

An OR-based Teaching Unit for Grade 12: The ROAR Experience, Part III

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ODS2023
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The case study of Filtrec S.p.A.



Serie F040
In manica, Elettromotore



F050 Series
In manica, Elettromotore



FH250 Series
In manica, Elettromotore



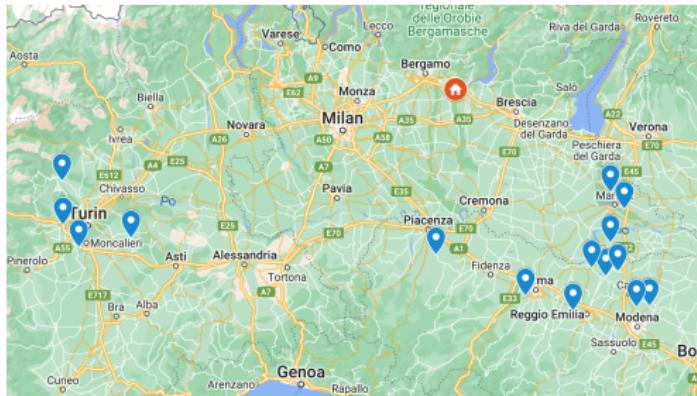
Serie F100
In manica, Elettromotore



FH100 Series
In manica, Elettromotore



Serie FD3
In manica, Elettromotore



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

Adaptations and simplifications...

- ▶ Filtrec-M1: one day, one depot, small subset of contractors, homogeneous vehicles, only delivery (avg values based on historical data);
- ▶ Filtrec-M1-bis: one day, one depot, small subset of contractors, homogeneous vehicles, only delivery (avg values based on historical data), **additional constraints**;
- ▶ Filtrec-M2: **multiple days**, one depot, small subset of contractors, homogeneous vehicles, only delivery (avg values based on historical data), additional constraints;
- ▶ Filtrec-M3: multiple days, one depot, small subset of contractors, homogeneous vehicles, **pickup and** delivery (avg values based on historical data), additional constraints;
- ▶ Other extensions.

...to make the problem suitable for Grade-12 students



Presentation at Filtrec S.p.A. headquarters on January 25th, 2023.

But how did we get there?

Ricerca Operativa Applicazioni Reali (ROAR)

Three-year project work that fitted into a
Path for Transversal Skills and Orientation (PCTO):



```
graph TD; A(( )) --> B(( )); B --> C(( )); C --> D(( )); D --> E(( )); E --> F(( )); F --> G(( )); G --> H(( )); H --> I(( )); I --> J(( )); J --> K(( )); K --> L(( )); L --> M(( )); M --> N(( )); N --> O(( )); O --> P(( )); P --> Q(( )); Q --> R(( )); R --> S(( )); S --> T(( )); T --> U(( )); U --> V(( )); V --> W(( )); W --> X(( )); X --> Y(( )); Y --> Z(( )); Z --> A; style A fill:none,stroke:none; style B fill:none,stroke:none; style C fill:none,stroke:none; style D fill:none,stroke:none; style E fill:none,stroke:none; style F fill:none,stroke:none; style G fill:none,stroke:none; style H fill:none,stroke:none; style I fill:none,stroke:none; style J fill:none,stroke:none; style K fill:none,stroke:none; style L fill:none,stroke:none; style M fill:none,stroke:none; style N fill:none,stroke:none; style O fill:none,stroke:none; style P fill:none,stroke:none; style Q fill:none,stroke:none; style R fill:none,stroke:none; style S fill:none,stroke:none; style T fill:none,stroke:none; style U fill:none,stroke:none; style V fill:none,stroke:none; style W fill:none,stroke:none; style X fill:none,stroke:none; style Y fill:none,stroke:none; style Z fill:none,stroke:none;
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ROAR I – Grade 10 (March – May 2021)

Mathematical modeling
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)

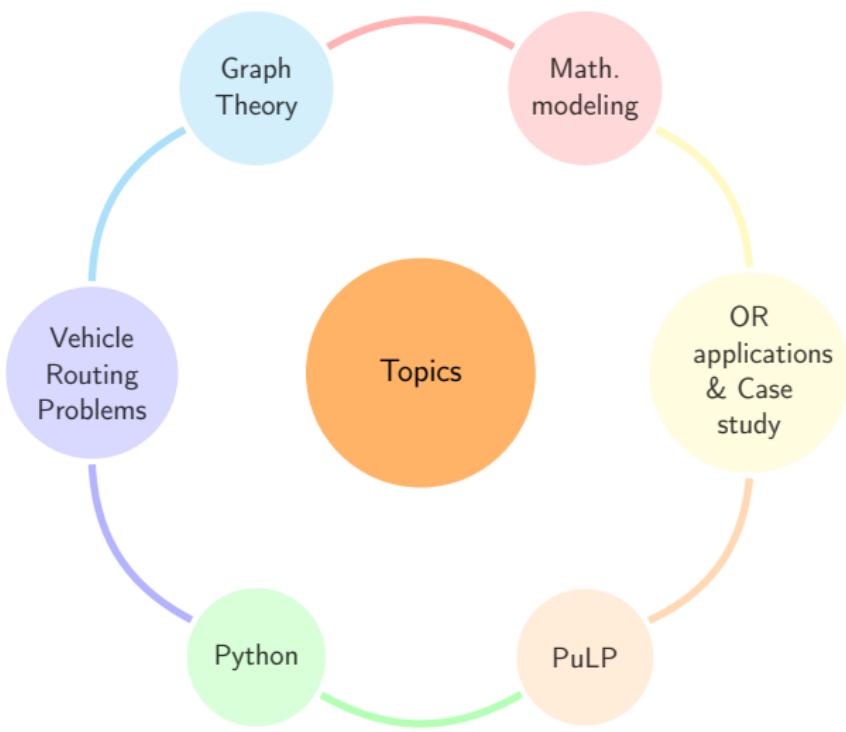
Implementation of mathematical models in Python
Resolution by means of PuLP
Digital technologies: + Spyder

In our experimentation: a classroom teacher (Marinella Picchi), two experimenters (Alessandro Gobbi and A.R.), and two observers (Gabriella Colajanni and Eugenia Taranto).

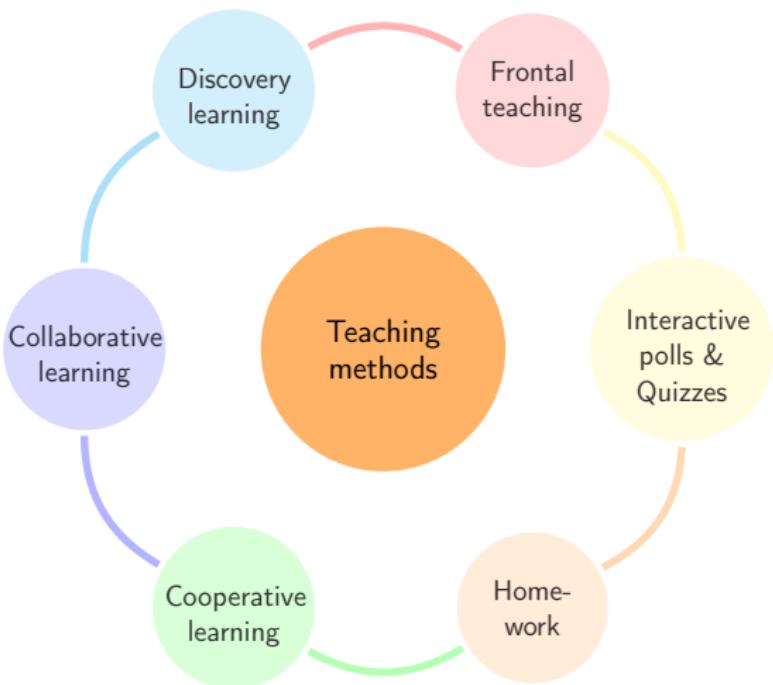
Design of ROAR III – Objectives

1. Teaching the fundamentals of the *Python* programming language
2. Teaching the usage of the Python library *PuLP*
3. Strengthening students' *programming skills*
4. Understanding and tackling an OR problem within a *business context*
5. Enhancing *mathematical modelling* skills and *graph theory* notions
6. Improving soft skills, such as problem-solving, teamwork, collaboration, cooperation, and public speaking

Design of ROAR III – Topics



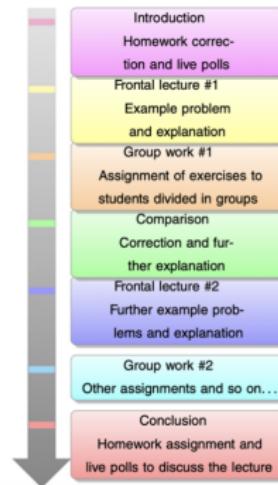
Design of ROAR III – Teaching methods



Implementation of ROAR III: October 2022 – January 2023

Calendar:

1. October 24, 2022 (4 hours) – Introduction to Python, PuLP, Colab, and Spyder



Optimization with PuLP

You can begin learning Python and using PuLP by looking at the content below. We recommend that you read The Optimization Process, Optimization Concepts, and the Introduction to Python before beginning the case-studies. For instructions for the installation of PuLP see [Installing PuLP at Home](#).

The full PuLP function documentation is available, and useful functions will be explained in the case studies. The case studies are in order, so the later case studies will assume you have (at least) read the earlier case studies. However, we will provide links to any relevant information you will need.

- Main Topics
 - » The Optimization Process
 - » Optimization Concepts
 - » Basic Python Coding
 - » Installing PuLP at Home
 - » Ansible
 - » README

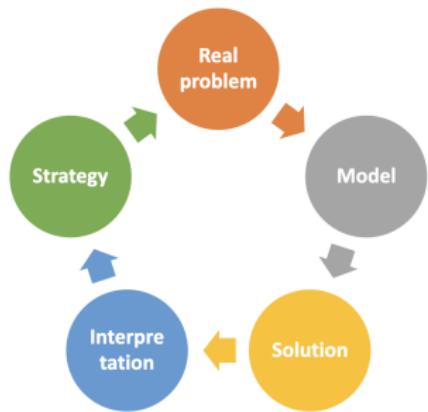


2. November 05, 2022 (5 hours) – Using ROAR I and ROAR II problems to introduce more Python and PuLP features

Implementation of ROAR III: October 2022 – January 2023

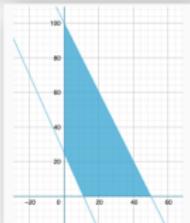
Calendar:

3. November 14, 2022 (5 hours) – Tackling old and new problems from their textual description to their Python+PuLP implementation, passing through their mathematical formulation



Problem description

A farm must determine how many hectares of land they can 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.



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

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

# Vincoli
model += 2*x_LNS + 2*x_POM == 100
model += 2000*x_LNS + 4500*x_POM == 50000

# Funzione obiettivo
model += x_LNS + x_POM

# Chiamata solver
model.solve()

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

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

Calendar:

4. November 26, 2022 (4 hours) – Presentation of the final project and a seminar + activities by **Stefano Bortolomiol (OPTIT S.r.l.)**



Implementation of ROAR III: October 2022 – January 2023

Classe 5^a LSSA
PROVA PRATICA PW ROARIII

Calendar:

5. December 03, 2022 (4 hours) – Work on the final project
6. December 19, 2022 (2 hours) – Summative assessment (valid for Maths & ICT)
7. January 25, 2023 (5 hours) – Final presentation at Filtrec S.p.A. headquarters

Gli organizzatori di un'importante conferenza internazionale devono decidere quali relatori far intervenire durante la giornata di apertura. Gli iscritti alla conferenza sono 15, ma non tutti potranno intervenire nella prima giornata: l'apertura dei lavori è prevista per le ore 9:00, mentre la chiusura alle ore 17:00, ma gli organizzatori vogliono riservare nella giornata 2 ore per un cocktail di benvenuto e mezz'ora per una coffee break nel pomeriggio. A ciascun relatore è stato chiesto di stimare il tempo (in minuti) necessario per il suo intervento. Gli organizzatori hanno poi valutato da 1 a 10 l'originalità di ciascun contributo. Tutte queste informazioni sono elencate nella tabella a lato.

id contributo	tempo stimato (min)	punteggio originalità
1	20	5
2	25	9
3	40	5
4	10	6
5	40	7
6	45	8
7	10	1
8	45	10
9	25	2
10	g+m/10	8
11	15	9
12	20	3
13	45	7
14	10	4
15	30	6

a) Formulare un modello di programmazione lineare intera che aiuti gli organizzatori a decidere quali interventi pianificare, massimizzando il punteggio complessivo di originalità degli interventi scelti, scrivendolo nello spazio sottostante.

VINCOLI

- BUDGETTI (SONO JS E EQUIVOCANO A 0 SE NON

SCELGO IL RELATORE MENTRE LO SELO (SCELGO)

VISUALIZZAZIONE

$\sum_{i \in \text{Relatori}} x_i * \text{TEMPO}_i \leq 330$ (QUESTO VINCOLO RAPPRESENTA CHE LA SOMMA DEI TEMPI DEI RELATORI SCELTI NON DEVE SUPERARE IL TEMPO A DISPOSIZIONE. IL TEMPO È 330 MINUTI PERCHÉ TOGNINI IL WELCOME DI BENVENUTO E IL BENVENUTO IL TEMPO DISPONIBILE DIVENTA DI 5 h 30 min ossia 330 minuti)

FUNZIONE OBiettivo

→ MASSIMIZZAZIONE → $\sum_{i \in \text{Relatori}} x_i * \text{ORIGINALITÀ}_i$ i.e Relatori

Final project of ROAR III



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

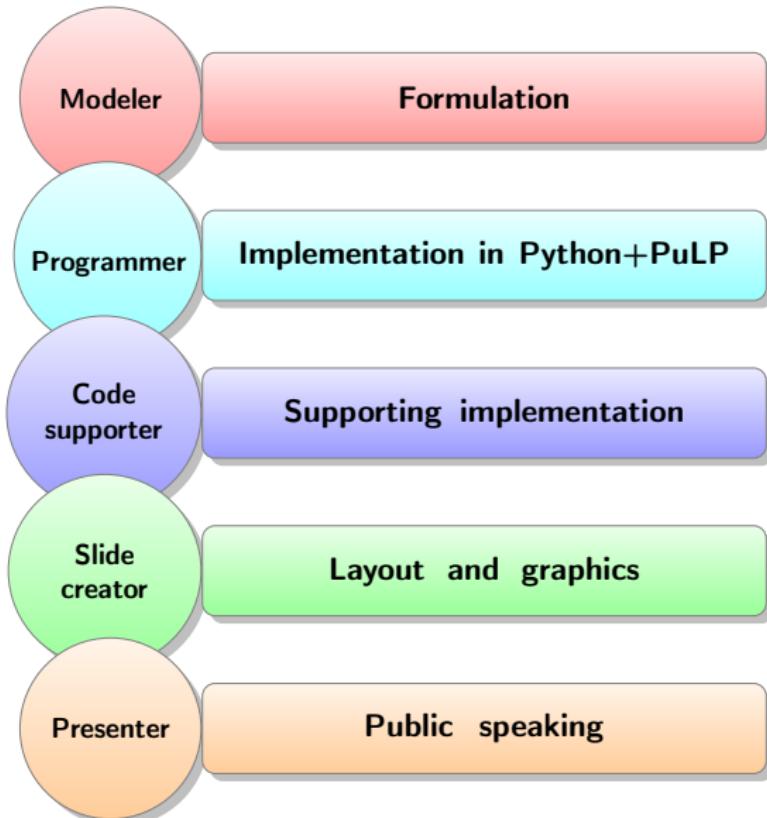
Again, students were divided into five groups, but this time these competed with each other in solving the same challenging problem



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

Students were divided into five groups and held specific roles within the group. Also, they joined forces with the experimenters to tackle a real industrial problem

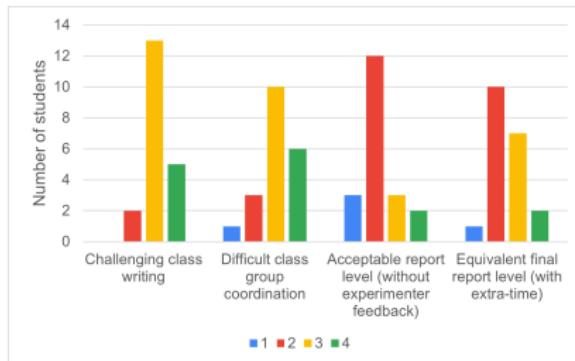
Final project of ROAR III – Roles inside each group



Final project of ROAR III – Interactions and results

Problem	Group 1	Group 2	Group 3	Group 4	Group 5	Experimenter's support
Filtrec-M1	✓	✓	✓	✓	✓	Correction in class
Filtrec-M1-bis	≠ vehicles for some contractors	Contractors with priority	Max # of contractors per vehicle	Same vehicle for close contractors	Max distance per vehicle	Feedback through email
Filtrec-M2	X	X	X	X	X	-

Groups had to cooperate to write a **final report** to be delivered to Emanuele Giliani (Filtrec operations manager). Their opinion about that:



From 1 (absolutely not) to 4 (absolutely yes)

Final project of ROAR III – Last meeting

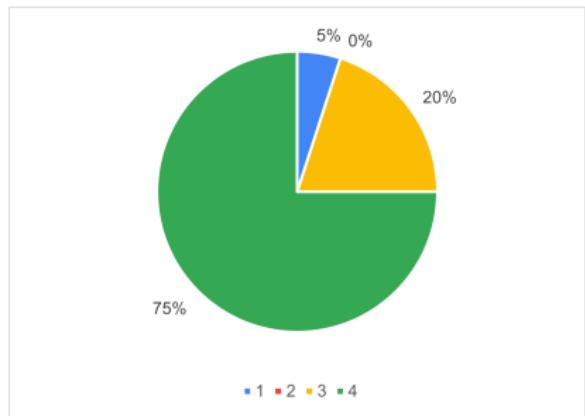
- ▶ Introduction to the company by Giacomo Modina (general manager) and Emanuele Giliani (operations manager)
- ▶ Final presentation by the Grade-12 class



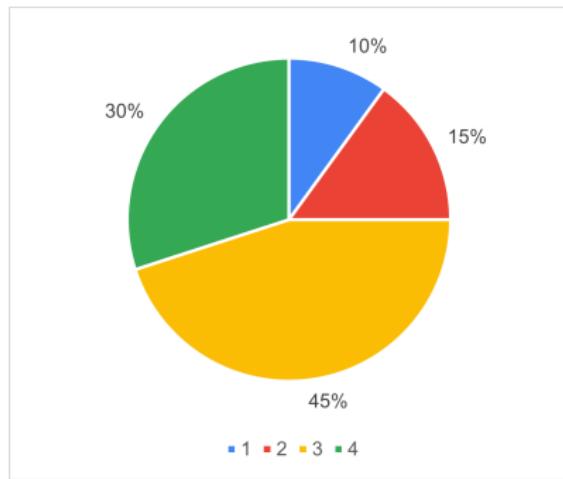
- ▶ Visit to the company factory and R&D department

ROAR III – Feedback from students

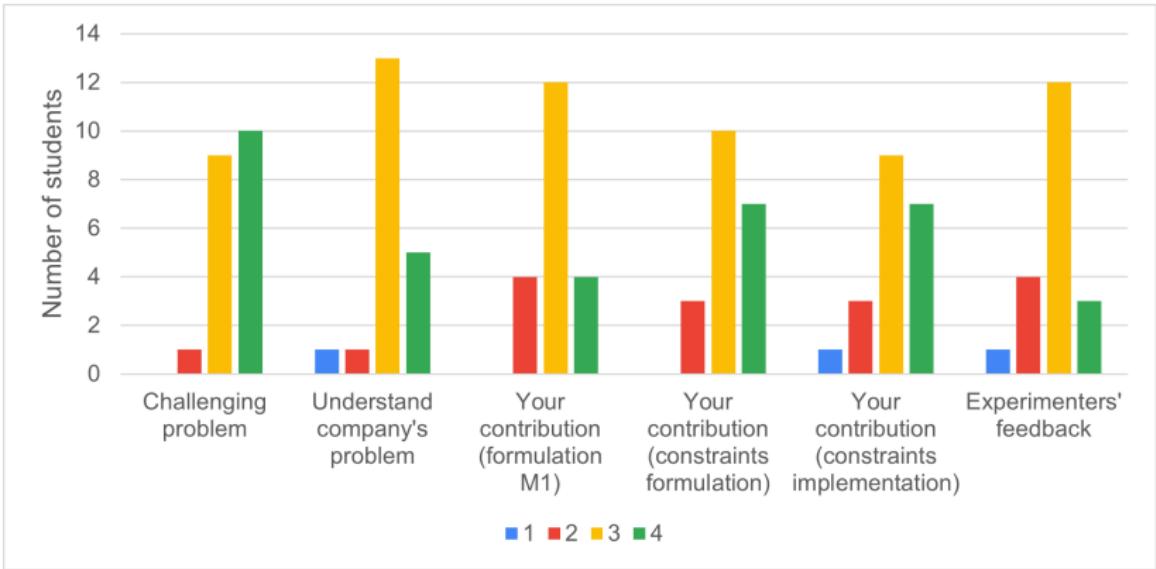
Appreciation of the visit to
Filtrec S.p.A.



Usefulness of studying the milk-run
problem before the visit

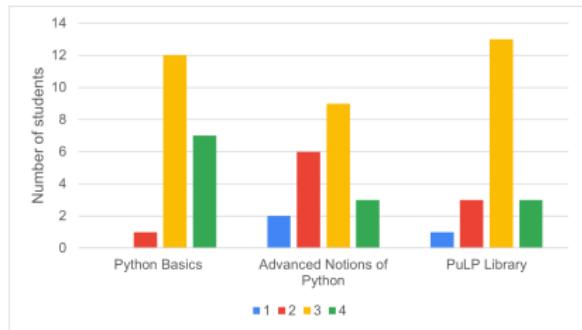


From 1 (absolutely not) to 4 (absolutely yes)



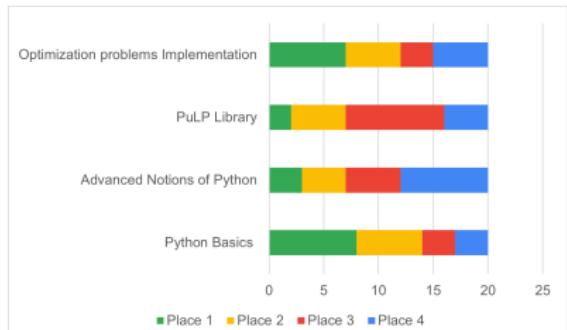
From 1 (absolutely not) to 4 (absolutely yes)

Understanding and application of Python and PuLP features



From 1 (absolutely not)
to 4 (absolutely yes)

Favorite topics of ROAR III



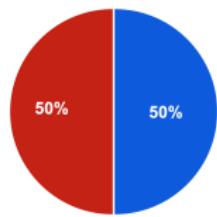
- ▶ **Emanuele Giliani (operations manager)**: “*An excellent example of how academic notions can find practical feedback within the industrial business. Students have demonstrated their ability to develop a concrete project, contextualize it, and present it to a potential end user. The project represented 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 – Feedback from teachers

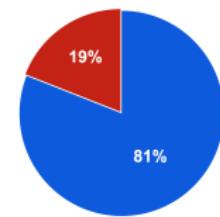
- ▶ **Maths:** “*ROAR has allowed to enhance students' different aptitudes through group work. The resolution of real problems also with the use of information technology has allowed students to understand the importance of mathematical modelling [...] Experimenters also became a guide for future university 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

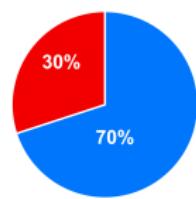
“Do you think what you learned during ROAR has changed or influenced the idea you had about mathematics and its applications in the real world?”



ROAR I



ROAR II



ROAR III

Timeline – Past and current work

- 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 
 - Sep 2023 • Submission of ROAR II on MTL 

Timeline – Future work

- Oct 2023 • Submission of ROAR III on ITED 
- Oct 2023 – Apr 2024 • PCTO based on ROAR I  Enna
- Oct 2023 – Apr 2024 • Teacher training course on ROAR I  Catania
- Feb 2024 • Invited seminar on ROAR at the Laboratorio FDS
(Formazione e Sperimentazione Didattica) of PoliMI 
- Mar – May 2024 • Implementation of ROAR I  Iseo (PNRR)
- Apr 2024 • PCTO based on ROAR I-II  Milano Bicocca (PNRR)
- TBD 2024 • Submission of a longitudinal study on ROAR 

Resources

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

Il team di ROAR

Siamo un gruppo interdisciplinare di giovani ricercatori e docenti, esperti in Ricerca Operativa e Didattica della Matematica.



Gabriella Colajanni

Università degli Studi di Catania

Educa alla Capacità a utilizzare la Ricerca Operativa e la Matematica e l'Informatica nell'Università degli Studi di Catania dove nel 2011 è stata assoggettata di ricerca e docenza a controllo. Ha conseguito un Dottorato di Ricerca in Matematica presso l'Università degli Studi di Catania. Svolge attività di ricerca nell'ambito della Ricerca Operativa. In particolare si è sia riconosciuta e finalizzata sui modelli di ottimizzazione circolante basati reti, reti di flussi con Memorie ROI, Supply Chain Network, Disegnatrice Venanziana, ottimizzazione lineare e non lineare, problemi di selezione dei percorimenti incrociati, problemi aspettativi.

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Alessandro Gobbato

Università degli Studi di

Alessandro Gobbato è laureato nel 2016 e post-laureato in Ingegneria dell'Informazione presso l'Università degli Studi di Catania. Presso lo stesso ente accademico è stato assistente didattico per il corso di "Ricerca Operativa". Insieme all'Ingegneria dell'informazione è stata anche coinvolto per il corso di "Informativa e Progettazione" dell'Ingegneria Meccanica e assoggettato di ricerca presso il Dipartimento di Ingegneria Meccanica e Aeronautica. Attualmente è assistente didattico per il corso di "Ingegneria dell'informazione" e della sua didattica. È stato anche coinvolto per il corso di "Ingegneria dell'informazione" e della sua didattica. È stato anche coinvolto per il corso di "Ingegneria dell'informazione" e della sua didattica.

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ROAR è un progetto didattico triennale rivolto a studentesse e studenti del triennio della scuola secondaria di II grado che mira ad accrescere il loro interesse e migliorare le loro abilità nelle discipline scientifiche attraverso la ricerca operativa.



Per scoprire di più sui ricercatori e le ricercatrici che lavorano a ROAR



Materiali

Per mettere a disposizione risorse da cui prendere spunto o da riutilizzare in altri progetti



Iniziative

Seminari per studentesse e studenti e corsi di formazione per docenti



Pubblicazioni

Presentazioni e articoli scientifici per approfondire i risultati ragionati dal team e dalle classi

Raffaele et al.

An OR-based Teaching Unit for Grade 12

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References

- ▶ Raffaele, A., Gobbi, A. (2021). **Teaching Operations Research Before University: A Focus on Grades 9–12.** *SN Operations Research Forum* 2, 13
- ▶ Colajanni G., Gobbi A., Picchi M., Raffaele A., Taranto E. (2022). **An Operations Research based Teaching Unit for Grade 10: The ROAR Experience, Part I.** *INFORMS Transactions on Education*.
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- ▶ Colajanni G., Gobbi A., Picchi M., Raffaele A., Taranto E. (2023). **An Operations Research based Teaching Unit for Grade 11: The ROAR Experience, Part II.** *INFORMS Transactions on Education*.
- ▶ Colajanni G., Gobbi A., Picchi M., Raffaele A., Taranto E. (2023). **Competitive versus collaborative learning: enhancing problem-solving skills through an optimization problem-based challenge.** *Mathematical Thinking and Learning* (submitted).
- ▶ Colajanni G., Gobbi A., Picchi M., Raffaele A., Taranto E. (2023). **An Operations Research based Teaching Unit for Grade 12: The ROAR Experience, Part III.** *INFORMS Transactions on Education* (working paper).



Thank you for your attention!