

# Investigation of Systems Thinking Skills of students aged 11 to 14 years old

Sara Zanella  
sara.zanella2@education.unibz.it

Measurement in STEM Education (MESE1)  
Naples, 30-31 January, 1 February

# CONTEXT

## RESEARCH QUESTION 1:

**What level of competence in Systems Thinking do middle school students (11-14 years) have?**

**(a) What are and how do these skills and abilities evolve from the first class up to the third grade?**

STATISTICAL SURVEY

Test STAI administration:  
Lower Secondary School,  
Province of Trient

Rasch analysis  
ANOVA  
Frequencies analysis

INTERVENTION STUDY

Intervention in three  
classes: 2 grade.  
Systems Thinking Tools

Narration  
Skills table  
Systemic analysis

Systems Thinking categories  
and skills

## RESEARCH QUESTION 2:

**How to introduce Systems Didactics in the Middle School?**

**(a) What elements facilitate this learning?**

# Systems Thinking Assessment (STA)

PhD thesis, validated, Rasch analysis, think aloud interview.

Cyprus Greek

Age, kind of item

Students experience supposed to be similar to italian/european student regarding the items

29 cross items

4 category:

Definition of the system

Interactions in the system

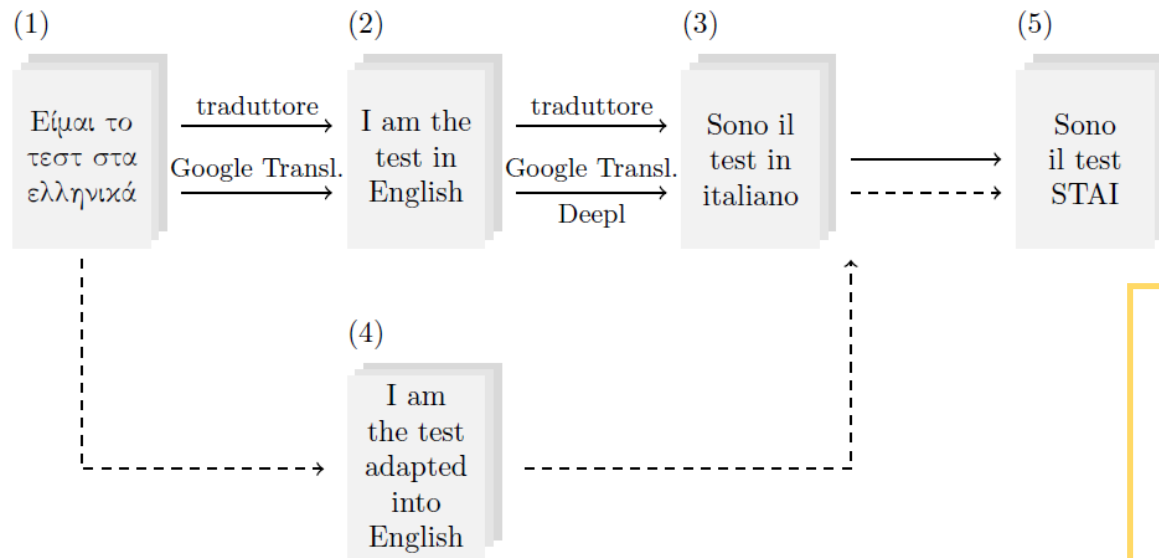
Flows in the system

Balance in the system

Abilities in the categories

Categoria	Abilità	Domanda
1 Definizione del sistema	1 Identificare gli elementi base del sistema.	1, 2
	2 Identificare i limiti temporali.	5, 6, 9
	3 Identificare i confini.	11, 15, 16
	4 Definire e identificare sistemi.	/
	5 Riconoscere che un sistema mostra fenomeni emergenti.	/
2 Interazioni nel sistema	1 Riconoscere l'effetto del comportamento delle parti sul comportamento di altre parti del sistema.	17, 20
	2 Riconoscere l'effetto del comportamento del sistema sul comportamento delle sue parti.	3, 23, 25
	3 Suggestire cambiamenti per generare comportamenti specifici (riconoscere la causa e/o le soluzioni).	21, 22, 24
	4 Riconoscere i comportamenti del sistema (fenomeni emergenti) come indicazioni di interazioni dentro il sistema.	/
3 Flussi nel sistema	1 Riconoscere i flussi lineari dei cambiamenti di materia o di energia all'interno di un sistema.	8, 18, 19
	2 Riconoscere i flussi circolari di materia all'interno di un sistema.	12, 13, 14
4 Dinamiche nel sistema	1 Riconoscere i cicli rinforzanti (aumenta A $\rightarrow$ aumenta B, aumenta B $\rightarrow$ aumenta A).	4, 7, 10
	2 Riconoscere i cicli bilanciati (aumenta A $\rightarrow$ aumenta B, aumenta B $\rightarrow$ diminuisce A).	26, 27

# Systems Thinking Assessment Italia (STAI)



\* Translation not as asked from literature

27 cross items

4 category:

- Definition of the system
- Interactions in the system
- Flows in the system
- Dynamics\* in the system

Systems Thinking Assessment (STA) [3] -> **Systems Thinking Assessment Italia (STAI)**

# Sampling

Province of Trento  
Lower Secondary School  
Asked for availability to all the schools of Trentino

Fall 2020 – Spring 2021

Table: number of test collected in 9 schools

Grade	Participants
1	509
2	251
3	306
All	1066

Table: selected sample

Grade	Age	Male *	Female *	Numerosity
1	11-12	123	117	240
2	12-13	118	114	232
3	13-14	123	114	237
All	11-14	364	345	709

\* Based on residents in Province of Trient on 1st January 2021 (Geolstat)

# Analysis

Rasch analysis

Anova of the abilities of the students

Anova of the difficulty of the items

Response frequency analysis

# Rasch analysis: STAI test reliability

How well the model fits the actual value?

Person Reliability	0,734
Item Reliability	0,754

$R > 0,7$

Students' answers show more or less randomness than expected?

Domanda	Infit	Outfit	Domanda	Infit	Outfit
I1	0.974	1.009	I15	1.042	1.048
I2	0.983	0.962	I16	0.982	0.989
I3	1.080	1.118	I17	0.898	0.880
I4	1.030	1.044	I18	0.975	0.970
I5	1.071	1.143	I19	1.081	1.100
I6	1.203	1.412	I20	0.962	0.954
I7	0.953	0.888	I21	0.936	0.858
I8	0.954	0.921	I22	0.974	0.969
I9	0.949	0.942	I23	1.056	1.067
I10	1.013	1.018	I24	0.958	0.954
I11	1.097	1.209	I25	0.946	0.933
I12	0.968	0.959	I26	0.937	0.930
I13	1.065	1.133	I27	0.928	0.919
I14	0.949	0.885			

\* Software Jamovi, SnowIRT module

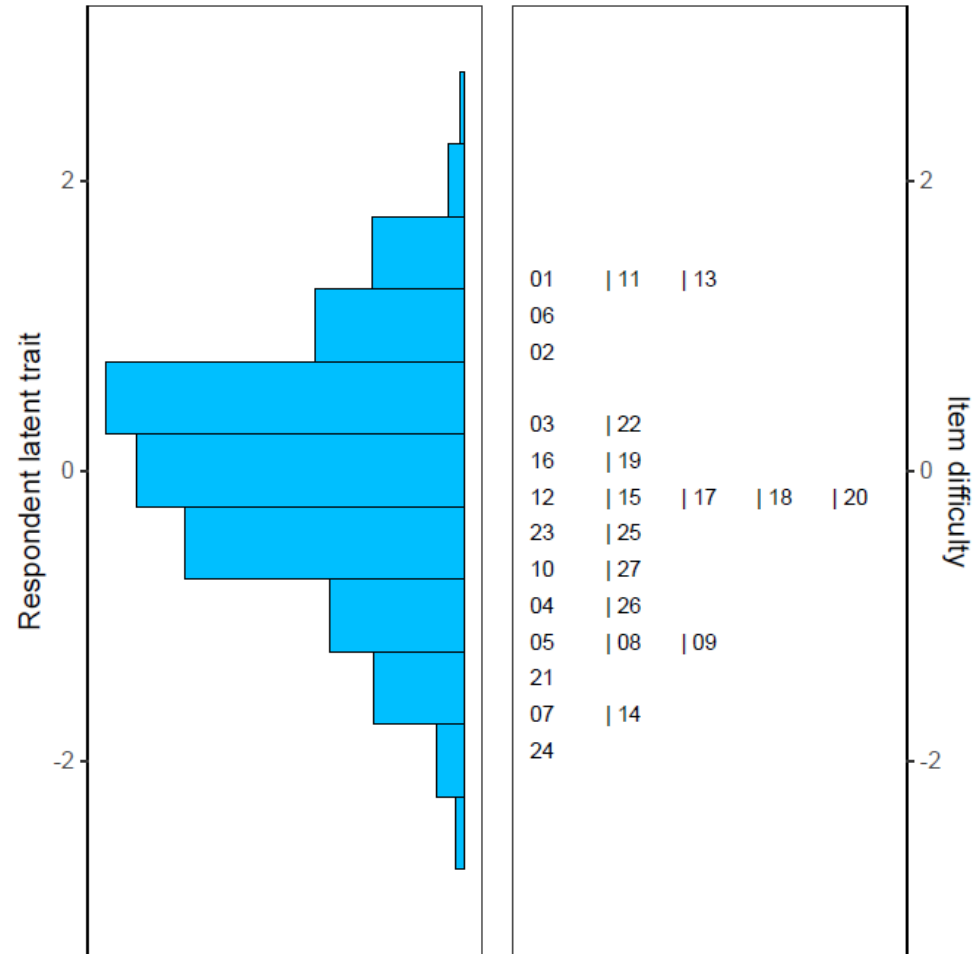
[2] Boone W. J. (2020)

[4] Testa I. et al (2020).

- $0,7 < \text{MNSQ (Infit, Outfit)} < 1,3$   
[predicibility, variability]
- Item and Person



# Rasch analysis



Item measure -> Difficulty of the item/test  
Person measure -> Ability of the student/sample

Suitable, a little easy

\* Jamovi, snowIRT module

# Anova of the abilities of the students

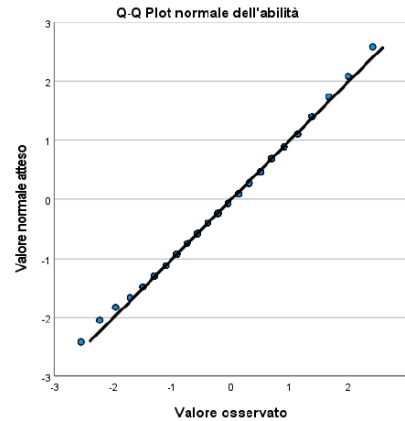
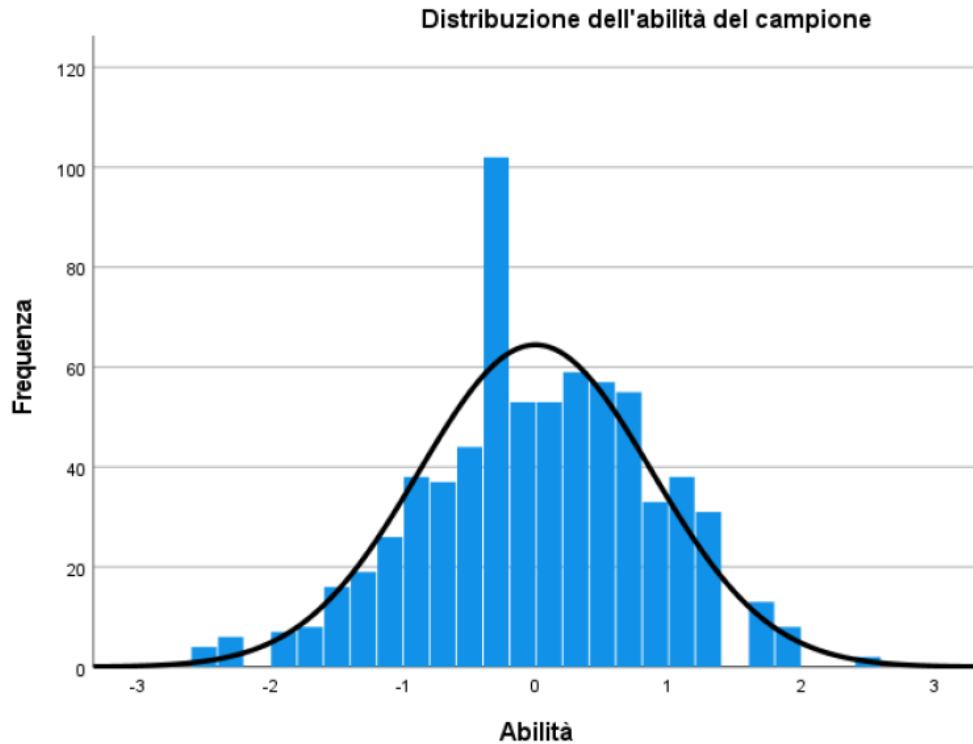
Groups		Numerosity
	All	709
G <sub>1</sub>	First grade	240
G <sub>2</sub>	Second grade	232
G <sub>3</sub>	Third grade	237

The **null hypothesis** for the calculation of variance predicts that all group averages are equal ( $\mu_1 = \mu_2 = \mu_3$ ), i.e. that there is no variability between the first, second and third classes.

The **alternative hypothesis** is that at least one mean is different.

The aim is therefore to test whether the variability within (**within the class group**) depends only on chance (individual differences) and whether the variability between (**between class groups**) is the result of a different ability of the three groups G<sub>1</sub>, G<sub>2</sub> and G<sub>3</sub> or of the treatment.

# Anova of the abilities of the students



Media	0.00	
Mediana	-0.05	
Media-Mediana	0.05	
Skewness (asimmetria)	-0.15	-1<s<+1
Std err Skewness	0.09	
Skewness/Std err Skewness	1.67	-2<se<+2
Kurtosis	-0.09	-7<k<+7
Std err Kurtosis	0.18	

Classe	Varianza ( $S^2$ )
$G$	0.770
$G_1$	0.780
$G_2$	0.658
$G_3$	0.772

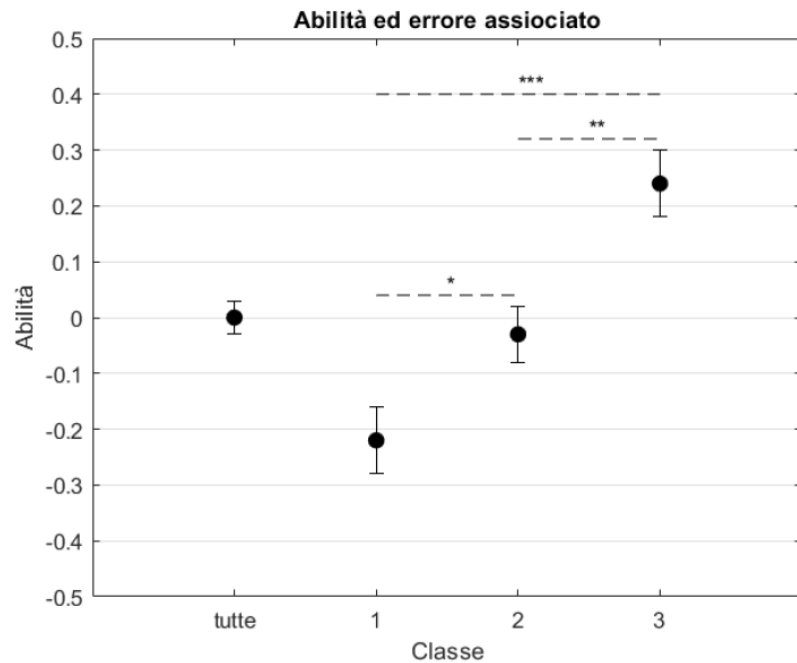
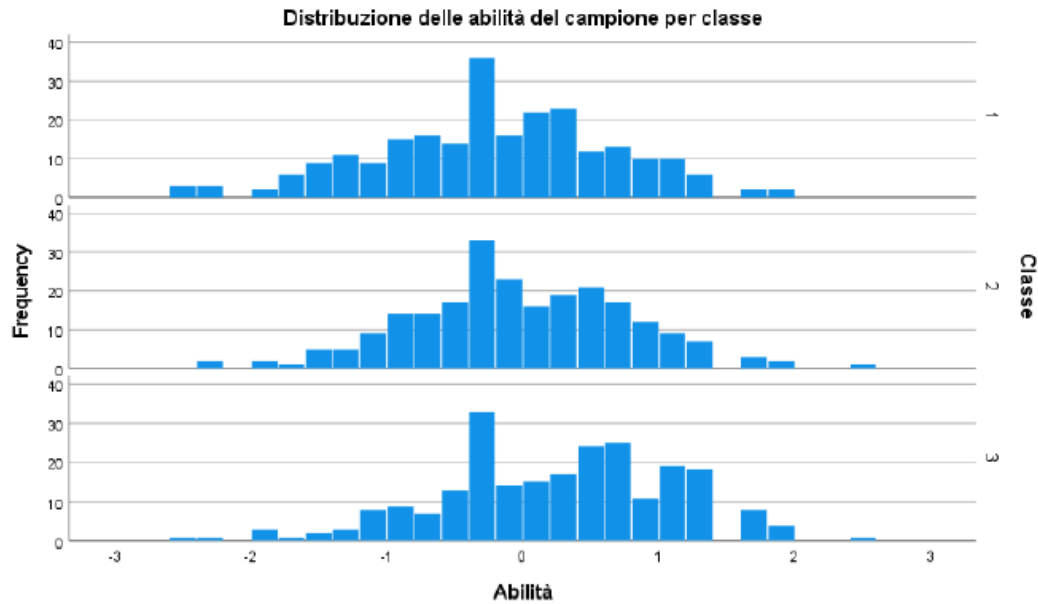
  

	p-value (significatività)
Test di Levene	0.325

Interval – Independence – Normality – Homogeneity

\*SPSS

p-value > 0,05



$$F = \frac{S_{between}^2}{S_{within}^2} = 16,7 \text{ (p-value <0,001)}$$

Significative differences between at least two groups

#### Tukey Post-Hoc Test

		$G_1$	$G_2$	$G_3$
$G_1$	Differenza della media	-	-0.187	-0.452
	p-value	-	0.048*	<.001***
$G_2$	Differenza della media		-	-0.266
	p-value		-	0.002**
$G_3$	Differenza della media			-
	p-value			-

- $p < .05$ , \*\*  $p < .01$ , \*\*\*  $p < .001$

\*SPSS, Matlab

# Anova of the abilities of the students: results

Students have ST competence (regarding this test)  
Personal experience  
Slight improvement from the first class to the third class  
Not depending from school  
Proposal of activities to all grades

# Anova of the difficulty of the items

Aspects	Numerosity (!)
All	27
Definition of the system	8
Interactions in the system	8
Flow in the system	6
Dynamics in the system	5

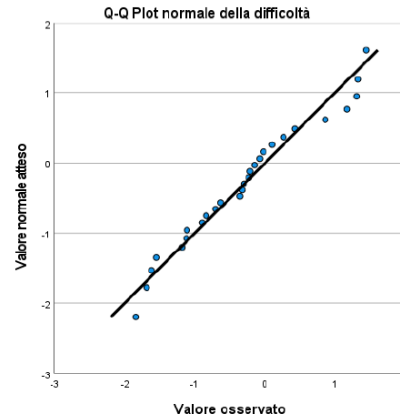
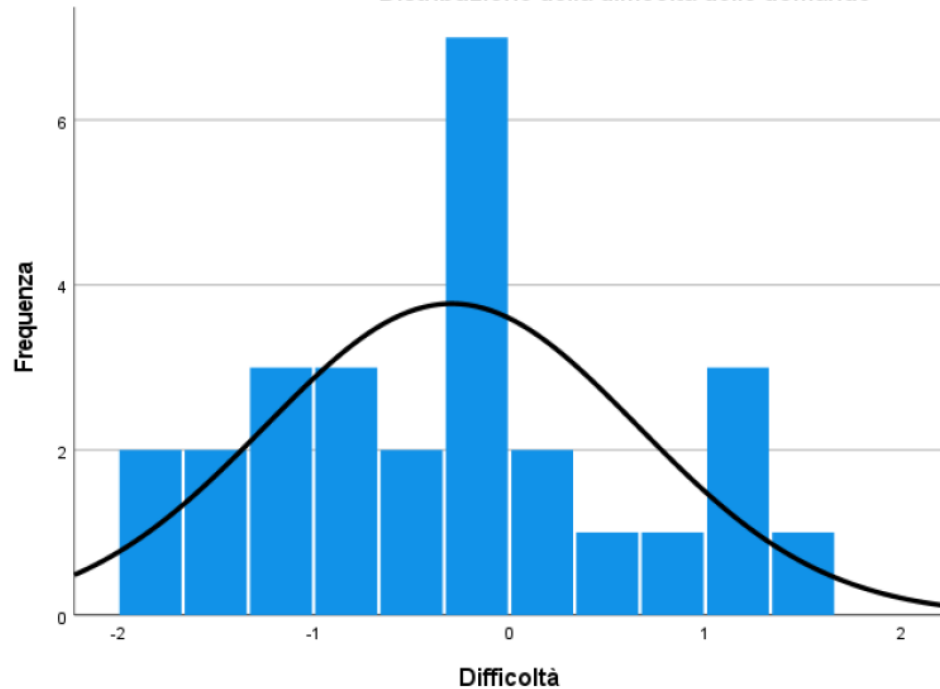
The **null hypothesis** for the calculation of variance predicts that all averages are equal ( $\mu_1 = \mu_2 = \mu_3 = \mu_4$ ), i.e. that there is no variability between them.

The **alternative hypothesis** is that at least one mean is different. The aim is therefore to test whether there is variability within, i.e. whether questions of different difficulty can be identified within the category.

The variability between can provide information regarding the difficulty of the categories (which categories are more difficult and which are easier).

# Anova of the difficulty of the items

Distribuzione della difficoltà delle domande



Media	-0.30	
Mediana	-0.30	
Media-Mediana	0.00	
Skewness (asimmetria)	0.29	-1<s<+1
Std err Skewness	0.45	
Skewness/Std err Skewness	0.65	-2<se<+2
Kurtosis	-0.66	-7<k<+7
Std err Kurtosis	0.87	

Aspetto	Varianza ( $S^2$ )
Totale	0.872
Definizione	1.130
Interazione	0.661
Flusso	1.064
Dinamiche	0.154
	p-value (significatività)
Test di Levene	0.184

Interval – Independence – Normality – Homogeneity

p-value > 0,05

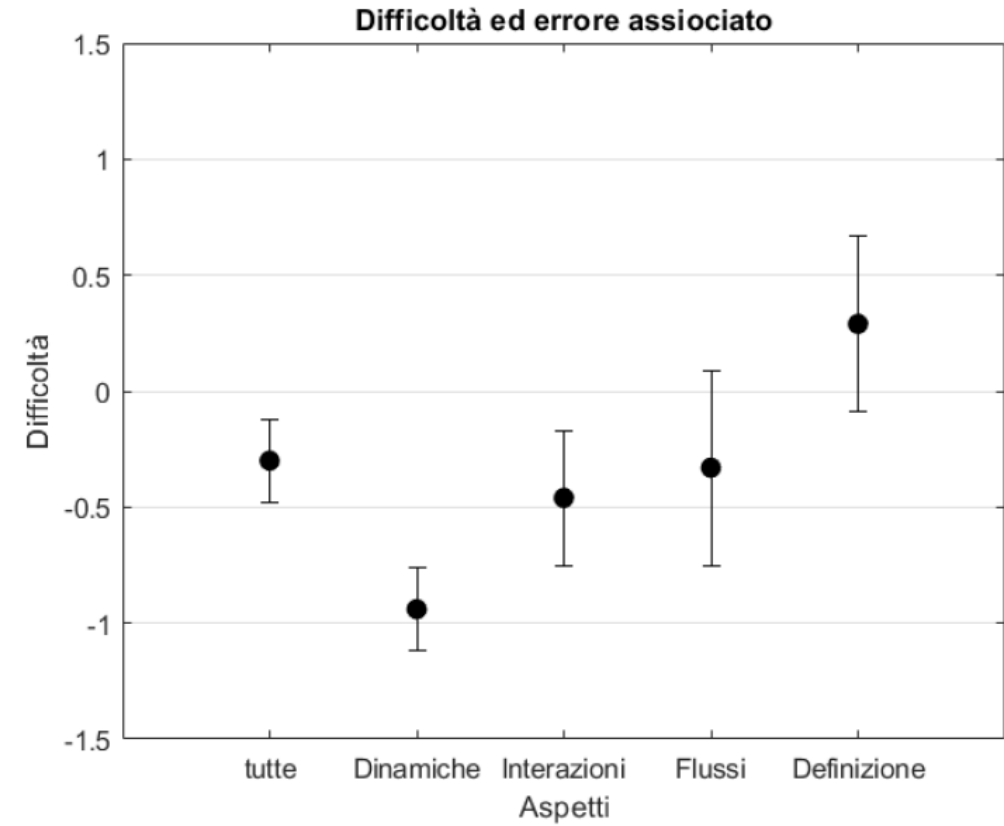
\*SPSS

Tukey Post-Hoc Test			<i>Def</i>	<i>Int</i>	<i>Flu</i>	<i>Din</i>
<i>Def</i>	Differenza della media	-	0.754	0.621	1.233	
	p-value	-	<b>0.356</b>	<b>0.582</b>	<b>0.103</b>	
<i>Int</i>	Differenza della media		-	-0.133	0.479	
	p-value		-	<b>0.993</b>	<b>0.785</b>	
<i>Flu</i>	Differenza della media			-	0.612	
	p-value			-	<b>0.677</b>	
<i>Din</i>	Differenza della media				-	
	p-value				-	

\* p<.05, \*\* p<.01, \*\*\* p<.001

Low significance

$$F = \frac{S_{between}^2}{S_{within}^2} = 2,104 \text{ (p-value=0,127)}$$



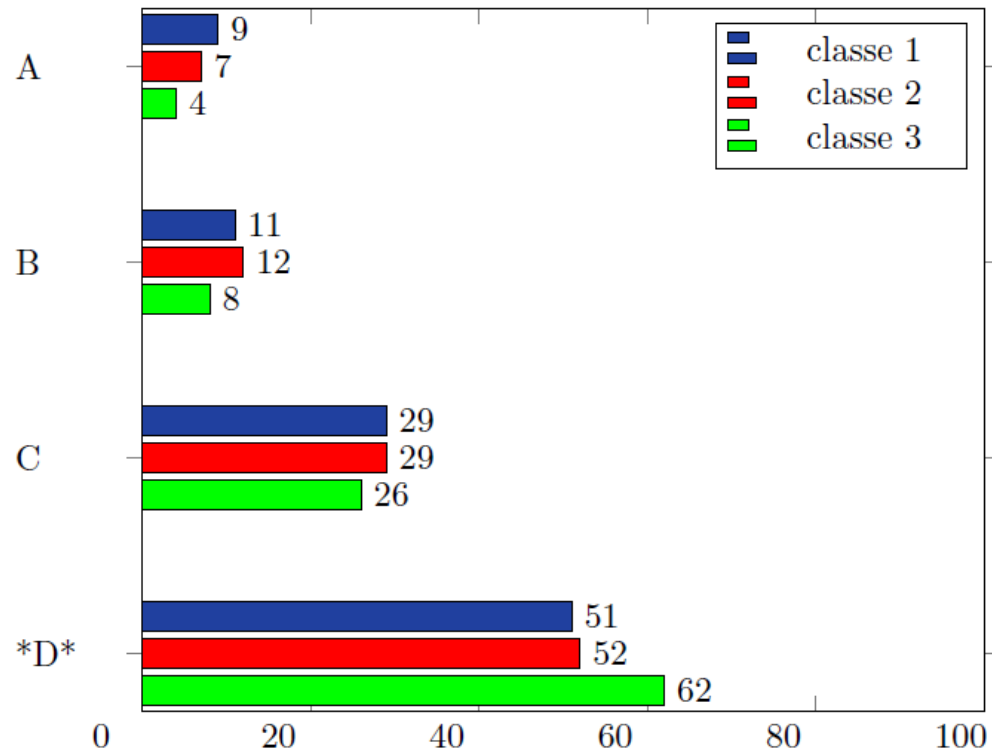
\*SPSS, Matlab



# Anova of the difficulty of the items: results

Differences due to the within variance  
Test not able to discriminate categories  
Need to re-do the analysis

# Response frequency analysis



\* LaTeX

## NOTIONS in SYSTEMS THINKING

- Elements in a system
- Emerging elements
- Time frame
- Boundary
- Space frame
- Mechanism and system
- Interactions
- Polarity
- Intensity
- Non-linearity
- Future prediction
- In flow
- Out flow
- Flow intensity
- Reinforcing loop
- Balancing loop

# THANK YOU FOR YOUR ATTENTION

Sara Zanella  
sara.zanella2@education.unibz.it

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# Bibliography

[1] Barbaranelli, C. (2010). *Analisi dei dati. Tecniche multivariate per la ricerca psicologica e sociale*. Edizioni universitarie di lettere economia diritto.

[2] Boone, W. J. (2020). *Rasch Basics for the Novice*. Rasch Measurement. Application in Quantitative Educational Research (pp. 9-30). Springer.

[3] Κωνσταντινίδη, Κυριακή Χ. (2015): Ανάπτυξη και ερευνητική επικύρωση ενός δοκιμίου αξιολόγησης της συστημικής σκέψης παιδιών ηλικίας 10-14 χρόνων. Konstantinidi, K. (2015). Development and research validation of a test system for assessing systemic thinking in children aged 10-14 years. [Doctoral dissertation, University of Cyprus]. Gnosis Institutional Repository.

[4] Testa, I., Capasso, G., Colantonio, A., Galano, S., Marzoli, I., Scotti, U. d. U., and Serroni, G. (2020). Validation of University Entrance Tests Through Rasch Analysis. Rasch Measurement. Application in Quantitative Educational Research (pp. 99 124). Springer.