INVALSI

MESE 1

Measurement in STEM Education (MESE1)

Naples, 30-31 January, 1 February

DISP Dipartimento di Scienze Politiche Università degli studi di Napoli Federico II

Università degli Studi di Napoli Federico II - Dipartimento di Fisica "Ettore Pancini"

Mathematics achievement at the end of upper secondary school during COVID-19 pandemic: insights from the INVALSI national assessment

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OUTLINE

1. “Measuring” mathematics achievement at the end of secondary upper school: the INVALSI computer based assessment
2. A cohort analysis on INVALSI data: longitudinal predictors of mathematics achievement in the COVID-19 era.

Latent variable (construct)

- conceptually defined by the **INVALSI Theoretical Framework** (INVALSI, 2018), in line with the **National Guidelines**, as well as with the main results of **research findings in mathematics education**, and is characterized by
  - ✓ "vertical" continuity (across school grades)
  - ✓ "transversal" continuity (common knowledge and competences across school tracks)
- operationalized through a **Rasch-model-based item bank, administered through computer-based test**.

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The INVALSI item bank for Grade 13

❖ **Content Domain**:
- Numbers
- Space and Figures
- Data and Forecasts
- Relationships and Functions

“vertical” continuity

❖ **Cognitive process**:
- Knowing
- Problem Solving
- Arguing

“transversal” continuity

The INVALSI item bank for Grade 13

- **maintenance (M)** items are about fundamental content knowledge and competences, in continuity with the goals of the lower secondary school and the first two years of the upper secondary school. For all school tracks.

“vertical” continuity

- **Recontextualization items** (R): the mathematical situations are similar to those of grade 8 or 10 (for reference objects, contexts, etc.), but require the acquisition of new tools and new mathematical contents learned during the subsequent school years. For all school tracks;

“transversal” continuity

- Items for Technical Institute (T) and/or Scientific Lyceum (S) (e.g. mathematical analysis).

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An Item Bank is a large collection of test items systematically classified and stored with their associated information (metadata).

In a Rasch item bank, items are placed onto a common underlying linear scale, so that different subsets of these items produce interchangeable measures (Wolfe, 2000).

Rasch item bank

- Designing multiple test forms - Test security/flexibility
- Describing proficiency levels
- Improving measure validity
- Measuring trends across administration cycles (and the linking error)

Provide Individual feedback

Improve School System evaluation

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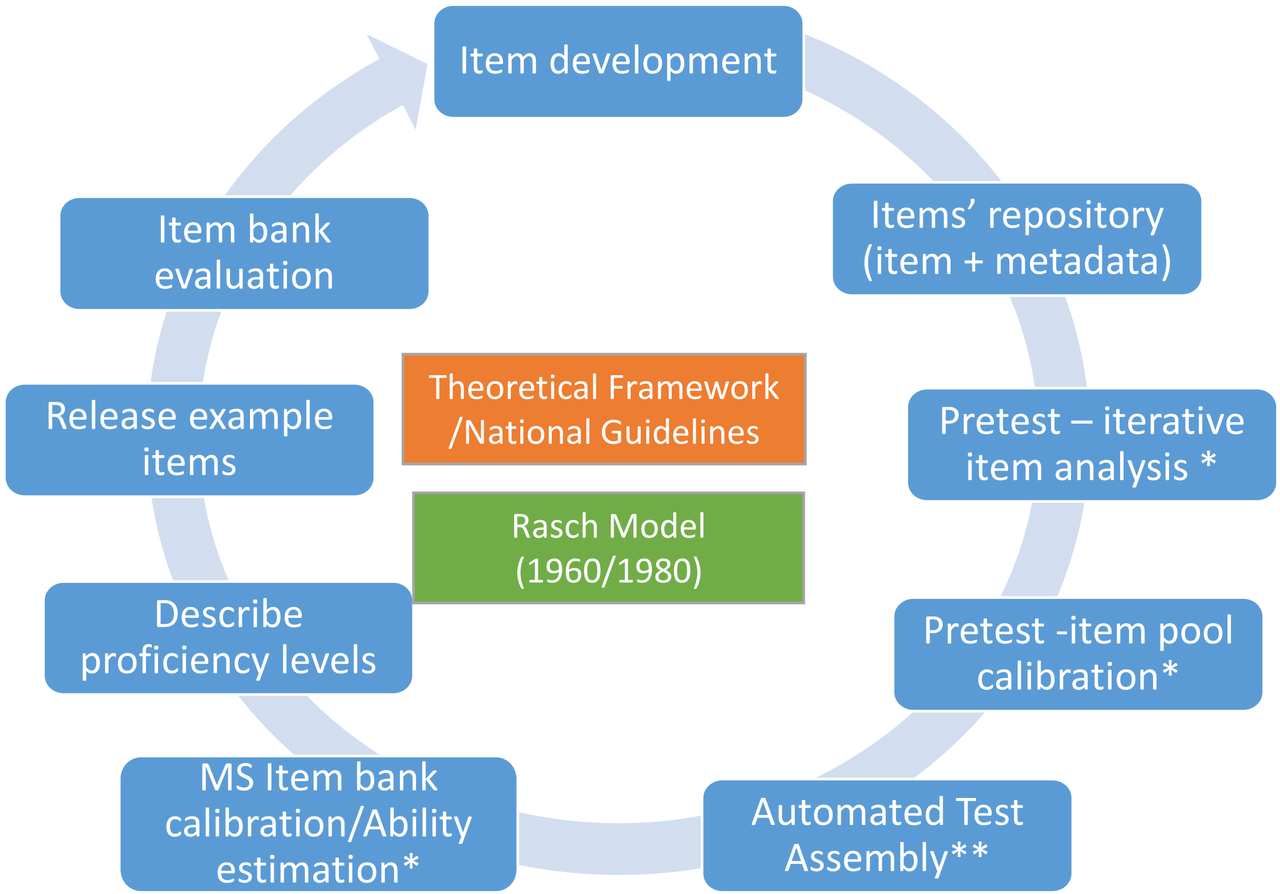
INVALSI ITEM BANK CYCLE



*AcerConquest (Wu, Adams, Wilson & Haldane, 2007)

**ATA software (Verschoor, 2007)

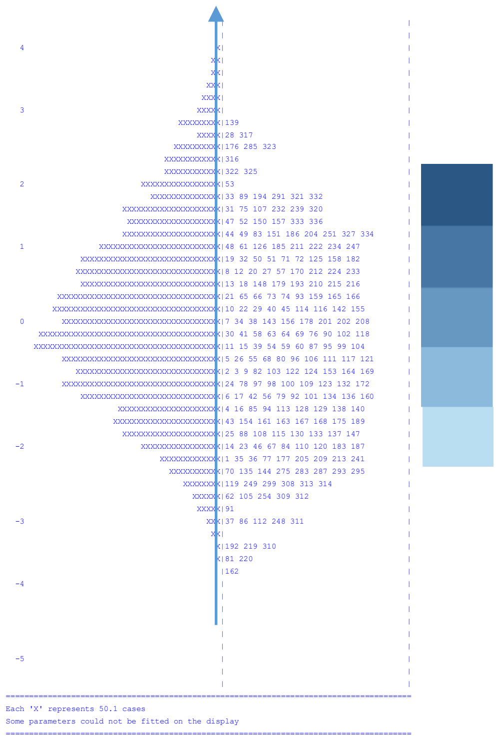
The mathematics proficiency scale – G13

Students' locations along the latent variable continuum are described by:

- ✓ **numerical scores**, which quantifies «how much» of the measured latent variable is present.
- ✓ **5 levels** describing the skills and proficiencies of students who attained scores that are within that particular segment of the scale. A described proficiency level **"puts into words what the numerical score means"** (Turner, 2014)

Person ability estimates

Item difficulty estimates



Item-person map

The mathematics proficiency scale – G13

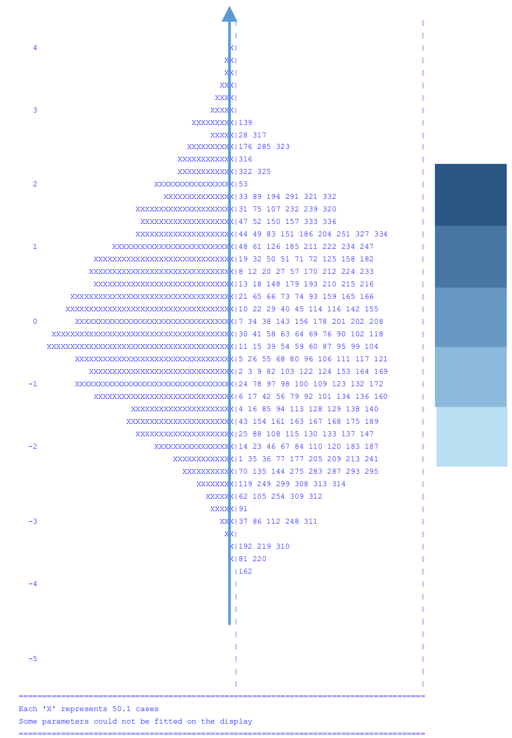
✓ allows to directly compare different cycles of administration (e.g. G13 COVID-COHORT vs G13 pre-COVID-COHORT), taking into account the linking error;

✓ Is not (**yet**) on the same metric of the INVALSI-mathematics scales of grades 8 and 10.

✓ does not (**yet**) allow to measure students' progresses across grades by comparing students locations on one common scale.

Person ability estimates

Item difficulty estimates

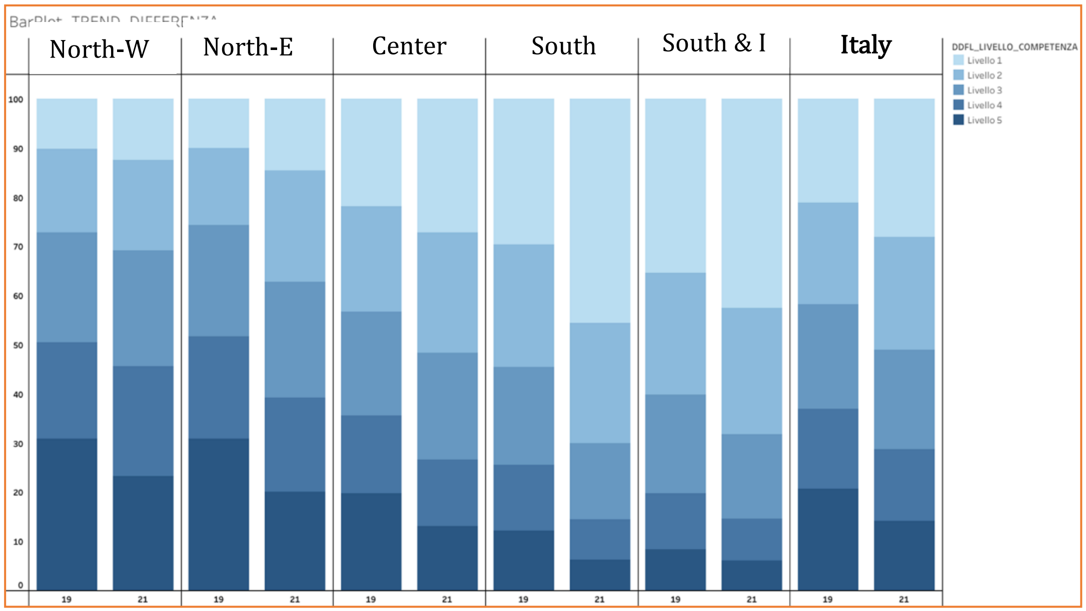


Item-person map

Subject	Grade	Overall Gap $_{2021\text{-}2019}$ (Unit:SD)
Italian language (Reading)	2	0.12 *
Mathematics	2	-0.06
Italian language (Reading)	5	0.12 *
Mathematics	5	-0.06
English (Listening)	5	0.01
English (Reading)	5	0.03
Italian language (Reading)	8	-0.07 *
Mathematics	8	-0.18 *
English (Listening)	8	0.00
English (Reading)	8	0.00
Italian language (Reading)	13	-0.24 *
Mathematics	**13**	**-0.23** *
English (Listening)	13	0.05
English (Reading)	13	0.06

* p<.05 taking into account the Linking Error

Source: authors' elaboration with the INVALSI data



Source: *INVALSI (2021)* https://public.tableau.com/app/profile/invalsi/viz/RAPPORTO2020-2021_16261728450410/INIZIO

Lowest proficiency level → **Highest proficiency level**

G13-mathematics proficiency scale*

* a proficiency scale describes the extent to which the learner possesses the skills, knowledge and understanding that comprise the area (Turner, 2014)

AIM

Exploring **individual and contextual predictors** of students' **mathematics achievement during the COVID-19 pandemic** (Grade 13, s.y. 2020-2021), taking into account their pre-pandemic learning levels (Grade 10, s.y. 2017-2018).

Predictors at individual and higher levels will be considered, such as **students' sociodemographic characteristics, learning environments characteristics, and an estimate of the duration of school closures** in the s.y. 2020-2021.

The predictive role of students' **educational aspirations** and **interest in mathematics** are also considered in the study. We hypothesized that these constructs are consistent predictors of academic resilience across the challenging COVID-19 Pandemic period.

Our contribution:

- explore the joint distribution of students' mathematics levels on the G10 maths proficiency scale and the G13 maths proficiency scale [1];
- investigate predictors of students relative progresses in mathematics during pandemic through a multilevel approach [2].

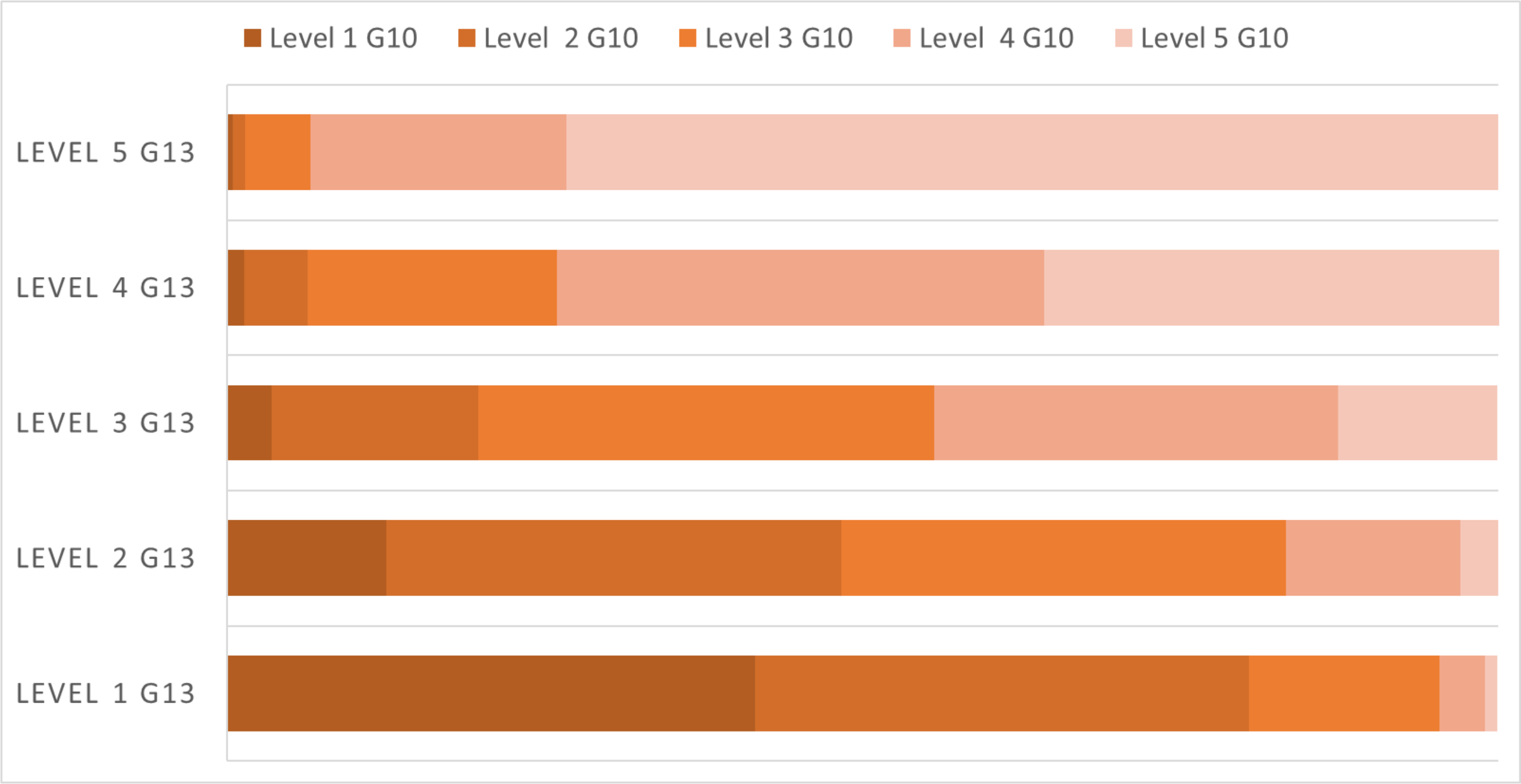
	s.y. 2017-2018 (T1)	s.y. 2018-2019	s.y. 2019-2020	s.y. 2020-2021 (T2)
Cohort	**Grade 10**	Grade 11	Grade 12	**Grade 13**

- **Data:**

[1] INVALSI population data (G10+G13+questionnaire): Cases N=406,494 (missing=17.8%)

[2] A random sample of schools (n=718) from the INVALSI database (classes = 2,988; students = 41,388)

Conditional distribution (%) of G10-proficiency scale within the G13-proficiency levels – Pandemic Cohort

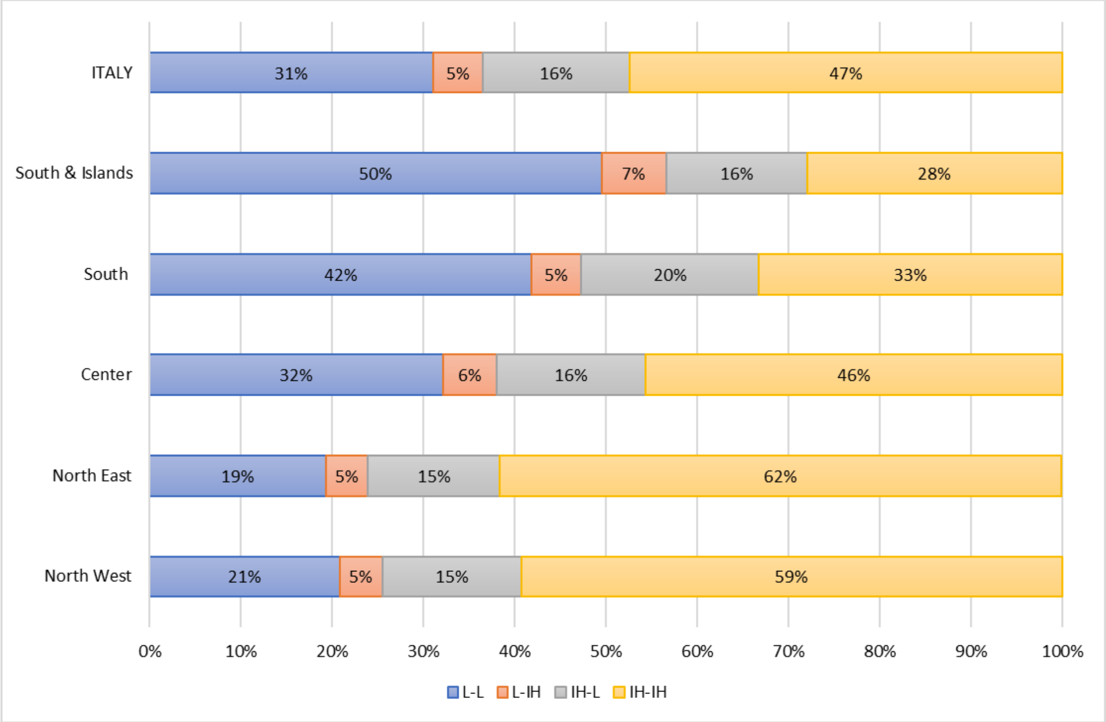


Level 1 – Grade 13

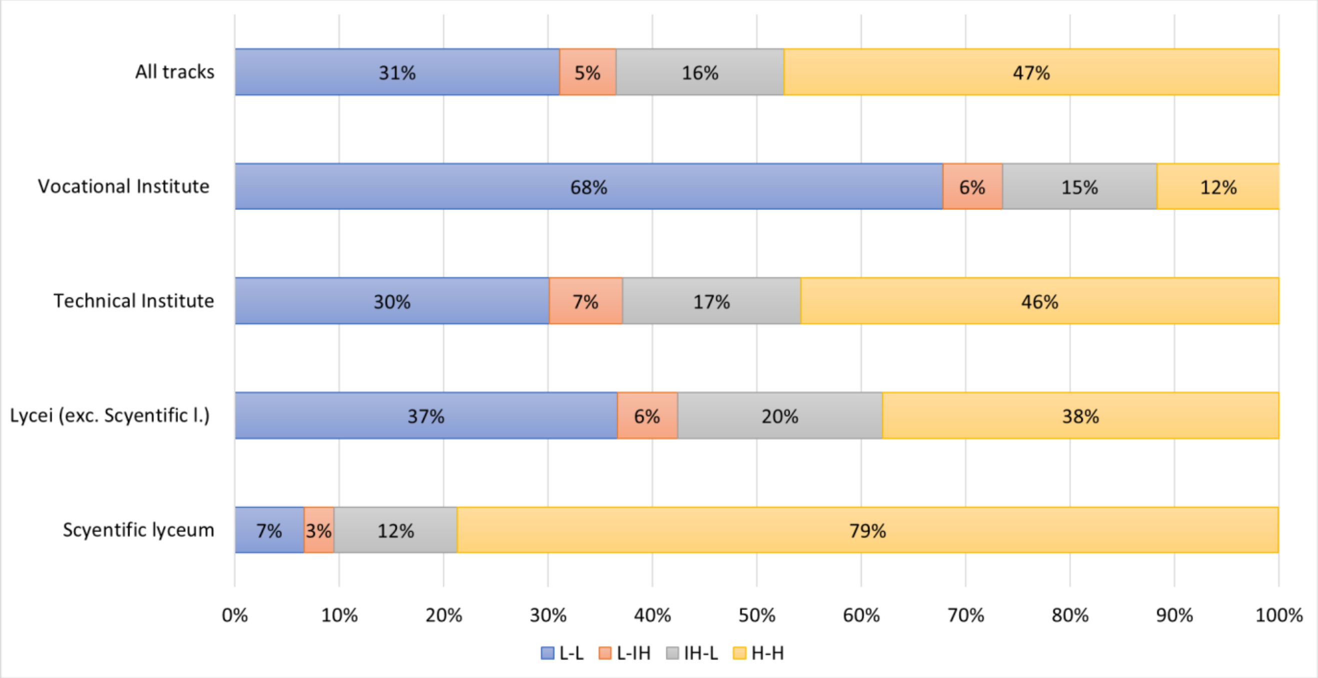
The student can use **basic content knowledge and procedures mainly acquired in lower secondary school and, partly, at the end of the first two years of upper secondary school**. Can answer simple questions using easily identifiable information. Can solve problems concerning familiar contexts that require simple procedures.

Level 2 – Grade 13

The **student knows the basic mathematical concepts as outlined in the national guidelines in the first two years of upper secondary school.** Can answer questions that require simple processing of available data (e.g., comparing various kinds of graphs). Can solve problems for which it is necessary to extrapolate data from the text and use mathematical knowledge acquired in previous grades (i.e., lower secondary school and the first two years of upper secondary school).



Group	Level Grade 10	Level Grade 13
L-L	Low (1-2)	Low (1-2)
L-IH	Low (1-2)	Intermediate to High (3-5)
IH-L	Intermediate to High (3-5)	Low (1-2)
IH-IH	Intermediate to High (3-5)	Intermediate to High (3-5)



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IH-IH	Intermediate to High (3-5)	Intermediate to High (3-5)

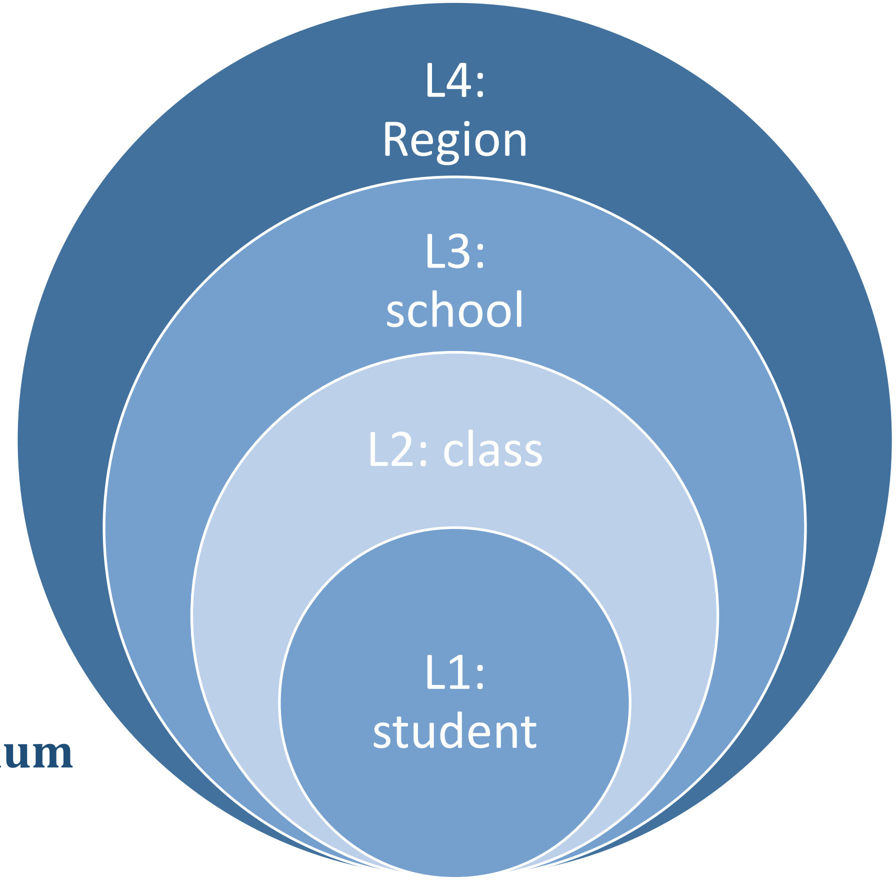
Multilevel analyses.

Outcome:

G13-mathematics ability estimate

Level 1:

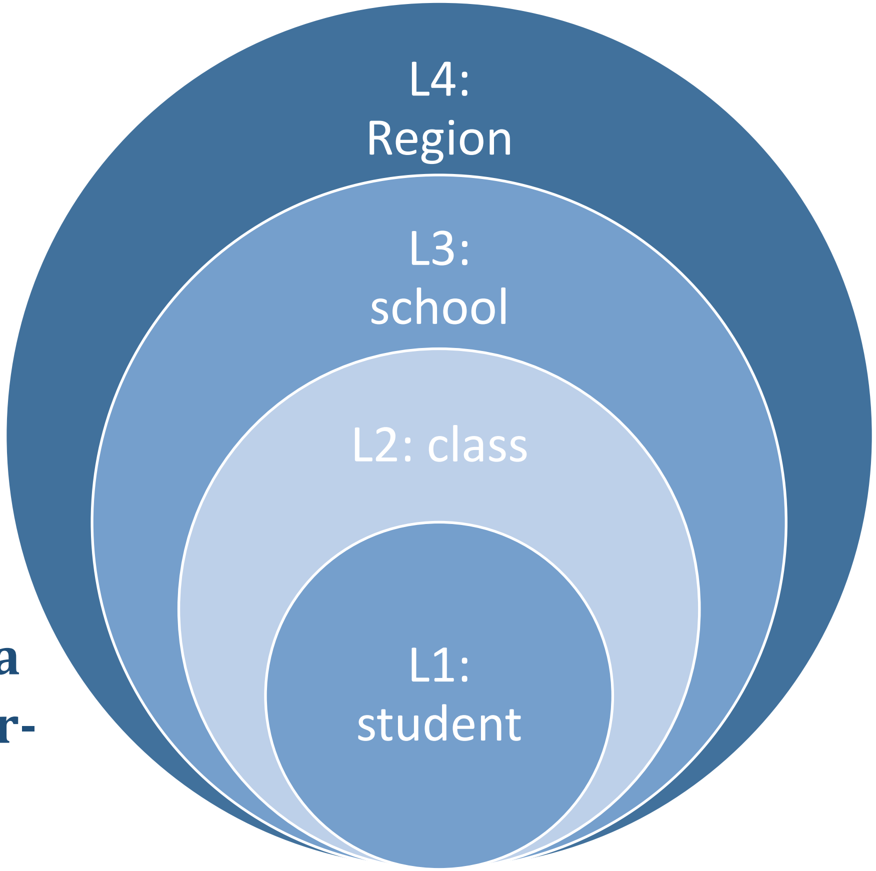
- **G10-mathematics ability estimate;**
- **sociodemographic characteristics;**
- **interest in mathematics;**
- **educational aspirations (0= at maximum high-school diploma; 1= higher).**



Multilevel analyses.

Level 2:

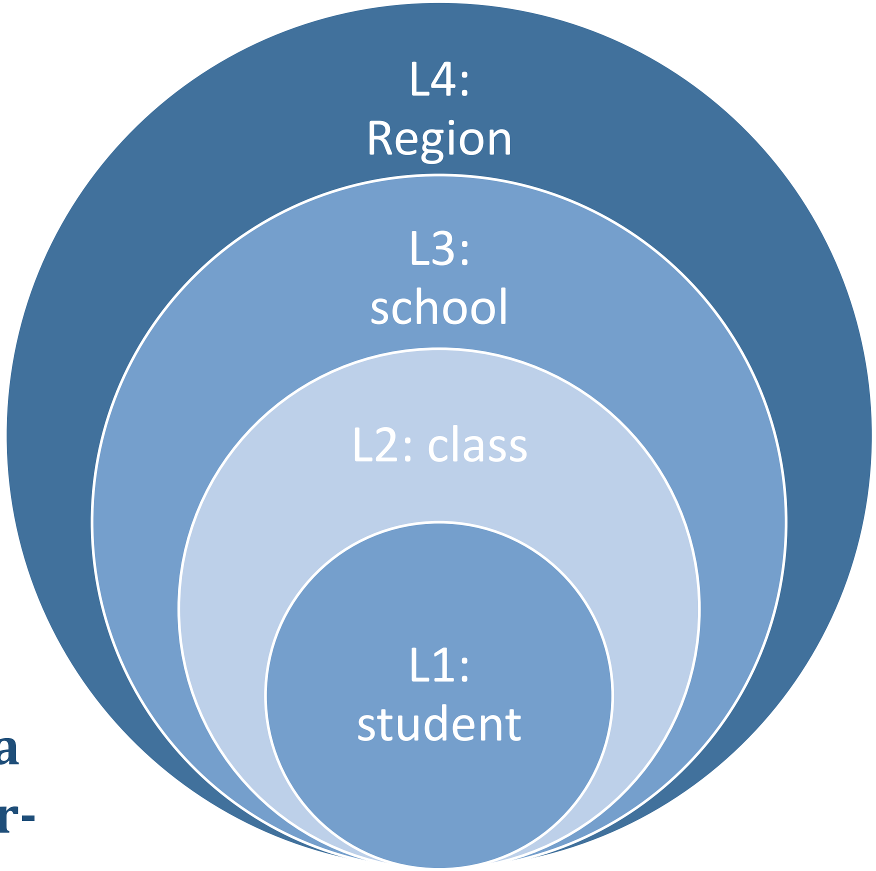
- **G10-class average mathematics ability estimate;**
- **class-composition based on sociodemographic characteristics;**
- **class average interest in mathematics;**
- **prop. of stud.s aspiring to achieve a higher attainment level than upper-secondary school diploma.**



Multilevel analyses.

Level 3:

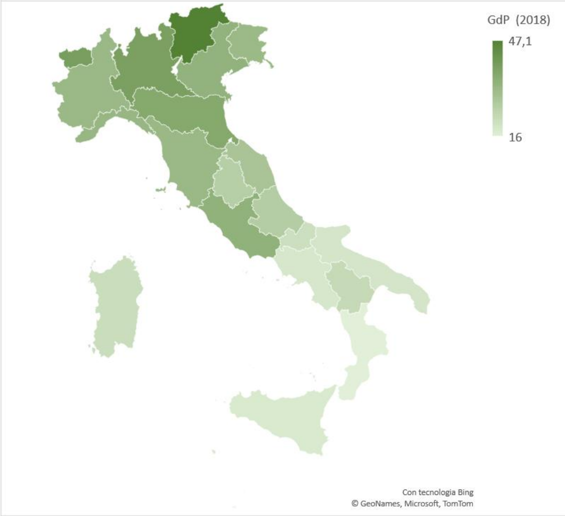
- **school tracks;**
- **G10-school average mathematics ability estimate;**
- **school-composition based on sociodemographic characteristics;**
- **school average interest in mathematics;**
- **prop. of stud.s aspiring to achieve a higher attainment level than upper-secondary school diploma.**



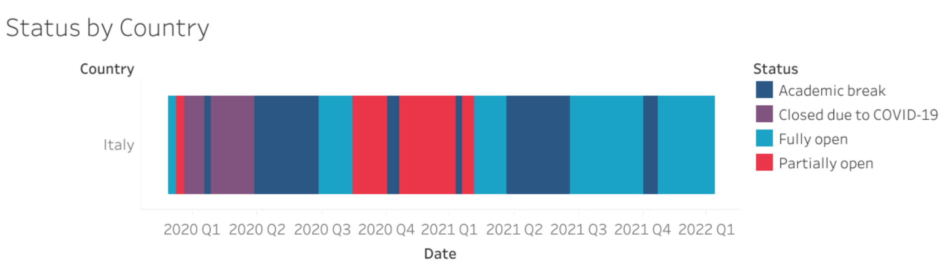
Multilevel analyses.

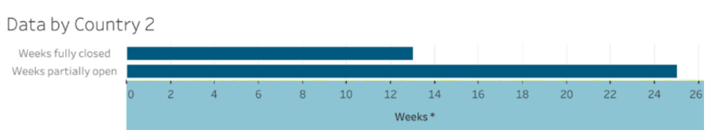
Level 4: Italian Regions

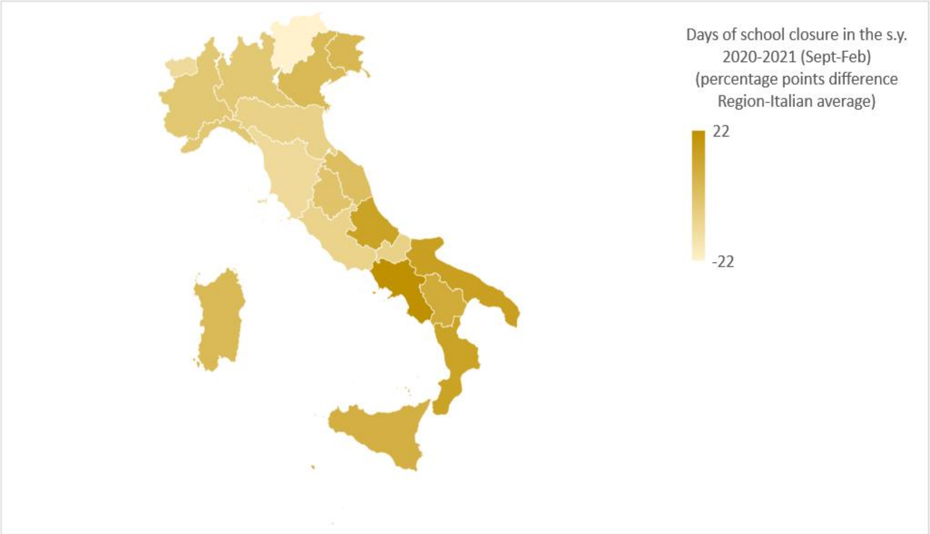
- ✓ G10-region average mathematics ability estimate;
- ✓ Days of school closure in the school year 2020-21 (%);
- ✓ Gross Domestic Product (GDP) per capita-2018 (source: Italian National Istitute of Statistics, ISTAT);
- ✓ % of NEET (young people neither in employment nor in education and training, source: ISTAT).



School closures caused by COVID-19 in Italy







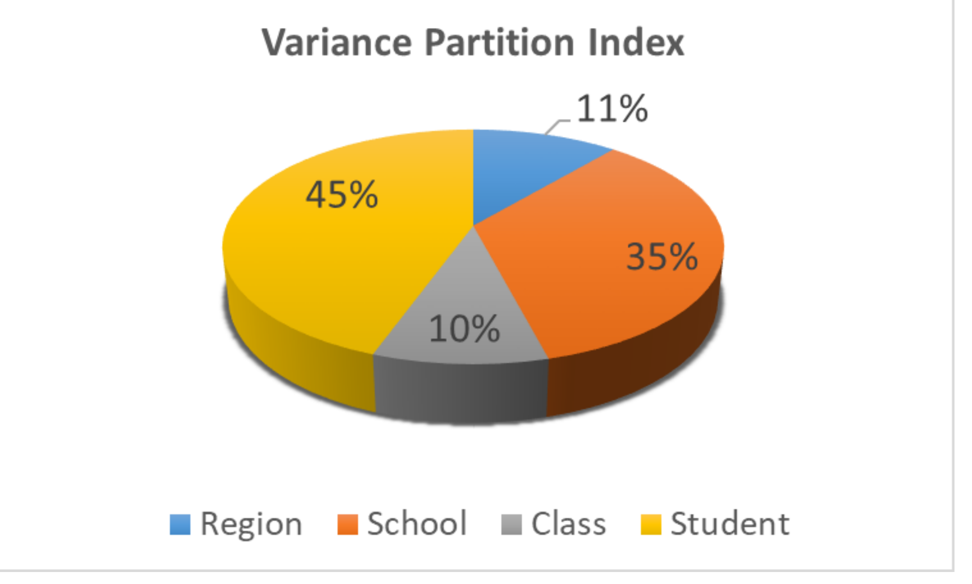
Source: UNESCO map on school closures (https://en.unesco.org/covid.19/educationnresponse) and UIS. March 2022 (https://data.uis.unesco.org)

Source: authors' elaboration with the data of the Bank of Italy Note (Bovini & De Philippis, 2021) based on the Decree DPCMs and regional ordinances.

How G13 mathematics ability estimate during pandemic varies between students (within class), between classes (within school), between schools (within Region) and between Regions?

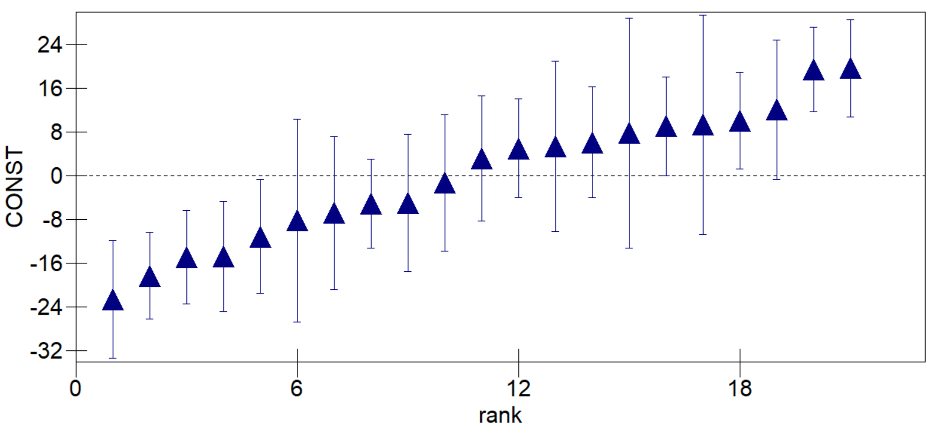
Results: Random intercept model

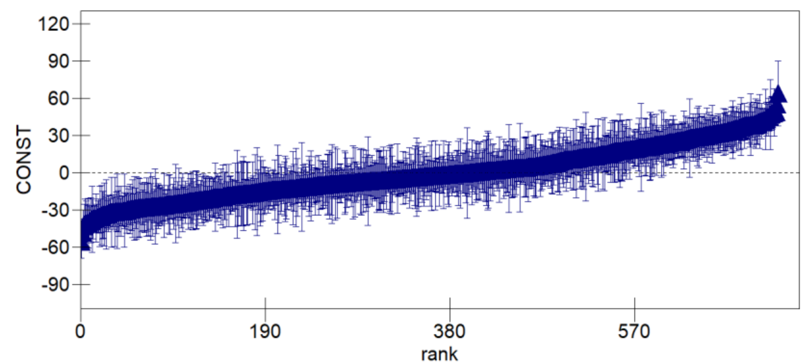
The 11% of the variation in mathematics scores lies between Regions; 35% lies within Region between schools; 10% lies between classes within school and 45% between students.

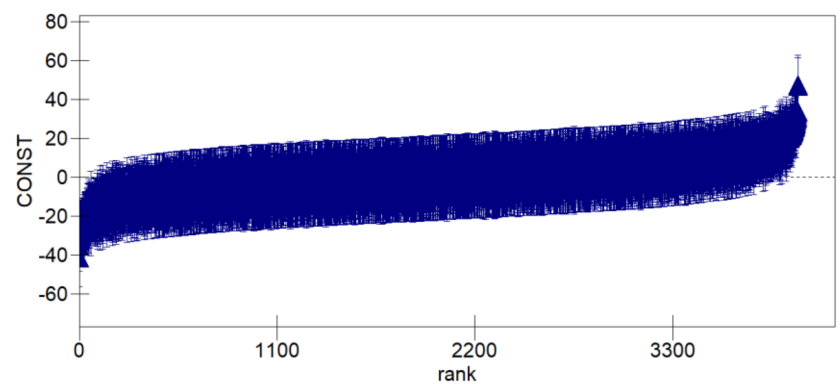


LR test (4-level model *vs* 3-level model (χ^2_1= 163.897. p < 0.01)).

How G13 mathematics ability estimate varies between classes (within school), between schools (within Regions), and between Regions during pandemic?



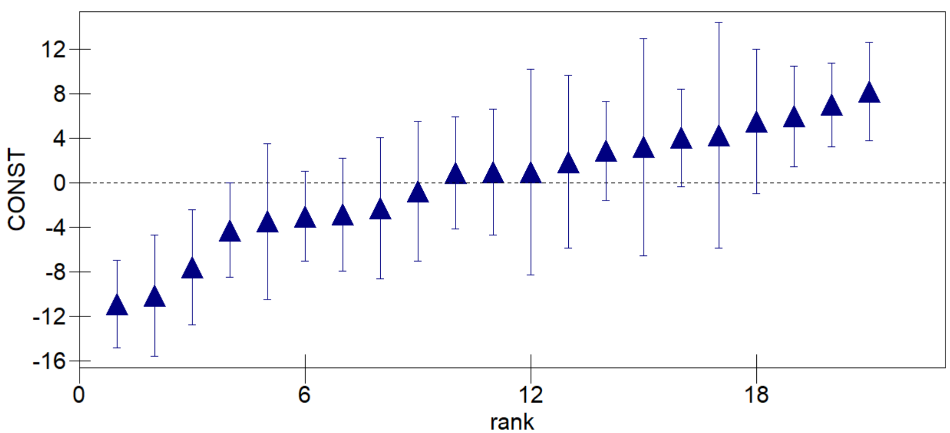


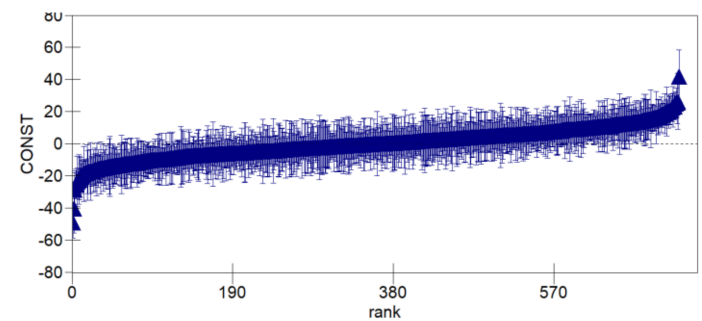


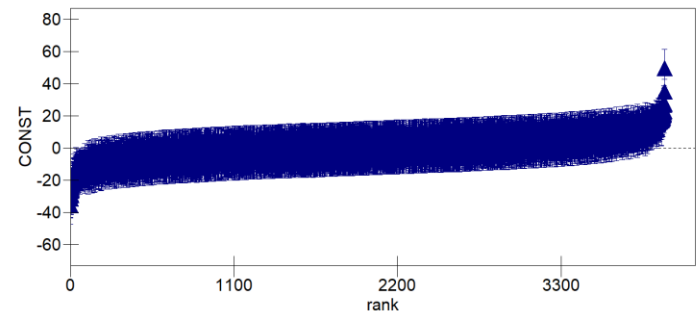
The range of values of the Region residuals (departure from the grand mean: 189.66) is from a reduction in mathematics ability estimate of 23 points to an increase of 19 points.

How mathematics ability estimate varies during Pandemic once the pre-pandemic baseline level (Mathematics-G10) is accounted for?

Results: Random intercept+fixed effect of MATH10 (GMC)







The range of values of the Region residuals (departure from the overall mean: 194.188) is from -11.8 points to + 8.16 points.

Adjusting for MATH10 explains 55% of variability in MATH13 score.

Large decline in the Region- (66%) and School- (61%) level. Large differences between students’ mathematics level at the baseline (class-level reduction is 27%; student-level reduction is 21%)

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Direct within and between effects

Centering: CWC(M) (Brincks et al. 2017; Yaremych, Preacher & Hedeker, 2021)

	Fixed Part	Estimate	SE		Contextual effect	
	Intercept	198,026	3,256			
Student baseline	Maths 10	0,532	0,004	**		
Student level	Female	-2,674	0,256	**		
	First Generation Immigrant	-4,44	0,645	**		
	Second Generation Immigrant	-2,561	0,481	**		
	ESCS	0,174	0,126			
	Interest in mathematics	3,11	0,129	**		
	Educational aspiration	2,401	0,295	**		
Class level	Average Math-10	0,667	0,019	**	0.136	**
	Prop. Female	-4,725	1,156	**	-2.051	
	Prop. FGIMM	3,305	3,874		7.745	*
	Prop. SGIMM	-2,204	3,079		0.358	
	Average ESCS	0,644	0,796		0.47	
	Average interest in mathematics	4,152	0,693	**	1.042	
	Prop. educational aspiration	1,729	1,693		-0.671	
School level	Average Math-10	0,713	0,028	**	0.046	
	Scientific lyceum (vs Other Lycei)	4,891	1,721	**		
	Technical Institute	0,298	1,799			
	Vocational Institute	-7,278	2,298	**		
	Prop. Female	-8,482	2,277	**	-3.757	
	Prop. FGIMM	-9,131	9,198		-12.436	
	Prop. SGIMM	-7,777	6,808		-5.573	
	Average ESCS	-2,131	1,357		-2.775	
	Average interest in mathematics	2,644	1,602		-1.508	
	Prop. educational aspiration	4,083	3,635		2.354	
Region level	Math10_GMC	0,537	0,091	**	-0,176	
	days of school_closure (%): LOW	-2,509	1,6			
	days of school_closure (%): HIGH	-5,361	1,709	**		
	NEET_C_ITALY	-0,658	0,18	**		
	GDP_C_ITALY	0,061	0,183			

Adjusting for L1-L4 covariates explains 62% of variability in MATH13 score.

Conclusions

- The overall differences between pre-pandemic and pandemic cohorts in Italy suggest a **pandemic achievement gap in mathematics** at the end of upper secondary school (INVALSI,2022; Bazoli, Marzadro, Schizzerotto & Vergolini., 2022);

- Considering low-performers starting points (G10) in a longitudinal perspective, it emerges that although most of **G13 low performers** were already struggling with mathematics, **about one out three moved from intermediate-high (G10 scale) to lowest levels (G13 scale)**.

- More encouraging results are those from another subgroup of pandemic-cohort students who maintained **intermediate to high performance in mathematics** (with respect to G10 and G13 scales), suggesting positive patterns of adaptation in the context of adversity due to the COVID-19 crisis.

- **Future perspective**: vertical scaling for monitoring progresses across upper secondary school by using a common vertical scale.

Conclusions

- Multilevel approach allows to depict an overview of the relevance of different variables in supporting students' relative progresses in mathematics during pandemic:

  - ✓ **socioeconomic and cultural background** seems to play a **minor role** in predicting students' progresses from G10 to G13. However, students ESCS might play an indirect effect through other covariates and over the previous grades;

  - ✓ **within classes**, being a student with an immigrant background and being a female is associated with relative smaller progresses in mathematics from G10 to G13 during pandemic; contextual effects also emerged for class-average baseline level;

  - ✓ **interest in mathematics** and **educational goals students set for themselves** act a key role in predicting students' relative progresses in mathematics (**protective factors**) in the context of adversity due to the COVID-19 crisis and might be eligible target variables for intervention programs.

  - ✓ **Regions showing a higher disengagement of young people** from the process of entering adult life, the labour market, and the possibility of accessing it through education or training (Bynner and Parsons, 2002) are more likely to report **lower progresses in mathematics during pandemic**, even when the Regions' school closure duration is accounted for.

Thank you for your attention

"The ability to adapt well in the face of hard times is a valuable skill for young adults. The good news is that resilience is something that can be learned" (APA, 2020).