Teaching Operations Research before University: a focus on Grades 9–12

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5th AIROYoung Workshop
February 10, 2021

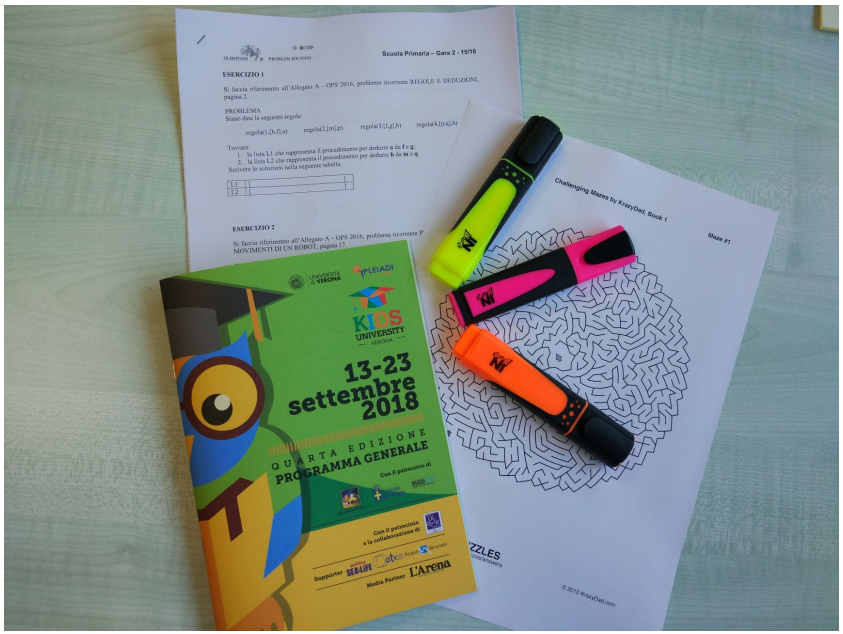
Once upon a time, during the 3AYW...

3rd AIROYoung Workshop in Rome (Italy), March 26–29, 2019

...there were two PhD students, wondering...

- Is Operations Research taught before university?
  - If yes, *how?*
  - If no, *why not?*
- How much is Operations Research known in Italy and abroad, speaking in terms of education?

How our interest grew



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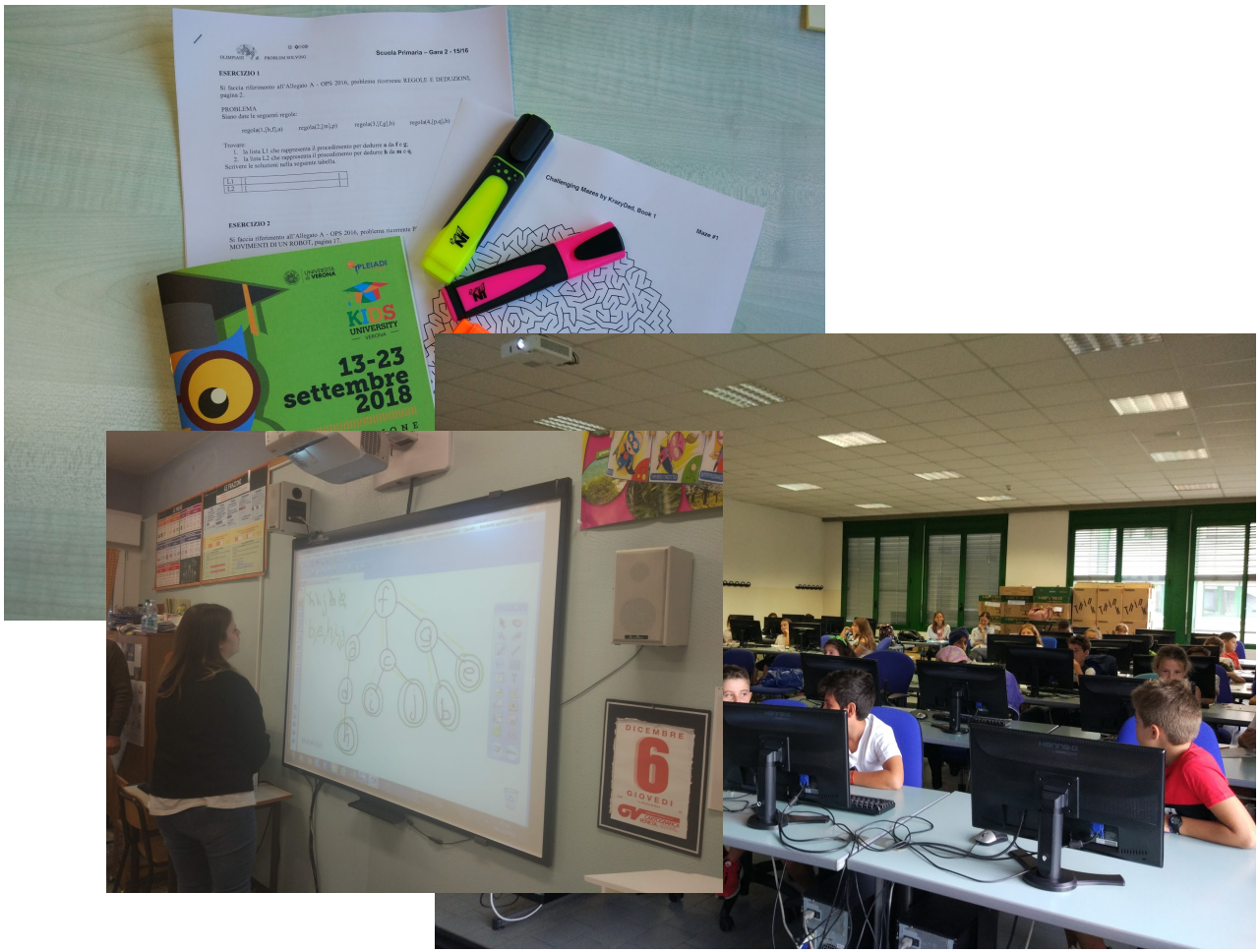

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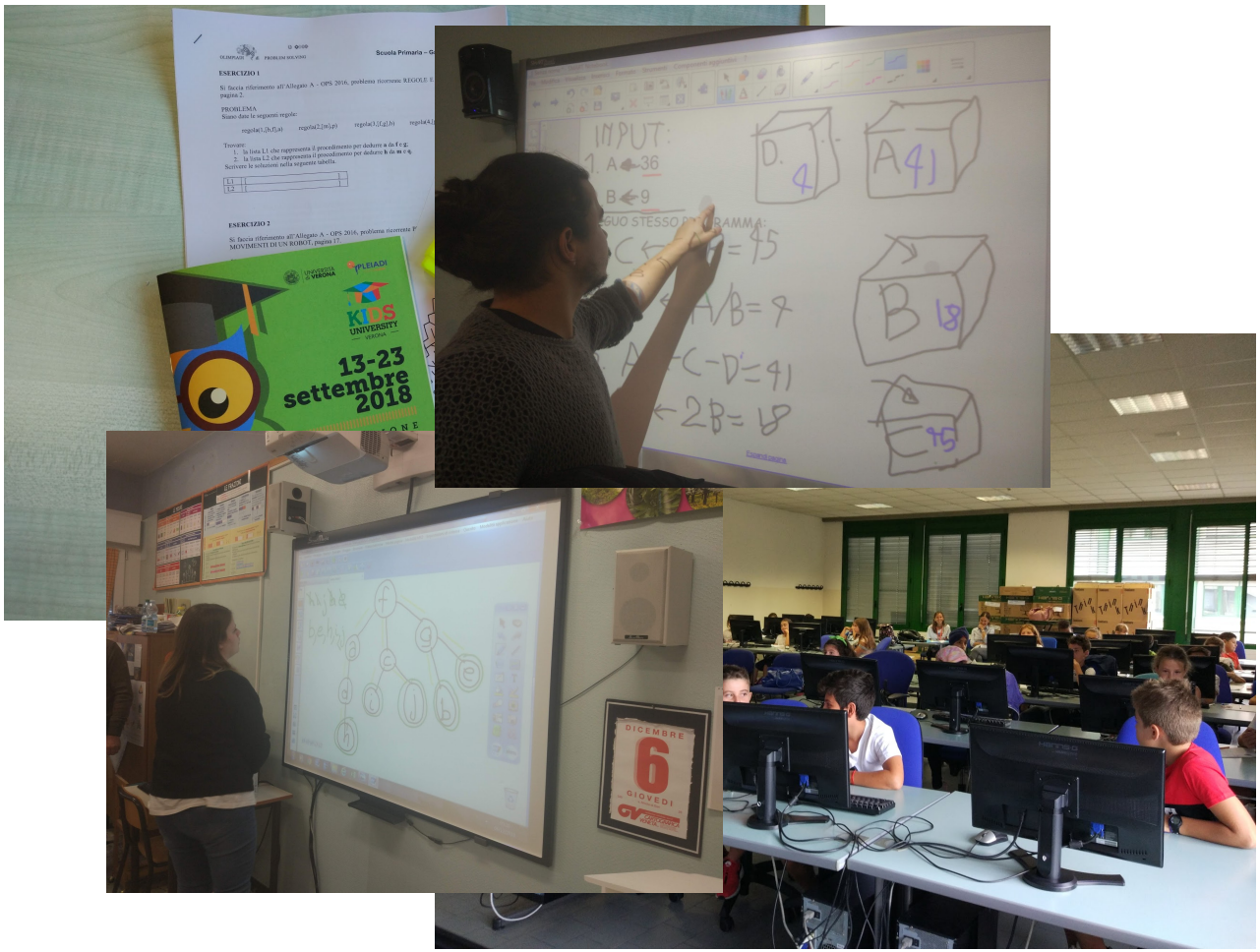

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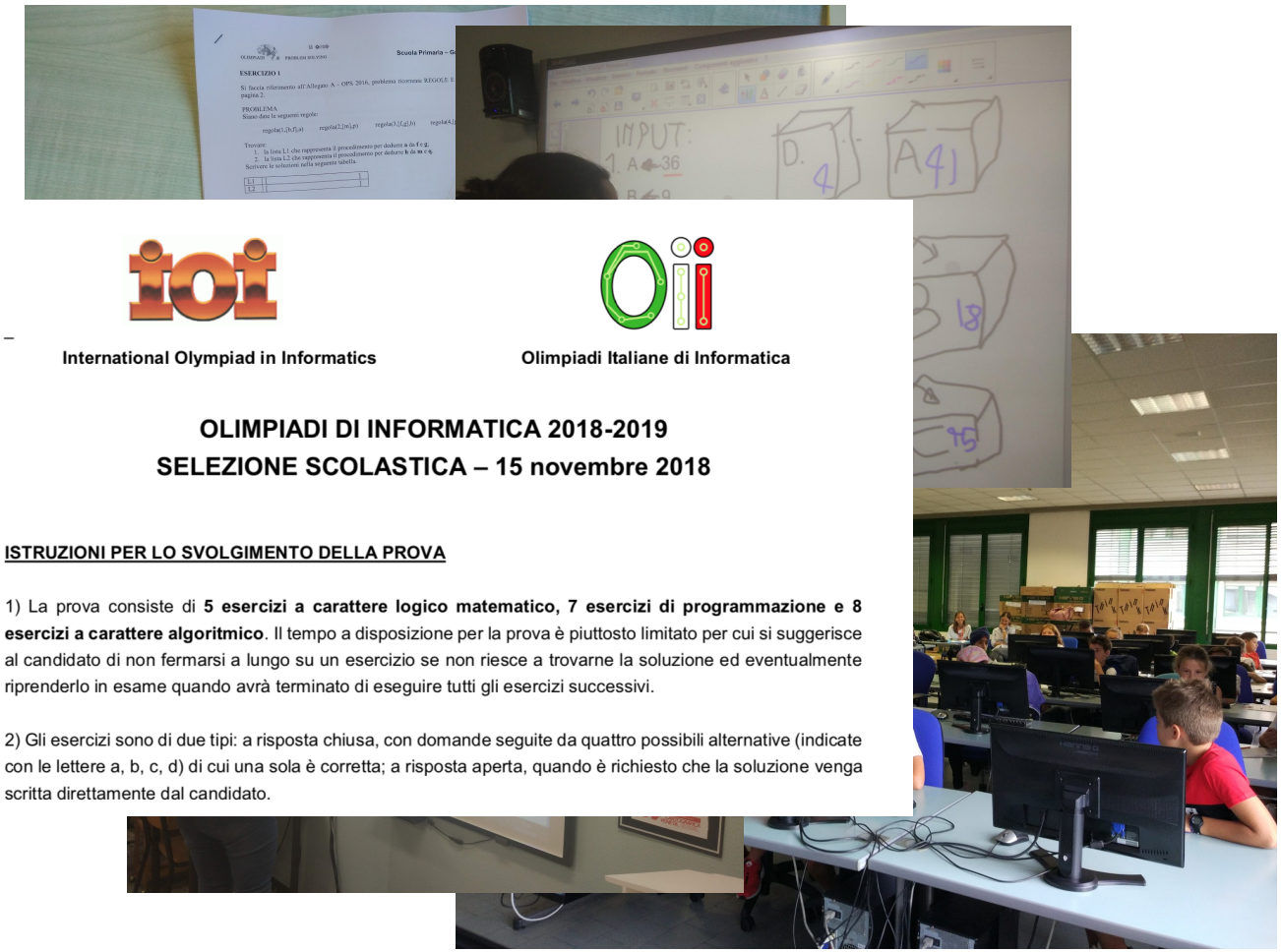


International Olympiad in Informatics

Olimpiadi Italiane di Informatica

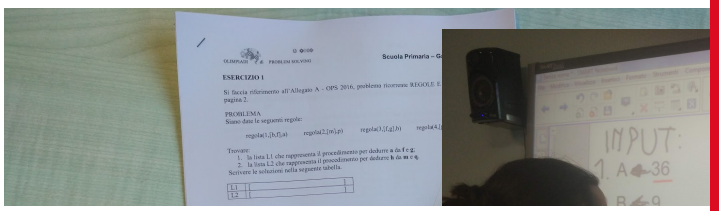
OLIMPIADI DI INFORMATICA 2018-2019
SELEZIONE SCOLASTICA – 15 novembre 2018

ISTRUZIONI PER LO SVOLGIMENTO DELLA PROVA

1) La prova consiste di **5 esercizi a carattere logico matematico, 7 esercizi di programmazione e 8 esercizi a carattere algoritmico**. Il tempo a disposizione per la prova è piuttosto limitato per cui si suggerisce al candidato di non fermarsi a lungo su un esercizio se non riesce a trovarne la soluzione ed eventualmente riprenderlo in esame quando avrà terminato di eseguire tutti gli esercizi successivi.

2) Gli esercizi sono di due tipi: a risposta chiusa, con domande seguite da quattro possibili alternative (indicate con le lettere a, b, c, d) di cui una sola è corretta; a risposta aperta, quando è richiesto che la soluzione venga scritta direttamente dal candidato.

How our interest grew



International Olympiad in Informatics

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Why doing this?

- OR can help increase pupils' motivation and interest towards Mathematics and other STEM disciplines.
- No particular prerequisites for younger students to learn, some mathematical skills already part of a standard mathematical background.

Our main goals:

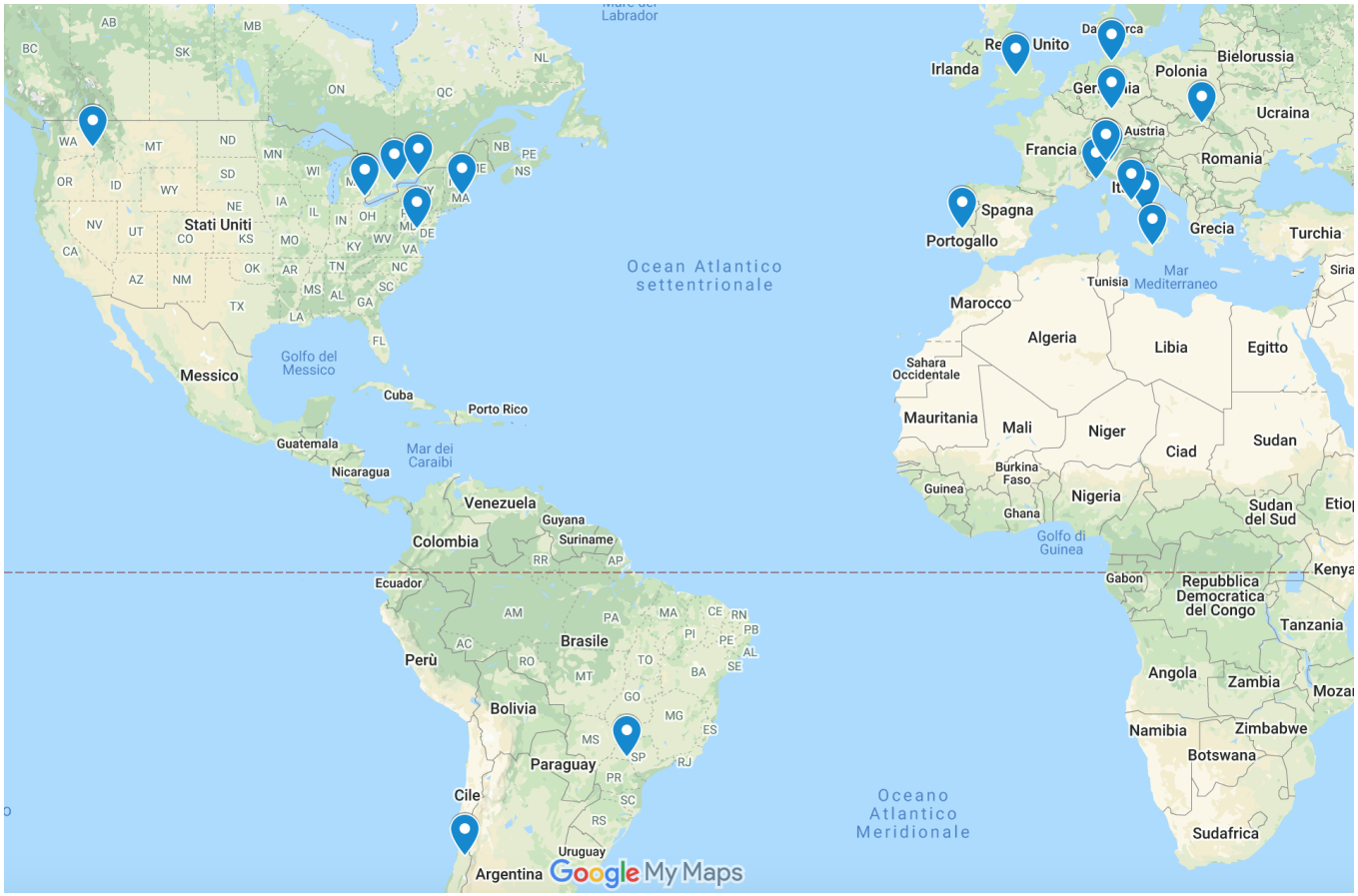
- Collecting, classifying and comparing OR educational initiatives addressed to Grades 9–12.
- Looking for references to OR in international and national guidelines for mathematics education.

(Desperately) Searching for initiatives...

Categories


National and International Projects
Promotion by societies
Competitions
OR educational initiatives
Didactic units or Lectures
Training Courses for Teachers
Workshops for Students

Current map



Link: `https://cutt.ly/SkiZqpj`

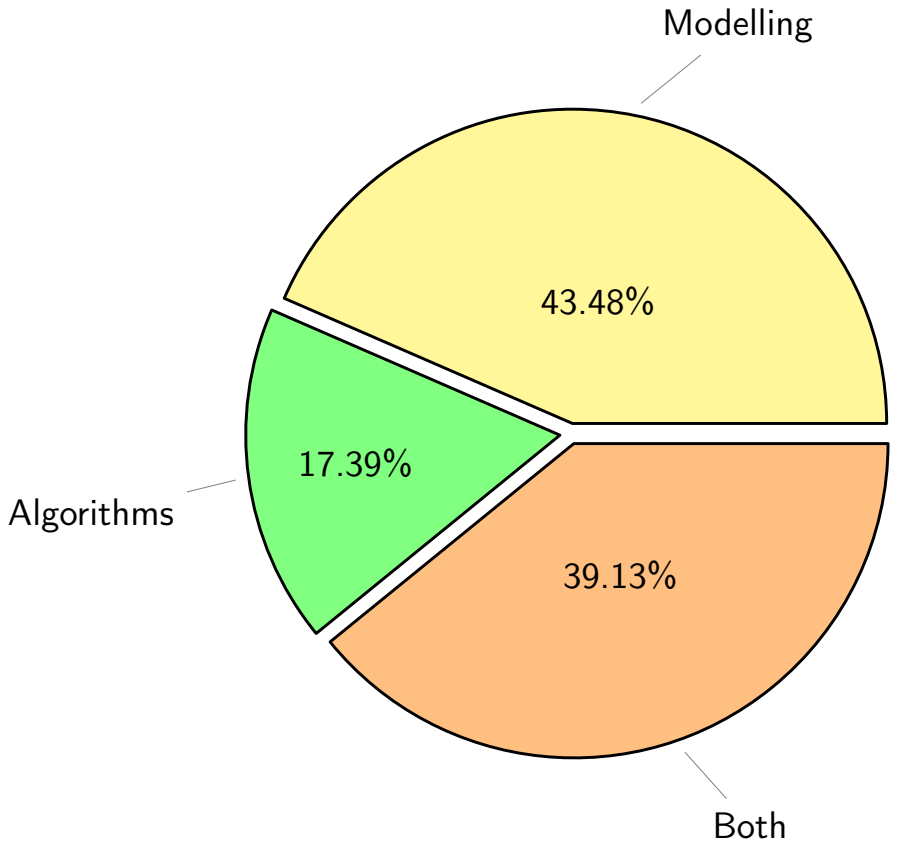
Classification

23 initiatives (12 still active) from 9 countries

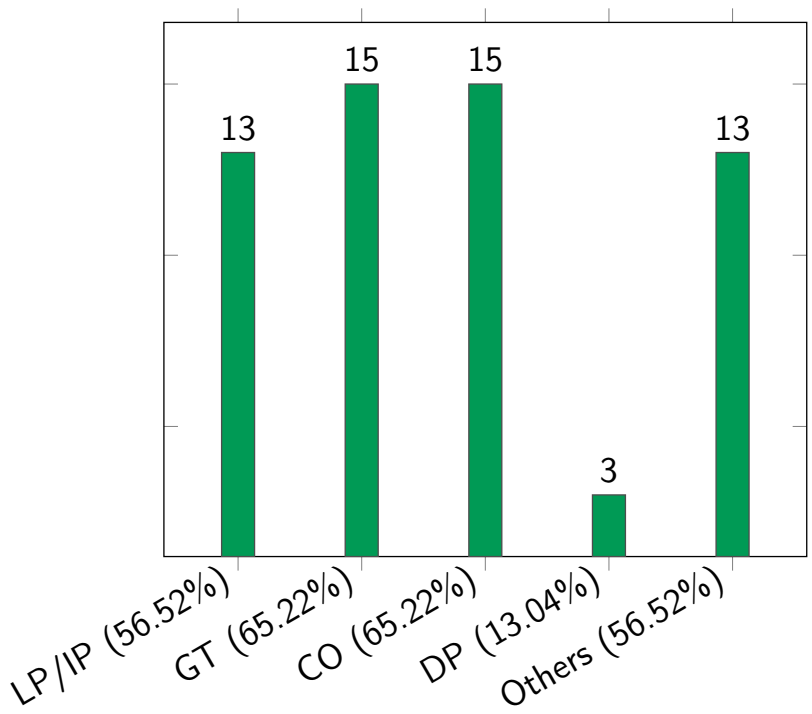
OR initiative	Country	Year	Promo-tion	National project	Internatio-nal project	Compe-tition	T. courses for teachers	Workshops for students	Didactic units	Still active
The OR Society	UK	1948	✓	✓	✓		✓	✓		✓
IOI	World	1989		✓	✓	✓				✓
INFORMS	World	1995	✓	✓	✓		✓	✓		✓
HSOR	USA	1996		✓			✓			
Kaiser	Germany	2000					✓	✓		
Schuster	Germany	2000						✓	✓	
McDuffie	USA	2001							✓	
Cechlárová	Slovakia	2005				✓		✓		
AIRO Challenges	Italy	2008		✓		✓				
InGenio Community	Chile	2008	✓	✓			✓	✓	✓	✓
MINDSET	USA	2008		✓			✓		✓	
Logimat	Italy	2008					✓			
Ottimizziamo!	Italy	2009					✓	✓		✓
OPS	Italy	2011		✓		✓				✓
TORCH	Canada	2011		✓		✓				✓
Schettino and Bonetto	Italy	2013							✓	✓
AMP21	USA	2015					✓	✓		✓
Lonati et al.	Italy	2017							✓	
Colaço et al.	Portugal	2018							✓	
BLOSSOMS	USA	2018	✓	✓	✓					✓
Taranto et al.	Italy	2018					✓	✓		
RabbitMath	Canada	2019		✓			✓	✓	✓	✓
Rangel	Brazil	2019						✓		✓

Objectives and focus

- Engage students' interest in approaches to problem solving and build awareness of OR.
- Connect abstract concepts with the real world.
- Competitions are more focused on strategies.
- Training courses are more centered on translating problems into mathematical language.
- Mathematical modelling is preparatory to design correct algorithms.

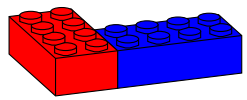


Topics

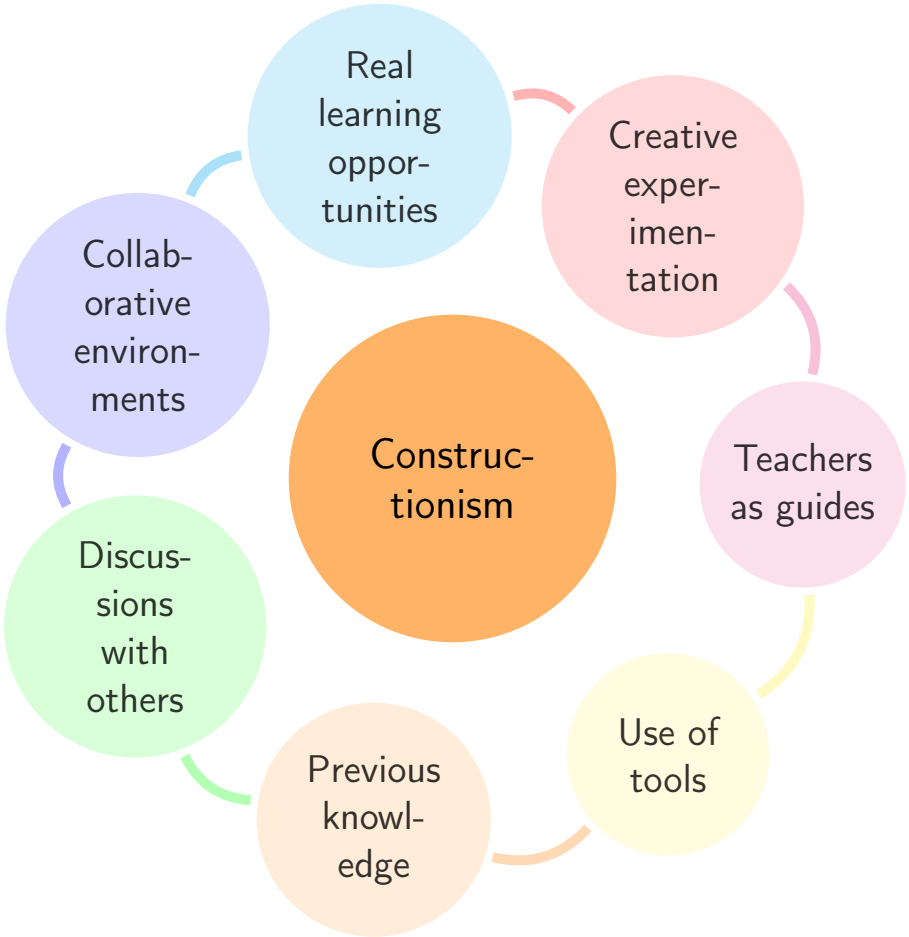


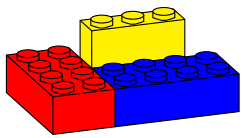
- LP as a base for more advanced topics.
- GT suitable for real-world applications.
- More and wider contents offered by HSOR, MINDSET, AMP21, BLOSSOMS, international societies.
- Challenges propose planning, scheduling, transportation, production, diet and assignment problems.
- Others: Probability and Statistics, Nonlinearity, History of OR, Multiple Criteria Decision Methods, Greedy algorithms, Computational Complexity.

Legend:
LP/IP: Linear/Integer Programming
GT: Graph Theory
CO: Combinatorial Optimization
DP: Dynamic Programming

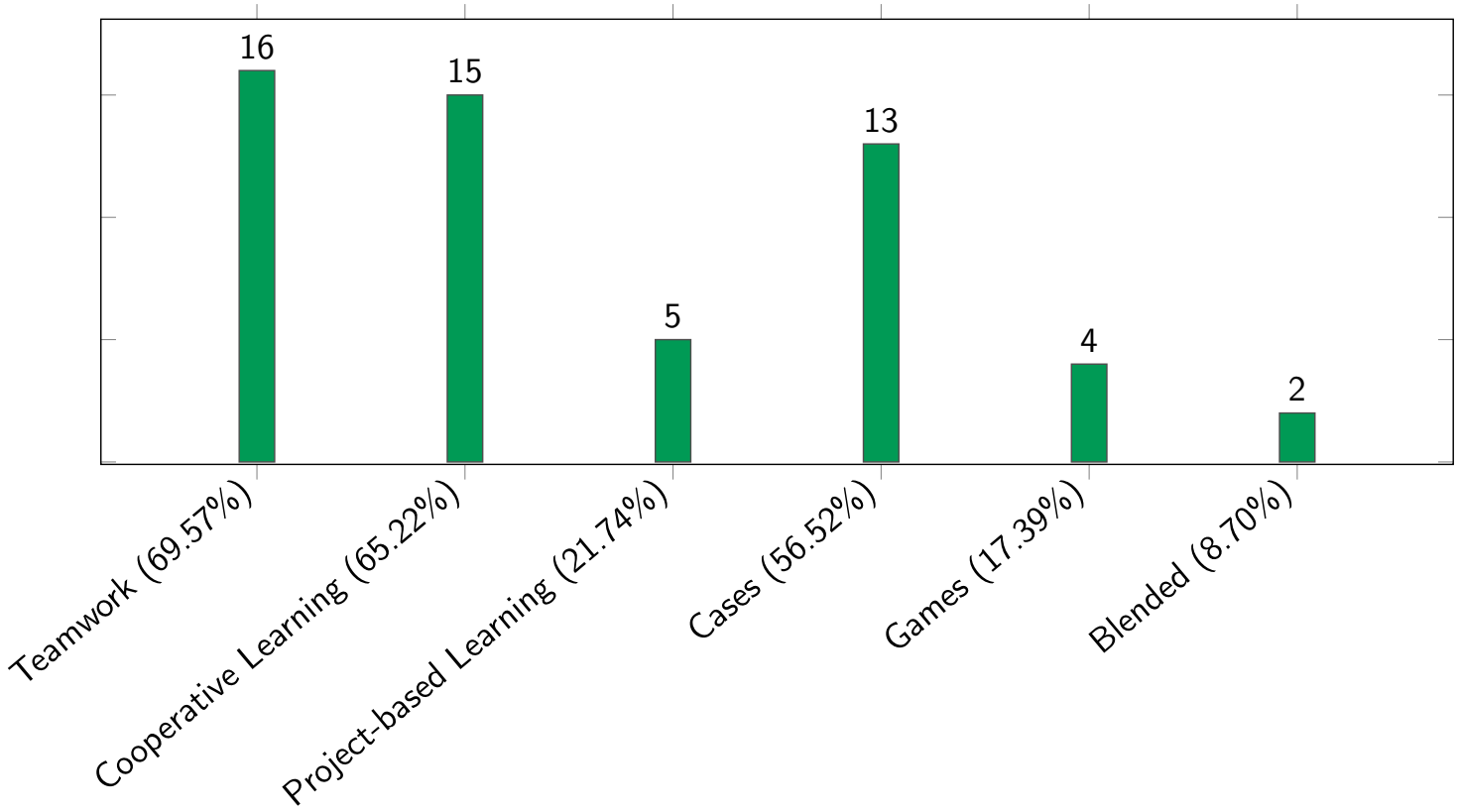


Teaching methods (I)





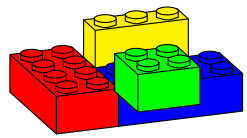
Teaching methods (II)



- Active and inquiry-based learning to keep students' attention.
- Case studies vs teaching cases.
- Romance (Whitehead), experience (Dewey) and sculpture (Papert).

Instruments and software

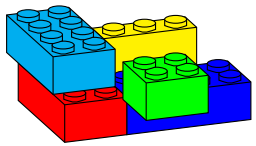
- Repositories of problems, teachers' manuals and video libraries by The OR Society , INFORMS and BLOSSOMS .
- Books (e.g., in 2004, after HSOR , "*Does this line ever move? Everyday Applications of Operations Research*" ; in 2012, after MINDSET , "*Mathematical Modeling with Algebra: Using Authentic Problem Contexts*" and "*Mathematical Modeling with Probability: Using Authentic Problem Contexts*")
- Tools: calculators, almanacs, maps and timetables, interactive whiteboards.
- Software: *Wolfram Alpha*, *GeoGebra*, *Excel Solver*, *Google Spreadsheet*, *AMPL*, *MATLAB*, ad hoc tools (*Gurobi* or *CPLEX* not exploited).
- Competitions usually do not allow for computers.



Feedback

From students:

- In general very enthusiastic.
- Able to get to adequate interpretations and strategies.
- Possibility to think about problems, not to know solutions immediately.
- Complex modelling examples carried out by average students in ordinary schools.
- Chance to solve challenging real-life problems.



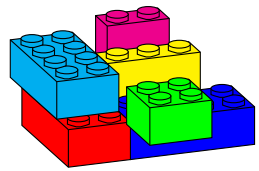
From teachers:

- Satisfied by the educational value of a model-oriented approach integrating thinking and exercises solved with tools.
- Difficulty to integrate the approach in the traditional school curriculum.
- Supported in several ways (e.g., online and onsite training courses, monitoring systems, repositories).
- Practical training should be integrated in university courses.

Looking for explicit and implicit references to OR (I)

International guidelines

PISA	*Formulate*, *employ* and *interpret*
UN-ESCO	Strengthening of technology and mathematics education as *necessary for quality of education*
EU	Ability to develop and apply mathematical thinking to solve a range of problems in everyday situations



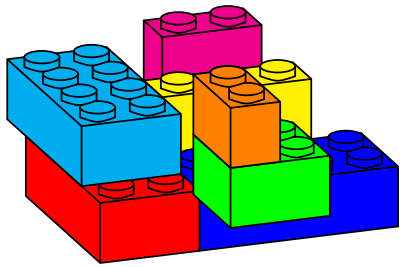
Looking for explicit and implicit references to OR (II)

National guidelines

USA	*Modelling* and *problem solving* as two of the main standards to achieve according to *Common Core Standards Initiative*
Australia	*Critical thinking* and *problem-solving skills*
China	*Learning by doing* through *mathematical abstraction* and *modelling*
Sweden	*Problem solving*, *modelling* and the development of *algorithms* for *everyday* situations
Italy	*Modelling* and *problem solving* to take decisions, by using *informatic tools* (*use*, *operate*, *compute*, *execute*)

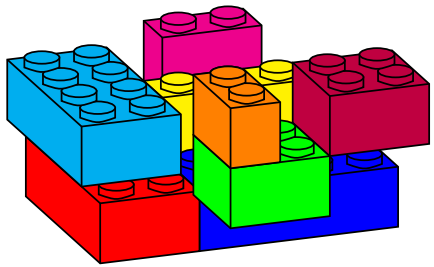
Conclusions...

- We collected a (non-exhaustive) list of OR educational initiatives addressed to Grades 9–12.
- The whole comparison is described in a paper that will soon be available on *Springer Nature Operations Research Forum*.
- We would like to keep the list updated: if you are aware of other initiatives not included in our list, we would be very glad to know and add them.



...and future work

- Together with Gabriella Colajanni and Eugenia Taranto (researchers at University of Catania), we developed an OR-based didactic unit addressed to Italian Grades 10-11, to be tested next year in several classes in different Italian regions.
- Actually, our pilot experiment will be "ROAR" (i.e., *Ricerca Operativa Applicazioni Reali*), a project work at IIS Antonetti, Iseo (Brescia, Italy):
  - Agreement between the school and University of Brescia;
  - Three-year project (first year: from March 15 to May 15, 2021);
  - Blended form (onsite with half of the students and online with the other half).



A few references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