<0.0001	2.69	0.13	<0.0001
634	0.70	0.08	<0.0001	1.05	0.06	<0.0001	4.62	0.12	<0.0001
643	-0.53	0.09	<0.0001	0.02	0.07	0.77	2.98	0.13	<0.0001
702	1.53	0.08	<0.0001	1.18	0.07	<0.0001	2.04	0.12	<0.0001
703	-1.00	0.09	<0.0001	-0.32	0.07	<0.0001	1.89	0.13	<0.0001

756	-0.03	0.09	0.71	-1.16	0.08	<0.0001	0.34	0.14	0.01
784	0.91	0.07	<0.0001	1.15	0.06	<0.0001	4.77	0.11	<0.0001
788	1.45	0.11	<0.0001	1.45	0.09	<0.0001	6.85	0.16	<0.0001
826	0.04	0.08	0.57	0.73	0.06	<0.0001	0.79	0.11	<0.0001
840	0.15	0.09	0.08	0.30	0.07	<0.0001	0.61	0.13	<0.0001
858	-0.26	0.10	0.01	0.43	0.08	<0.0001	2.06	0.15	<0.0001
970	1.43	0.07	<0.0001	1.34	0.06	<0.0001	3.85	0.11	<0.0001

5. Interpretation of results

Firstly, we found that adolescents' motivation in science study consists of three components:

- Interest
- perceived importance in future career
- daily involvement.

Boys have higher scores than girls. This is not surprising.
Comparison across 40 countries: Tunisia ranks first in all three components. United States ranks 19, 18, and 26, respectively.
Overall, there's a trend that adolescents with higher parental education are more motivated in science study. Previous studies have found that parents' education predicts children's educational outcomes. One possible explanation is that parents' education background influences the ways in which they interact with their children around learning activities both in the home and at school. [4]
Results from linear regression analysis showed that if the teaching methods encourage critical, independent thinking and creativity, then adolescents are more likely to show motivation in science study.

V. Conclusion

This study provides a comprehensive cross-national analysis of adolescents' motivation in science education and the pedagogical factors that may influence it. Drawing on data from over 100,000 students across 40 countries in the 2022Programme for International Student Assessment (PISA), the findings underscore the complex and multifaceted nature of student motivation. Three distinct components of motivation were identified—interest in science, perceived importance for future careers, and daily involvement in science-related activities—each of which contributes uniquely to students' engagement and learning outcomes.

A key contribution of this study lies in its empirical demonstration that teaching methods play a critical role in shaping students' motivational profiles. Specifically, pedagogical strategies that foster student autonomy, encourage critical thinking, and allow for creative exploration are positively associated with higher levels of motivation across all three dimensions. Conversely, more traditional or didactic teaching approaches—such as teacher-led explanation without contextual application or limited opportunities for student experimentation—were negatively associated with motivation scores. These findings support a growing consensus in the educational literature that student-centered, inquiry-based instruction is more effective in promoting sustained engagement with science.

The observed variation in motivation across gender, parental education levels, and countries also reveals important equity considerations. Male students and those with more highly educated parents consistently reported higher motivation, suggesting that both gender norms and socioeconomic background continue to influence science learning experiences. The cross-national comparisons further highlight that systemic and cultural factors significantly affect how science education is delivered and received. Notably, countries such as Tunisia and the United Arab Emirates ranked highest in all motivational components, suggesting that national education policies and curricular frameworks can play a pivotal role in fostering scientific enthusiasm.

From a policy and practice perspective, the results of this study point to the urgent need for education systems worldwide to adopt pedagogical reforms that prioritize engagement, relevance, and student agency. Teacher training programs should emphasize the development of instructional strategies that encourage exploration, dialogue, and real-world application of scientific concepts. Additionally, interventions aimed at reducing gender disparities and supporting students from less advantaged backgrounds are essential for ensuring equitable access to motivationally rich science education.

In sum, enhancing adolescents' motivation in science requires more than curricular content; it demands deliberate attention to how science is taught. By aligning instructional methods with the principles of motivation theory and student engagement, educators and policymakers can contribute meaningfully to cultivating the next generation of scientifically literate and inspired citizens.

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