The ROAR project: How to improve Grade 10-12 interest and motivation in Mathematics through a learning path based on Operations Research

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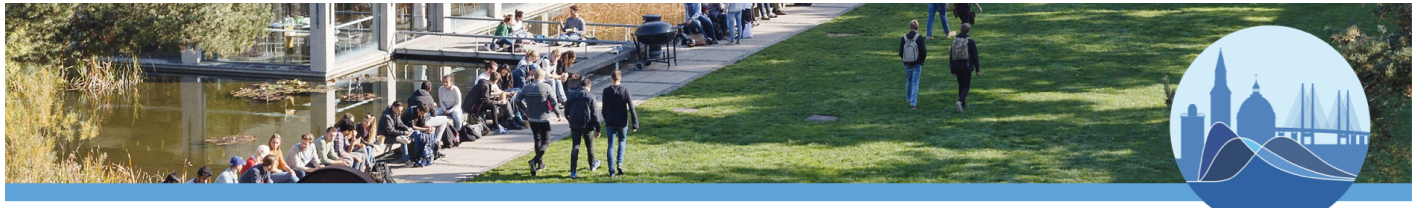
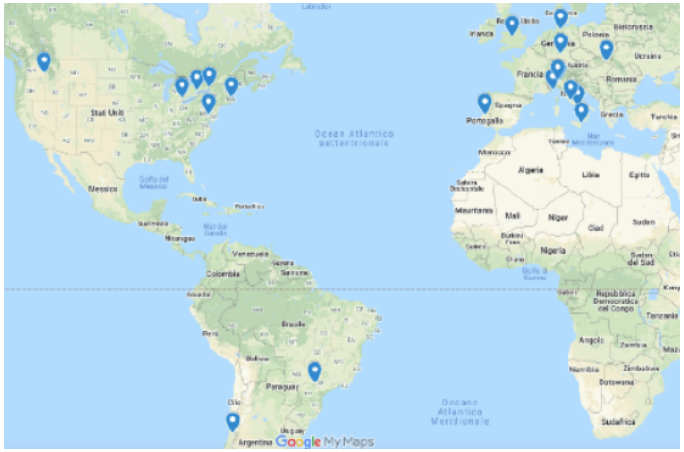


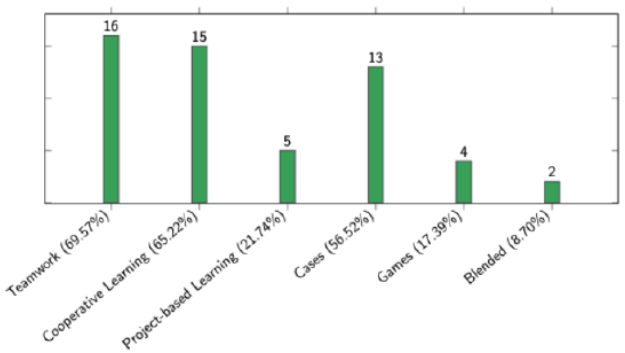
Outline

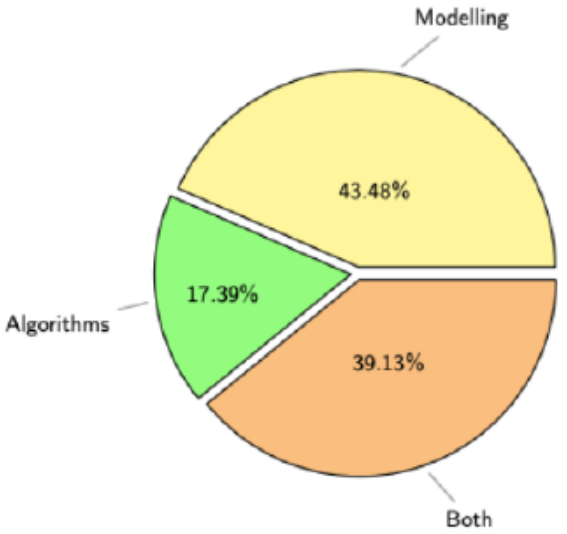
Introduction

Teaching OR before University

A literature review about OR initiatives addressed to Grades 9–12







Looking for explicit and implicit references to OR

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

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*)

The ROAR project

Research team

Gabriella Colajanni, University of Catania

Alessandro Gobbi, University of Brescia

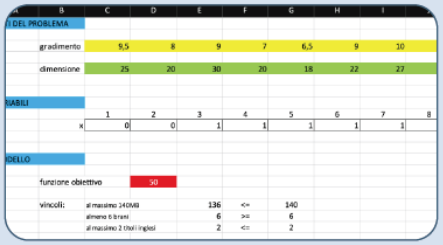
Alice Raffaele, University of Calabria

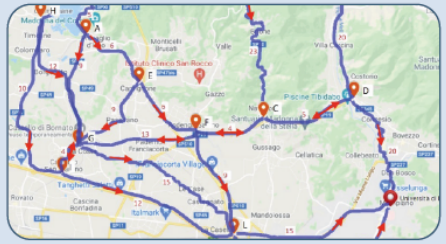
Eugenia Taranto, Kore University of Enna

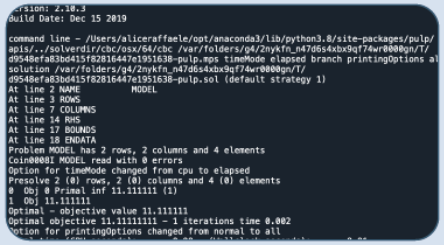
IIS Antonietti and
Dr. Marinella Picchi,
the mathematics and physics
teacher of the class

- Learning path for higher secondary schools based on **active learning** and **constructionism**
- Problems closely connected with **students' everyday life** or **reality**
- **Balance** of mathematical modelling and algorithms
- **Main goal**: improving students' interest, motivation, and skills related to STEM disciplines
- Three-year *Path for Transversals Skills and Orientation* at **IIS Antonietti** in Iseo (Italy)
- Formal agreement with the **University of Brescia**

ROAR teaching units







ROAR I – Grade 10
(March – May 2021)

Mathematical modelling

Linear, integer, and mixed-integer linear programming

Digital technologies: GeoGebra, Microsoft Excel add-in Solver, Mentimeter

ROAR II – Grade 11
(January – April 2022)

Graph theory and network applications (Minimum spanning tree, Shortest path, Travelling Salesman problems)

Heuristics and pseudocodes

Digital technologies: + Kahoot

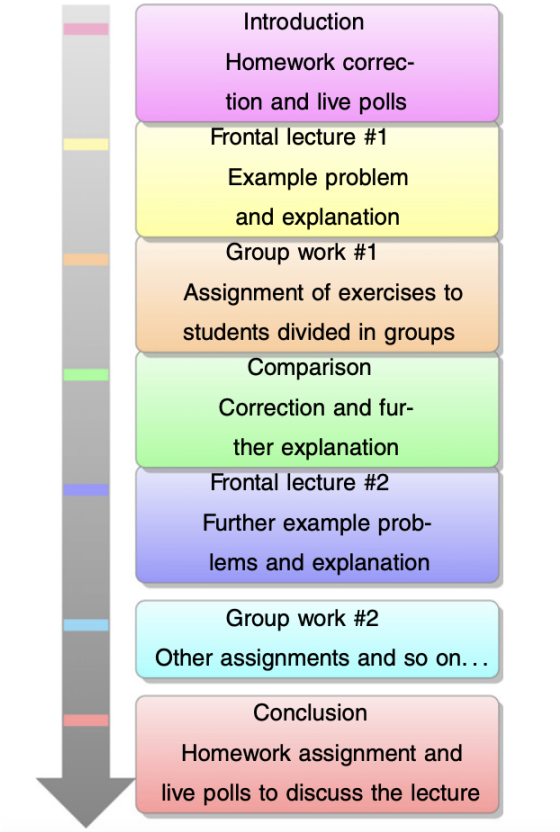
ROAR III – Grade 12
(October 2022 – January 2023)

Implementation of mathematical models in Python

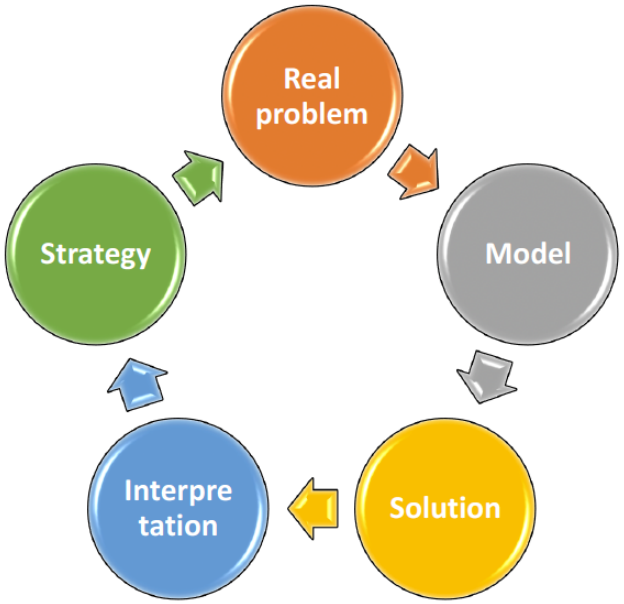
Resolution by means of PuLP

Digital technologies: + Spyder

Macro-structure of (almost) every lecture



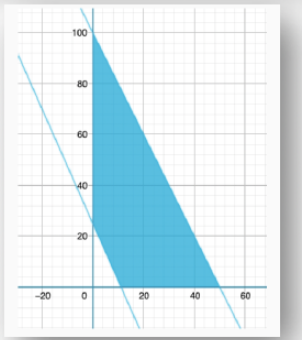
Example of a problem from ROAR I and ROAR III



Problem description

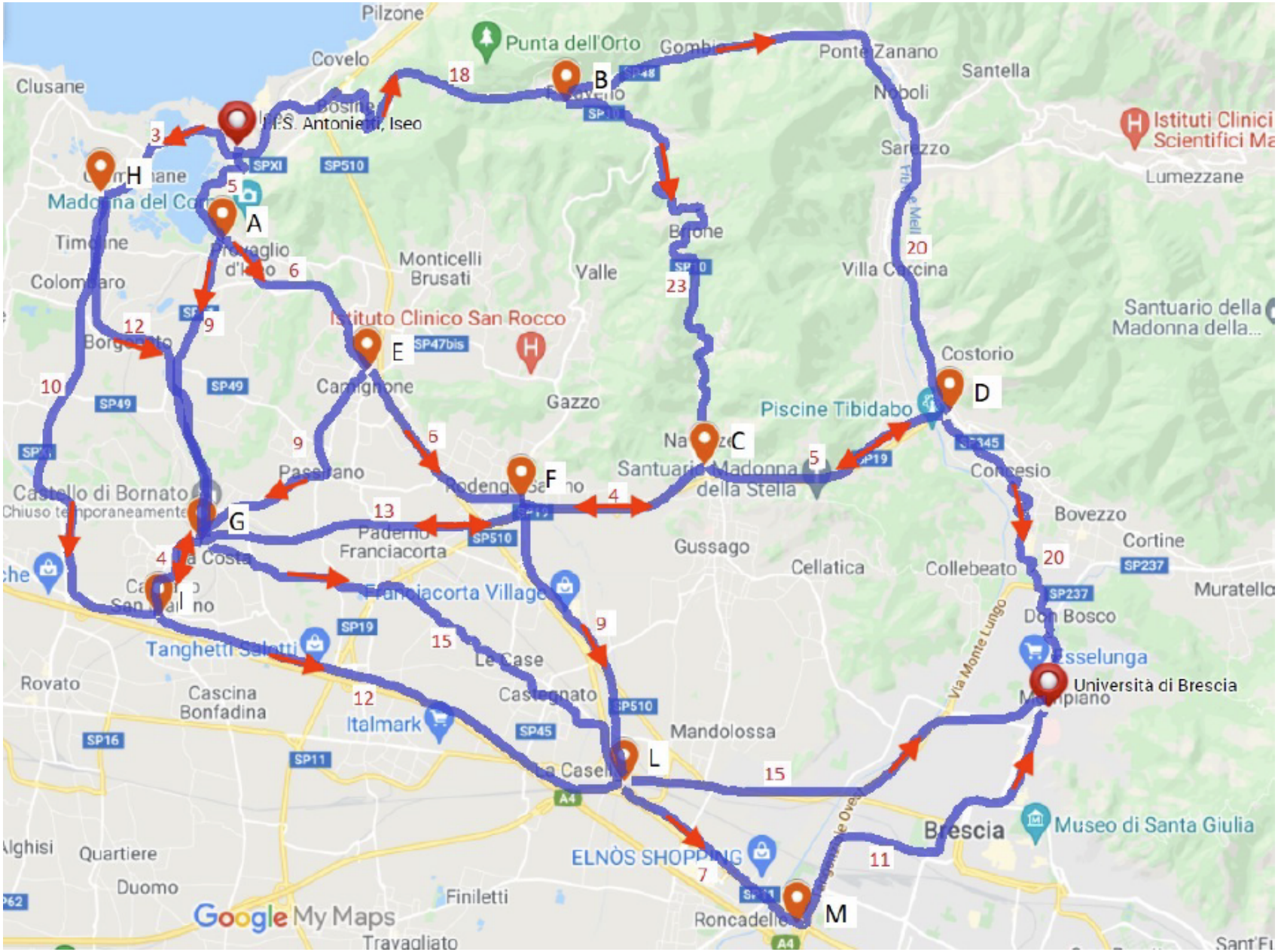
A farm must determine how many hectares of land they owe be dedicated to lettuce and tomato production. By cultivating one hectare of land, the company estimated that 20 quintals of lettuce and 30 quintals of tomatoes can be produced annually. To complete the crops, one laborer has to be assigned to each hectare planted with lettuce and two laborers have to be assigned to each hectare planted with tomatoes. In order to have enough manpower for other crops, the company does not want to use more than 100 workers. Also, the company sells every kilogram of lettuce and every kilogram of tomatoes for 1 euro and 1.5 euro, respectively. Moreover, it wants to ensure an annual profit of at least 50,000 euro from the sale of these two products.

$$\min \quad x_P + x_L$$
$$2x_P + x_L \leq 100$$
$$4500x_P + 2000x_L \geq 50000$$
$$x_P, x_L \geq 0$$

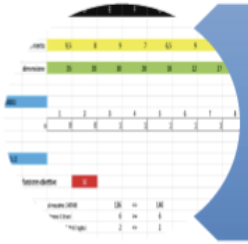



```
from pulp import *

# Inizializzazione del problema assegnando un nome e la direzione dell'ottimizzazione
model = LpProblem("InsalataPomodori", LpMinimize)

# Variabili
x_INS = LpVariable("Num_ettari_lattuga", lowBound=0, cat=LpContinuous)
x_POM = LpVariable("Num_ettari_pomodori", lowBound=0, cat=LpContinuous)

# Vincoli
model += 1*x_INS + 2*x_POM <= 100
model += 2000*x_INS + 4500*x_POM >= 50000

# Funzione obiettivo
model += x_INS + x_POM

# Chiamata al solver
model.solve()

# Stampa soluzione ottima trovata
for v in model.variables():
    print(v.name, " = ", round(v.varValue,2))

# Valore della funzione obiettivo
print("Numero minimo di ettari richiesti = {}".format(round(value(model.objective),2)))
```

Example of a problem from ROAR II



Final projects of the three units

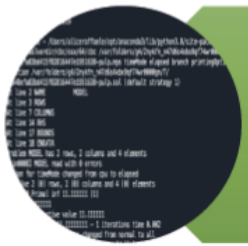


ROAR I (March – May 2021) – COLLABORATIVE LEARNING

Students were divided into five groups, each one tackling a different *authentic problem*

ROAR II (January – April 2022) – COMPETITIVE LEARNING

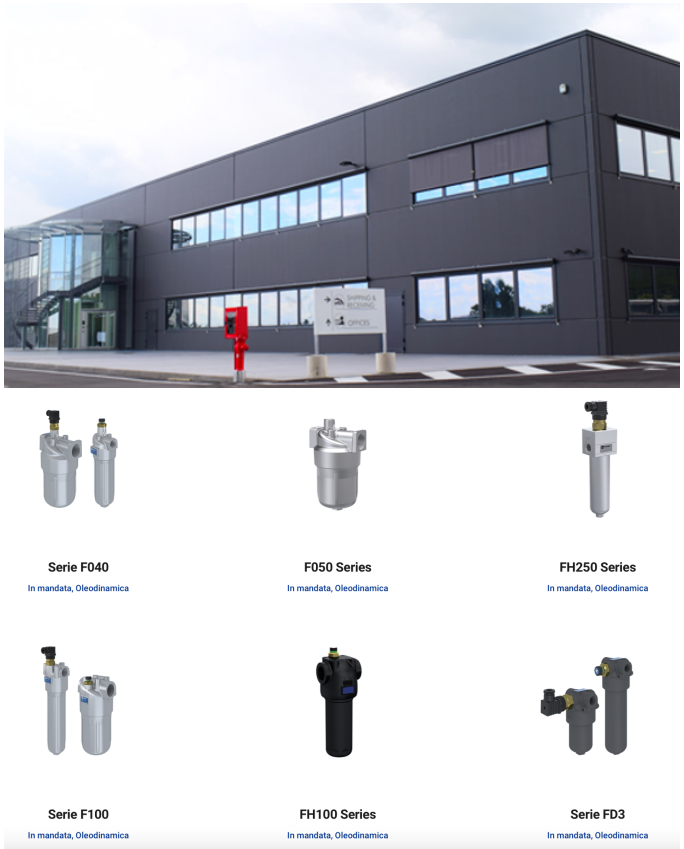
Again, students were divided into five groups, but this time they competed with each other in solving the same challenging problem

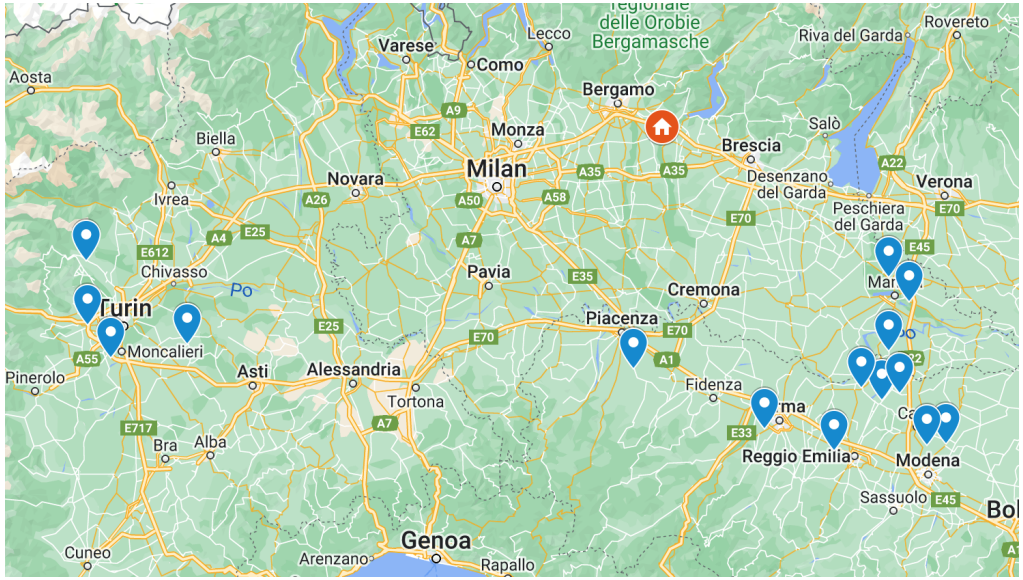


ROAR III (October 2022 – January 2023) – COOPERATIVE LEARNING

Students are divided into five groups, joining forces also with the experimenters to tackle a real industrial problem

ROAR III final project – The Filtrec S.p.A. case study





Problem: optimizing milk-run routes to visit contractors several times a week for pick-up and delivery operations

ROAR III final project – Presentation at Filtrec headquarters

ROAR III final project – Feedback from Filtrec S.p.A.

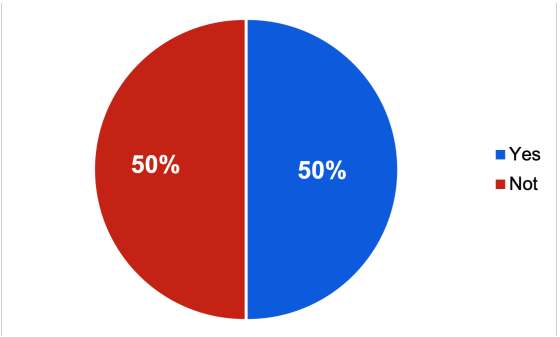
- **Emanuele Giliani (operations manager)**: "*An excellent example of how academic notions can find practical feedback within the industrial business. Students have demonstrated their ability to develop a concrete project, contextualize it, and present it to a potential end user. The project represented an opportunity for collaboration, transversal growth, and above all, a good starting point for future developments*".
- **Giacomo Modina (general manager)**: "*Students tackled the problem with enthusiasm, fully achieving our objectives. Being able to have a simple and parametrizable simulation tool will allow us to promptly reschedule critical transports within our supply chain.*"
- **Nicola Freri (consultant)**: "*the idea of developing a tool that would allow milk runs to be quickly redesigned whenever the need arose became very interesting. [...] It matters little if the model the students have worked on is a simplified version: the relevant aspect is that, with their work, they have brilliantly set up a modeling work that can certainly be further developed*".

ROAR III final project – Feedback from teachers

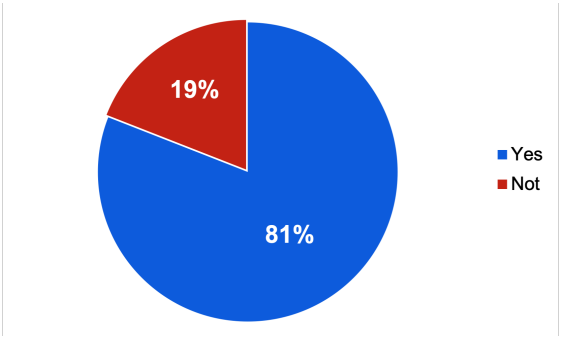
- **Maths**: "*ROAR has allowed to enhance students' different aptitudes through group work. The resolution of real problems also with the use of information technology has allowed students to understand the importance of mathematical modelling [...] Experimenters also became a guide for future university choices*".
- **ICT**: "*I appreciated the laboratory approach of the lectures in which students had to immediately apply to real problems the Python features introduced by the experimenters*".
- **English**: "*I think the project was well organized and I appreciated the attention to the active involvement of all students*".
- **Art**: "*Students experienced academic and corporate world facing a real problem thanks to accurate research methods*".

On the impact of ROAR

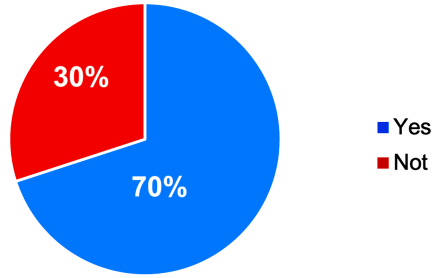
"*Do you think what you learned during ROAR has changed or influenced the idea you had about mathematics and its applications in the real world?*"



ROAR I



ROAR II



ROAR III

ROAR extensions

Single units and training courses

Teaching units

- IIS Antonietti – Iseo (Brescia)
- IIS Majorana-Cascino – Piazza Armerina (...
- Università degli Studi di Milano Bicocca
- Catania

Training courses for teachers

- IIS Amari – Giarre (Catania)
- IIS Majorana – Caltagirone (Catania)
- IIS Majorana-Cascino – Piazza Armerina (...
- IISS Capizzi – Bronte (Catania)

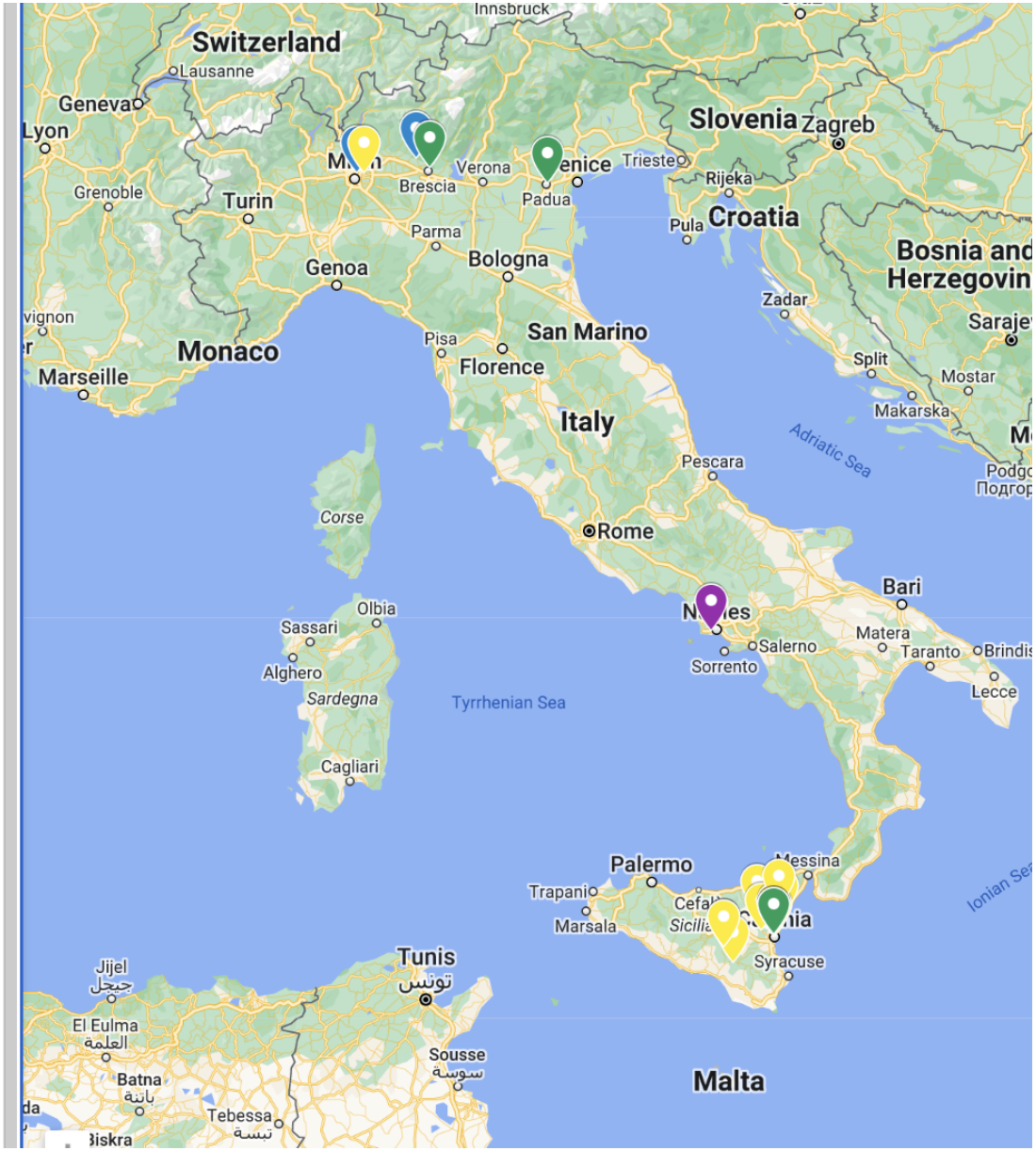
... 5 more

Collaborations with other projects

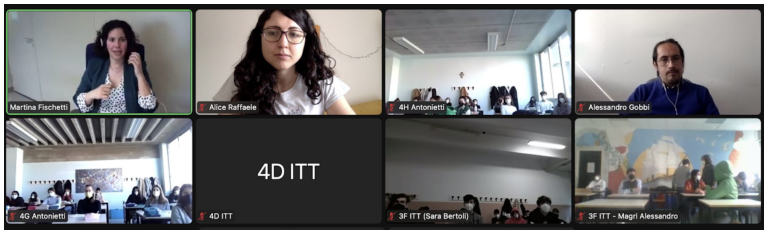
- OPS4Math

Research team

- Alessandro Gobbi – Università di Brescia
- Alice Raffaele – Università della Calabria ...
- Gabriella Colajanni – Università di Catania
- Eugenia Taranto – Kore Università di Enna



The "ROAR In Action!" seminars (Spring 2022 – Fall 2023)



- **Six Zoom meetings** with speakers (both from industry and academia) to present several OR applications: Fabio Bazzoli and Marco Gussago, Leonardo Drahorad, Veronica Dal Sasso, Martina Fischetti, Veronica Asta, Anna Melchiori, and Stefano Bortolomiol
- Focus also on their **background** and **career paths**
- **OR topics covered**: routing, facility locations, railway and freight transportation, public transportation, sustainability, and supply chain management

Conclusions and future work

Final remarks

- The implementation of a modelling pathway such as ROAR can be successfully tackled by ordinary higher secondary students
- ROAR broadened students' experiences with OR and their views of the mathematical world
- In our opinion, it is appropriate to include OR and its type of problems in regular mathematics lectures, clearly not every day, but on a regular basis

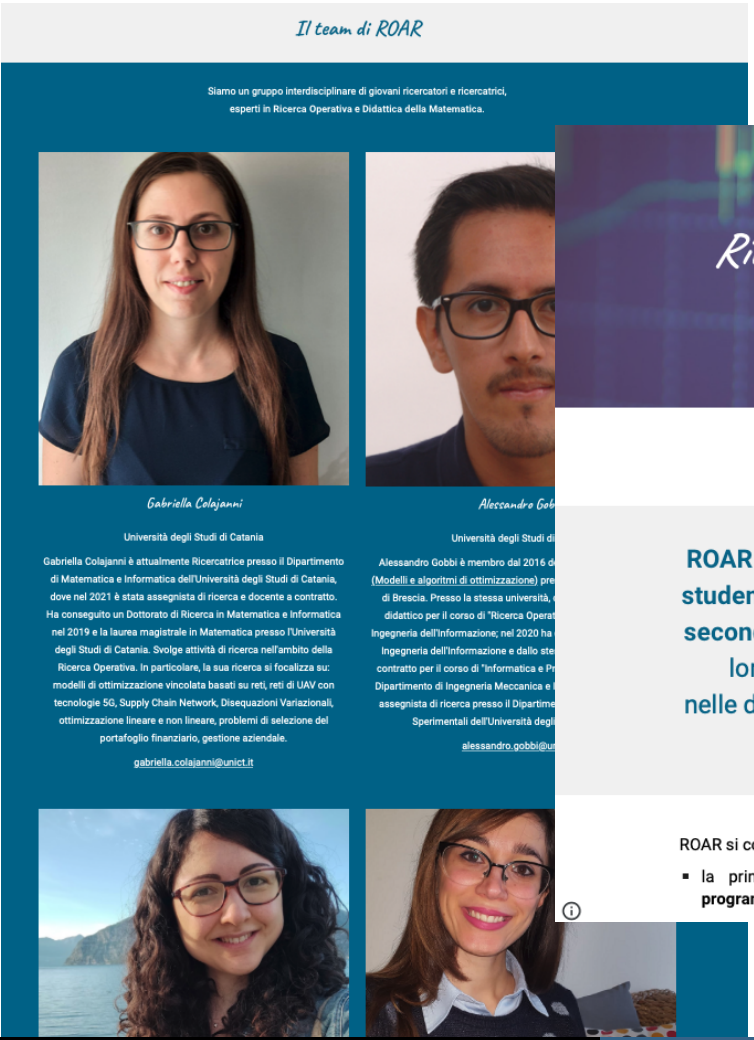
Timeline

Mar 2019	Idea of a literature review and a project at 3AYW
Mar 2021	Literature review on OR Forum
Mar – May 2021	Implementation of ROAR I Iseo
Sep 2021	ROAR I at ODS 2019
Oct – Nov 2021	Teacher training course on ROAR I Catania
Nov 2021 – Mar 2022	PCTO based on ROAR I Enna
Jan – Apr 2022	Implementation of ROAR II Iseo
Apr 2022	ROAR I on ITED
Aug 2022	ROAR II at ODS 2022
Oct 2022	Teacher training course on ROAR I-II for **OPS4Math** Napoli
Oct 2022	ROAR I on IJMEST
Oct 2022 – Jan 2023	Implementation of ROAR III Iseo
Oct 2022 – Apr 2023	Teacher training course on ROAR I Catania
Nov 2022	ROAR at GiMAT22
Nov 2022	ROAR at 4th Scientix Conference
Dec 2022	ROAR at Convegno Nazionale Liceo Matematico

Feb – May 2023	Teacher training course on ROAR I-II 📍 Cernusco sul Naviglio
Apr 2023	PCTO based on ROAR I-II 📍 Milano Bicocca (PNRR)
Apr – Jun 2023	PCTO based on ROAR I 📍 Enna
Aug 2023	ROAR II on ITED 📄
Sep 2023	ROAR III at ODS 2023 🗣
Dec 2023	Submission of ROAR III on ITED 📄
Dec 2023	Invited seminar on ROAR at the Laboratorio FDS (Formazione e Sperimentazione Didattica) of PoliMI 🗣
Dec 2023 – Jun 2024	PCTO based on ROAR I 📍 Catania
Mar 2024	ROAR on APDIO (invited) 📄
Mar – May 2024	Implementation of ROAR I 📍 Iseo (PNRR)
Apr 2024	PCTO based on ROAR I-II 📍 Milano Bicocca (PNRR)
Jul 2024	ROAR at EURO 2024 🗣
TBD 2024	ROAR on Nuova Lettera Matematica (invited) 📄
TBD 2025	Submission of a longitudinal study on ROAR 📄

Resources

Website [IT]: `https://sites.google.com/view/progettoroar`
Repository [IT/EN]: `https://github.com/aliceraffaele/ROAR`



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Thank you for your attention!