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EDUCATION AS COMMONS

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Summary

ITALIAN EDUCATIONAL POVERTY IN MATHEMATICS AND SCIENCE SKILLS. THE EFFECTS OF MATERIAL AND IMMATERIAL CULTURAL RESOURCES

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Abstract This study examines the determinants of mathematics and science skills among Italian students and adults, utilizing data from the Pisa 2018 survey. It explores the significant influence of parental education, cultural possessions, and home educational resources on academic performance. The findings highlight that students with highly educated parents and enriched home environments perform better in mathematics and science. Additionally, the study discusses the impact of gender and migration background on academic outcomes. The results underscore the importance of addressing educational disparities through targeted policies and interventions to enhance the overall competencies of the Italian population in these critical subjects.

INTRODUCTION

In contemporary societies, fundamental competencies in mathematics and science play a pivotal role in shaping both individual opportunities and societal progress. These competencies are crucial across various aspects of social life, influencing personal well-being, labour market access, and civic engagement (Restivo, 1988; Grootenboer et al., 2015; Pouliakas & Russo, 2015). Their importance extends beyond mere academic achievement, as they underpin critical thinking, problem-solving abilities, and the capacity to engage with ongoing scientific and technological requirements (Reyna, Brainerd, 2007; Stocker & Wagner, 2007). Mathematical and scientific literacy are foundational for navigating the complexities of modern life. Mathematical skills encompass a wide range of abilities, including logical reasoning, quantitative analysis, and the application of mathematical concepts to real-world situations (Lakoff & Núñez, 2000). These skills are essential for effective decision-making, from personal finance management to professional problem-solving. Similarly, scientific literacy involves understanding fundamental scientific principles, applying

scientific methods to analyse problems, and drawing evidence-based conclusions. In an era of rapid technological change, scientific literacy is critical for making informed decisions about the impact of scientific developments on society and the environment (Holbrook & Rannikmae, 2009).

Research consistently highlights the long-term benefits of developing mathematical and scientific skills early in education. These early skills are strong predictors of future academic success, career choices in STEM fields, and lifelong engagement with scientific and technological advancements (Chiu et al., 2007). Students who excel in mathematics and science during their formative years are more likely to pursue and succeed in higher education and STEM careers (Wang & Degol, 2013; Maass et al., 2019).

The distribution of these skills is not uniform across populations. In Italy, despite a gradual increase in STEM enrolments, the growth remains slow, particularly among young women. In 2022 the number of STEM graduates per 1,000 of population aged 20-29 in Italy (18,5) lagged behind other European countries like France (35,3), Spain (23.0%), and Germany (24,3) (Eurostat, 2024). Disaggregated by gender, this indicator shows that Italian women choose STEM disciplines significantly less often than men: for every 1,000 women aged 20-29, 14.3 graduate in STEM disciplines, compared to 21.0 men per 1,000 (Istat, 2024). These gaps have roots in early educational experiences, where weak mathematical and scientific competencies reduce self-efficacy and aspirations in scientific fields, reinforcing social and gender stereotypes (De Vita, Giancola, 2017; Salmieri, 2022).

Basic skills in mathematics and science are essential for adults too, serving as fundamental tools in various aspects of daily life, including work, information processing, and civic participation. These skills enable individuals to navigate a complex, technology-driven world with confidence and efficiency. In the workplace, mathematical and scientific literacy is increasingly critical (Oecd, 2016). Many professions, from healthcare to engineering, require a foundational understanding of these subjects. For instance, in the healthcare industry, professionals must interpret data, understand medical statistics, and utilize technology-based diagnostic tools (Reyna & Brainerd, 2007; Chen & Feeley, 2014). In engineering, problem-solving and quantitative analysis are essential for designing and implementing projects. Moreover, even non-technical roles often require basic mathematical skills for tasks such as budgeting, financial analysis, and logistical planning (Jonas, 2018).

Beyond professional contexts, mathematical and scientific literacy is vital for informed decision-making. Adults frequently encounter statistical information in news reports, health advisories, financial products, media coverages. The ability to critically evaluate this data prevents misinformation and enables sound personal and practical decisions. The lack of mathematical and scientific skills presents a significant challenge in understanding globally relevant phenomena that impact daily life, as evidenced during the Covid-19 pandemic (Heyd-Metzuyanim et al., 2021). Civic engagement also benefits significantly from these skills. A scientifically literate population is better equipped to engage in public debates on issues such as climate change, healthcare policy, and technological advancements. This engagement fosters a more informed electorate that can contribute to democratic processes with a clearer understanding of the scientific and mathematical underpinnings of policy decisions. Furthermore, the rapid advancement of technology in everyday life necessitates continuous learning and adaptation. Basic mathematical and scientific knowledge facilitates the use of new technologies, from smartphones to home automation systems or AI digital applications enhancing daily convenience and quality of life. Sociologically, the distribution of these skills can influence social mobility and equality. Access to quality information in mathematics and science is often linked to socioeconomic status, creating disparities in opportunities and outcomes.

Addressing these disparities is a critical challenge for educational policy. This paper explores factors contributing to these disparities, focusing on the Italian context, and examines conditions of poor mathematical and scientific literacy among diverse student and adult populations. By investigating the interplay of educational experiences, cultural factors, and policy frameworks, we aim to contribute to the debate on educational equity and effectiveness, essential for fostering small and large-scale policies addressed both to students and adults.

MATHEMATICS AND SCIENCE SKILLS OF ITALIAN STUDENTS

In the realm of mathematics and science education, national and international assessment surveys display a substantial stability or only slight variations over time in the performance of Italian students. According to data from the Trends in International Mathematics and Science Study (TIMSS), Italian primary school students (4th grade) consistently achieve scores slightly above average in mathematics and science literacy (Giancola & Salmieri, 2022). This relative consistency reflects the historically

moderate learning outcomes of the Italian educational system, particularly in primary education, which has experienced few significant changes over the years. The primary school system in Italy is characterized by a lack of curricular differentiation, a relatively standardized curriculum, and limited opportunities for families to exploit social differentiation strategies when enrolling children at local schools (Grimaldi & Serpieri, 2012).

However, as students progress through the education cycle, a decline in the quality, equity, and effectiveness of mathematical and scientific skills becomes evident. Students in the third year of lower secondary school (8th grade) consistently perform below the TIMSS average, with a slight peak only in 2011. Despite having average levels slightly lower than other Oecd countries, the influence of family background on Italian students' learning outcomes get plain as early as primary school. Students with better material resources (e.g., numerous books at home) and cognitive resources (parents' educational and cultural awareness) outperform those from disadvantaged or lower social classes. These gaps tend to widen by the 8th grade, indicating that inequalities in mathematics and science skills stratify and expand over time, consistent with the systematic distortion effect produced by the progressive accumulation of learning inequalities (Jackson, 2015; Giancola & Salmieri, 2022). The correlation between socioeconomic inequalities and disparities in school performance in mathematics and science intensifies during the transition from lower to upper secondary school, coinciding with the end of the common curriculum-based education cycle (Hanushek & Wößmann, 2006). At this point, tracking becomes a significant factor in stratification and differentiation, including the development of mathematical and scientific basic skills (Schiller et al., 2010).

To analyse the Italian students' skills in mathematics and science, we utilized data from the Pisa 2018 survey, which assesses 15-year-old students' abilities in reading, mathematics, and science. The survey provides a comprehensive overview of students' skills and highlights the role of multiple socio-economic and cultural factors in shaping educational outcomes. Similar to reading competencies, the average scores of 15-year-old Italians in mathematics and science consistently fall below the Oecd and Eu country averages. However, two contradictory trends emerge: in mathematics, Italian students show positive performance over time, particularly when comparing the two Pisa rounds where mathematics was a primary assessment topic (2003 and 2012). Conversely, in science, the trend forms a "bump" shape, with more

negative results in recent years but a slight positive trend during the rounds where scientific skills were the primary focus (2006 and 2015).

A persistent issue in Italy is the high proportion of "weak" students, or low achievers, who score below "level 2" on the mathematics and science competency scales. In mathematics, the proportion of low achievers slightly decreases with each survey but remains significant: in 2018, over one-third of 15-year-old Italian students were low achievers in mathematics. For scientific minimal literacy, the proportion of low achievers increases over time, rising from 32.8% in 2006 to 38.4% in 2015, then stabilizing at 37.3% in 2018. This trend appears linked to the low mathematical abilities of the entire Italian adult population (Oecd, 2013), limited awareness of general issues related to natural and ecological-environmental phenomena, and poor basic knowledge in physics, geography, and astronomy.

Basic mathematical and scientific abilities developed during adolescence are influenced by ascribed variables related to students' social origins, with parental education level playing a decisive role. To corroborate the effect of intergenerational transmission of educational poverty in mathematics and science, we conducted two sets of multiple linear regression models using Oecd Pisa 2018 data. The first model estimated the effect of basic ascribed variables (Model 1) such as parental education, student gender, and native or migrant background, on the level of competencies achieved in mathematics and science at age 15. The second model (Model 2) measured the effects of variables related to "objectified cultural capital" (Bourdieu & Wacquant, 2013) on mathematical and scientific skills levels. The third model (mixing 1 and 2) combines the effects of Model 1 and 2 to provide a comprehensive analysis of these influences.

	Reading	*Mathematics*	*Science*
Reading	1	,828*	,885*
Mathematics	,828*	1	,890*
Science	,885*	,890*	1

Table 1. Pearson correlation for Italian students' results in reading, mathematics, and science. Pisa 2018. Source: authors' elaboration based on Pisa 2018 database.

* The correlation is significant at the 0.01 level (two-tailed).

Notably, the explanatory structure resulting from the regression models (Tables 2 and 3) is almost identical for mathematics and science skills. The literature suggests a fairly high correlation between the two measures (Rylands, Coady, 2009), and for

Italian students evaluated in the Oecd Pisa 2018 survey, this correlation is significantly robust, as evidenced by the β values reported in Table 1. Generally, students who demonstrate high levels in one competency domain (mathematics or science) possess high knowledge and skills in the other. Correlations between reading comprehension competency levels and mathematics and science competency levels are slightly less pronounced but still sufficiently robust to outline a framework where the three domains reinforce each other, with reading and text comprehension skills being foundational to the other two domains (Yore et al., 2007).

The results from the first multiple linear regression model, which examines the effects of ascribed variables, indicate that parental education significantly influences student outcomes in mathematics and science skills. Specifically, having at least one parent with a university degree results in an increase of 20 to 24 points in student scores compared to those without such a background (see Table 2).

	Model 1			Model 2			Model mixing 1 e 2		
	B	std. error	β	B	std. error	β	B	std. error	β
(Costant)	*498,9*	*1,66*		*443,2*	*1,97*		*452,1*	*2,30*	
Parents with medium education level	20,2	2,03	0,11				10,7	1,93	0,06
Parents with high education level	24,5	1,93	0,14				6,8	1,91	0,04
Female	-16,4	1,61	-0,10				-21,4	1,53	-0,13
Second generation	-23,8	3,75	-0,06				-6,9	3,58	-0,02
First generation	-40,7	4,19	-0,09				-16,9	4,02	-0,04
Average CULTPOSS				6,2	1,95	0,04	6,5	1,93	0,04
High CULTPOSS				12,9	2,22	0,07	12,5	2,21	0,07
Average HEDRES				20,5	2,13	0,11	18,7	2,11	0,10
High HEDRES				22,6	2,00	0,14	21,6	1,99	0,13
26-100 books at home				34,9	2,15	0,19	33,5	2,14	0,19
101-200 books at home				53,2	2,45	0,26	51,6	2,47	0,25
> 200 books at home				61,0	2,45	0,32	59,4	2,50	0,31
	R^2=4,1%			R^2=12,6%			R^2=14,6%		

Table 2. Determinants of Italian students' performance in mathematics. Pisa 2018. Source: authors' elaboration based on Pisa 2018 database.

The results obtained with Model 2, shown in Table 2 for mathematics and Table 3 for science, highlight the significant impact of the variable measured by the CULTPOSS indicator (Cultural Possessions at Home). This indicator relates to the presence of high culture items, educational resources, and books in students' family

environment. A high presence of cultural objects in the home is an indicator of the positive effects that a culturally dynamic and advanced domestic environment has on learning outcomes in mathematics and science. Even more significant is the effect of the presence of educational resources and tools, measured by the HEDRES (Home Educational Resources) indicator. These include having a dedicated study space, a desk, access to educational software and technical books, a personal computer, etc. However, the most determining factor is the presence of numerous books at home. This availability not only directly influences the development of mathematical and scientific skills but also serves as a very accurate proxy for the cultural stimulation provided by the family environment and social background. This, in turn, benefits students' motivation, abilities, curiosity, and depth of study. Students with access to a rich cultural environment, characterized by a high number of books and educational tools, demonstrate better performance in mathematics and science. This finding emphasizes the role of early socialization in culturally rich environments in fostering academic success. This influence has also been tested using other data sources, yielding similar and robust results (Tan, 2020).

The high availability of "objectified cultural capital" indicates a space and wealth of informal learning that likely influences formal learning and academic results. This type of capital acts as a stimulus and has a socializing effect on academic subjects, including mathematics and science. The widespread presence of "objectified cultural capital" is linked to parents' higher education and their economic, ethnic, and migratory background. Cultural capital is a complex set of factors associated in various ways with parents' education, directly and indirectly affecting students' outcomes.

These findings indicate that, to counter educational poverty, a deep socialization to cultural tools and objects (books, dictionaries, manuals, reference texts, etc.) can effectively bridge the gap between disadvantaged life contexts and school environments. These school environments are historically and pedagogically characterized by a high level of curricular formalization, codification of knowledge, and conceptualization. As students progress in their educational careers, math and science subjects become more abstract and distant from their immediate life experiences. In this process of abstraction, early socialization through a culturally rich environment appears crucial in fostering positive outcomes in standardized math and science tests. Results in these domains will impact tertiary education aspirations, choice of study

paths, and career imaginations in STEM and technical-scientific fields (Laugksch, 2000).

	Model 1			Model 2			Model mixing 1 e 2		
	B	std. error	β	B	std. error	β	B	std. error	β
(Costant)	*475,8*	*1,63*		*429,4*	*1,95*		*435,6*	*2,28*	
Parents with medium education level	19,2	1,90	0,11				2,7	1,90	0,02
Parents with high education level	20,4	1,99	0,13				10,8	1,92	0,06
Female	-4,1	1,59	-0,03				-8,6	1,52	-0,05
Second generation	-32,9	3,69	-0,09				-17,7	3,55	-0,05
First generation	-46,2	4,12	-0,11				-24,9	3,99	-0,06
Average CULTPOSS				5,9	1,93	0,03	5,8	1,92	0,04
High CULTPOSS				11,8	2,19	0,07	11,4	2,20	0,07
Average HEDRES				17,6	2,10	0,10	15,6	2,10	0,09
High HEDRES				17,5	1,98	0,11	16,1	1,98	0,10
26-100 books at home				32,5	2,12	0,18	30,0	2,13	0,17
101-200 books at home				46,3	2,42	0,23	43,2	2,45	0,21
> 200 books at home				60,3	2,42	0,32	57,6	2,49	0,31
	R2=3,3%			R2=11,2%			R2=13,5%		

Table 3. Determinants of Italian students' performance in science. Pisa 2018. Source: authors' elaboration based on Pisa 2018 database.

Gender-related findings align with established literature, proving that female students generally score slightly lower in mathematics and science compared to male students (Contini et al., 2017; Rinaldi & Salmieri, 2020). The most pronounced disadvantage, however, is associated with students' migratory backgrounds: first-generation immigrant students are significantly more disadvantaged than their second-generation peers, as previously highlighted by Azzolini and Barone (2013). The interplay of these three factors—parental education, gender, and native or immigrant background—illustrates the latent but significant impact of social inertia on student performance in mathematics and science skills.

MATHEMATICS AND SCIENCE SKILLS OF ITALIAN ADULTS

While the TIMSS and Pisa surveys reveal how educational inequalities develop through various stages of schooling, highlighting the role of cultural capital deficits (and thus relative poverty) in learning, the Oecd-PIAAC survey allows for dynamic

analyses of educational poverty in adults, specifically in mathematical skills, but not in scientific ones. The PIAAC measure, numeracy, refers to the ability to use numerical and mathematical concepts in daily life. This type of assessment mirrors the application of skills and knowledge in real-life contexts, similar to the Pisa survey which is targeted instead at 15-year-old students.

The overall literacy results for the Italian adult population are concerning: the average score is 250, below the international average of 273. In numeracy, or mathematical skills, the disparity is similar: Italian adults score an average of 247, compared to the international average of 269 (Paccagnella, 2016).

When analysing the adult population, it is important to consider cohort composition effects absent in the student population, which is uniformly around 15 years old. Mathematical skills are particularly low among older adults aged 55-65, with a progressive improvement seen in younger cohorts. This trend is attributed to both the obsolescence of skills over time and the higher average education levels of younger generations. Consequently, younger age groups demonstrate better mathematical skills. This improvement is attributed to the expansion of educational access in the Seventies and Eighties and inclusive educational policies, such as comprehensive middle schools and the liberalization of university enrolment (Checchi et al., 2013). However, these comparisons should not be too reassuring, as even young Italian adults have lower mathematical skills compared to their peers in other PIAAC countries. Additionally, the educational divide in mathematical skills among older adults has widened over time. In 2012, the gap in numeracy scores among 25–34-year-olds was 57 points. These findings debunk the media myth, supported by some scholars, that today's youth are less competent than previous generations, as displayed in the previous section.

Based on this evidence, similar to the Pisa student evaluations, we can analyse the relationship between familial cultural capital, education levels, and mathematical skills in Italian adults. We developed a set of multiple linear regression models (see Table 4).

	Model 1			Model 2			Model mixing 1 e 2		
	B	std. error	β	B	std. error	β	B	std. error	β
(Costant)	*232,3*	*0,01*		*234,2*	*0,01*		*228,2*	*0,01*	
25-34 years old	7,4	0,02	0,06	20,5	0,02	0,17	7,6	0,02	0,06
35-44 years old	3,9	0,02	0,04	14,1	0,02	0,13	6,1	0,02	0,06
45-54 years old	1,5	0,02	0,01	10,6	0,02	0,09	5,0	0,02	0,04
Female	-12,4	0,01	-0,13	-9,7	0,01	-0,10	-11,6	0,01	-0,12
High School Diploma	33,2	0,02	0,34				29,7	0,02	0,30
Bache-lor's De-gree	50,5	0,02	0,36				41,8	0,02	0,30
At least 1 parent with a High School Diploma				27,3	0,02	0,24	15,9	0,02	0,14
At least 1 parent with a Bache-lor's De-gree				38,9	0,03	0,20	22,6	0,03	0,12
	R^2=20,6%			R^2=12,2%			R^2=23,1%		

Table 4. Determinants of Italian adults' performance in mathematics. PIAAC 2013. Source: authors' elaboration based on PIAAC 2013 database.

In the first Model, we included dummy variables for age groups, with the oldest cohort (55+) as the reference category; gender (female *vs.* male); and education level, with those below high school diploma as the reference category. In the second Model, we retained age and gender but replaced individual education with parental education levels, with those having parents below a high school diploma as the reference category. In the third and final Model (mix of 1 and 2), all variables were included simultaneously to estimate expected numeracy outcomes.

Consistent with descriptive analyses, the first model's regression results display a relative advantage for younger cohorts. However, beyond age effects, gender and respondents' education level have the most significant influence. For Italian adults, mathematical competency levels vary by gender, disadvantaging women. This

difference reflects historical educational disparities between men and women, which have only narrowed in recent decades, with women surpassing men in university graduation rates since the early Nineties. Educational attainment significantly impacts numeracy scores, with a university degree increasing scores by an average of 50 points on the PIAAC scale (range 0-500).

In the second Model, excluding individual education reveals the strong impact of age cohorts and parental education, highlighting the intergenerational reproduction of educational inequalities and mathematical skills. Finally, the third Model's results show that individual education levels absorb the predictive power of parental education. This is because children's education levels are closely correlated with their parents', and thus, intergenerational transmission of educational attainment influences adult numeracy. Nevertheless, family education still has a substantial net effect. The gender gap disadvantaging women persists, reflecting traditional gendered socialization patterns in educational and career choices, which have only recently begun to erode.

CONCLUSIONS

Our analyses revealed stratified and interconnected dynamics. On one hand, Italian adults' poor mathematical skills indicate widespread educational poverty, posing a clear risk of perpetuation across generations. On the other hand, younger generations, with higher average education levels, should reduce the extent of basic educational poverty in the future. Nonetheless, the influence of social origins remains significant, especially in the form of different allocations of material and immaterial culture in extracurricular learning contexts. The gaps in material and immaterial available resources at home highlight the very limited capacity of the Italian education system to counteract the intergenerational transmission of educational poverty.

The direct and indirect impacts of social origins are evident: direct impacts stem from parental cultural capital to children's mathematical and scientific skills, while indirect impacts grow via the mediating role of children's educational attainment. Notably, significant disparities in basic skills are observed among younger cohorts of Italian adults, particularly among those who left the education system before obtaining a diploma. Formal educational poverty, such as failing to achieve a diploma, translates into low, if not poor, mathematical and scientific elementary skills.

Considering that noondays' students and young adults (aged 25-34) will soon or have recently become parents, the risk of new cycles of educational poverty transmission is very high in Italy. This finding underscores the need for continuous efforts to enhance mathematical and science literacy across all age groups. We do not wish to appear apocalyptic or bold, but we believe that Italian policymakers should seriously consider the needs and opportunities to develop educational policies, addressing not only the school system but especially adult education. A clear outline of directions emerges from our analysis:

Early Intervention and Support: Implement targeted interventions in early education to support students from disadvantaged backgrounds. Providing access to high-quality early childhood education and culturally rich environments can help bridge the gap in educational outcomes, especially for the early cognitive embodiment of numeracy.

Gender Equity in STEM: Promote gender equity in STEM education by addressing stereotypes and providing role models and mentorship programs for young girls. Encouraging female participation in STEM fields from an early age is crucial for reducing gender disparities. At the same time, the decreasing share of male students enrolling in universities should not be underestimated, as it contributes to slowing the growth rate of Italians graduating in STEM fields.

Adult Education Programs: Enhance adult education programs to improve numeracy and scientific literacy. Lifelong learning opportunities should be made accessible to all, with a focus on skill development for older adults to combat skill obsolescence. The notion that adult education levels are fixed and that investing in adult generations is not worthwhile is highly dangerous. These generations transmit their educational poverty to their children, regardless of the role of formal education in counteracting this mechanism.

Cultural Capital Enhancement: Increase access to cultural and educational resources for families, particularly in disadvantaged communities. Public libraries, community centres, and digital resources can play a significant role in providing these opportunities.

Policy and Research Integration: Integrate educational policies with ongoing evidence-based research to continuously monitor and address disparities in basic skills.

Evidence-based policymaking is essential for developing effective strategies to enhance mathematical and scientific literacy.

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EDUCATION AS COMMONS

Selected Papers from AIS Education International Mid-Term Conference 2023

This volume stems from papers presented at the mid-term conference of the Education Section of the AIS (Italian Association of Sociology), held in Palermo, Italy, on April 12-14, 2023. Under the theme Education as Commons: Democratic Values, Social Justice, and Inclusion in Education, the conference inspired a call for extended contributions to capture key insights shared there. Reflecting the conference's pluralistic approach, the volume includes sociological and interdisciplinary perspectives, with both theoretical and empirical contributions that employ a range of methods—from qualitative to quantitative and mixed—and languages.

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