An OR-based Teaching Unit for Grade 10: The ROAR Experience, Part I

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Outline

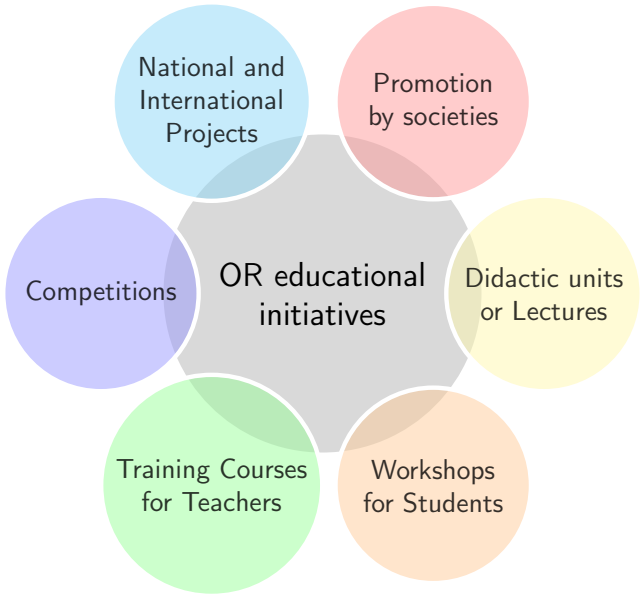
Previously on "*Teaching OR before University*"

Mar 2019	3rd AIROYoung Workshop: idea of a review
Sep 2019	ODS 2019: first preliminary results
Sep 2019 – Feb 2020	Activities for schools
Feb 2019	Collaboration with University of Catania
Jun 2019 – Sep 2020	Design of an OR-based teaching unit
Sep 2020 – Feb 2021	Design of ROAR
Feb 2021	5th AIROYoung Workshop: presentation
Mar 2021 – May 2021	Implementation of ROAR I

Review of OR-based initiatives addressed to Grade 9–12

A. Raffaele and A. Gobbi, *Teaching Operations Research Before University: A Focus on Grades 9–12*, Operations Research Forum 2(1):13, 2021:

- Collecting, classifying, and comparing 23 OR-based educational initiatives addressed to Grades 9–12.
- Looking for references to OR in international and national guidelines for mathematics education.



Review – Main results

- **Objectives and focus**: engage students' interest in problem solving and build awareness of OR.
- **Topics**: mostly mathematical modelling, Linear Programming and Graph Theory, plus applications.
- **Teaching methods**: constructionism, teamwork, cooperative learning, cases, project-based learning, games.
- **Instruments and material**: repositories of problems, books, tools, software (GeoGebra, Excel Solver).
- **Feedback**: very enthusiastic but some teachers encountered difficulties.

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*)

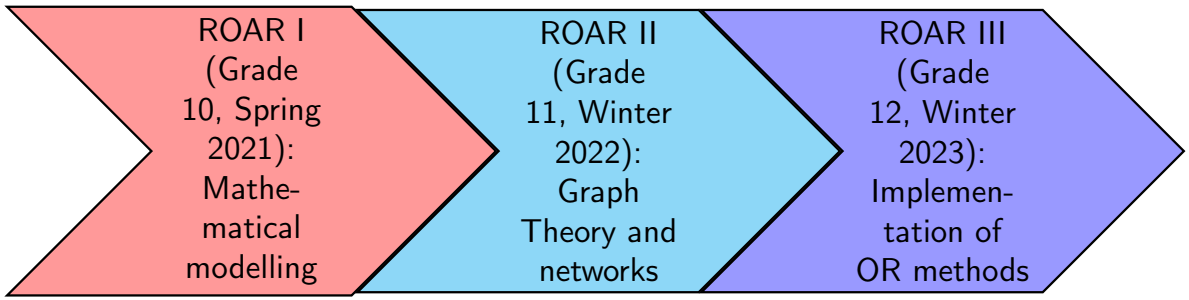
Outline

ROAR – Initial idea, issues, and COVID-19

- Together with Gabriella Colajanni and Eugenia Taranto (University of Catania), we developed an **OR-based teaching unit** addressed to Italian Grades 10-11, to be tested in 2020 in several classes from different Italian regions.
- Due to the **COVID-19** pandemic, we had to cancel/postpone several experimentations.
- Anyway, in March 2021, we could start our **first experimentation** in a Grade-10 class of the scientific high school IIS Antonietti at Iseo (Brescia), through an agreement between the institute and University of Brescia (Department of Industrial and Mechanical Engineering).

Ricerca Operativa Applicazioni Reali (ROAR)

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



- **Prerequisites**:
  - Mathematics: linear equations, linear inequalities, and some notions of analytic geometry, such as lines and families of straight lines, or plotting a function in a Cartesian coordinate system.
  - Digital technologies: at least familiar with Microsoft Excel and GeoGebra.
- **In our experimentation**: Grade-10 class composed of 16 males and 9 females.

ROAR I – Objectives

1) Introduce OR	Describe the origin and history of OR, increase its awareness, discuss its relevance and impact, show practical applications and classical problems studied in OR (e.g., knapsack, production, transportation, and assignment problems).
2) Mathematical modelling	Basic notions and definitions (e.g., *variables*, *constraints*, *objective function*, *model*, and *optimization problem*). Examples inspired either by a situation closely connected to students' everyday life or by the industrial reality.
3) LP-IP-MILP	Understand a textual description of a problem, identify the relevant data and translate these into a mathematical language, by applying the right paradigm to formulate a model.
4) OR methods	Discuss *brute-force methods* and *greedy algorithms*, introduce the *graphical method* to solve two-variable Linear Programming problems, mention to the Simplex method for problems with more than two variables.
5) Use of a solver	Tackle problems with more than two variables and develop *IT skills*.
6) Collaborative skills	Homework assignments (done individually) and exercises during the lectures (tackled by groups of students), to acquire *problem-solving* and *teamwork* skills in a *collaborative environment*.
7) Public-speaking skills	Assignment of an *authentic problem* as project and live presentation about its resolution at the end of the unit.

ROAR I – Instructors' roles

To develop the teaching unit, there must be at least one *experimenter* and a couple of *observers*.

Classroom teacher

- A teacher of the Grade-10 class.

Experimenter

- An OR expert who presents the teaching unit, in charge of leading the lectures.
- Assumed either by the classroom teachers or by some experts external to the class.

Observer

- Someone who attends the lectures and takes notes.
- Recommended to know OR, but not mandatory.

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

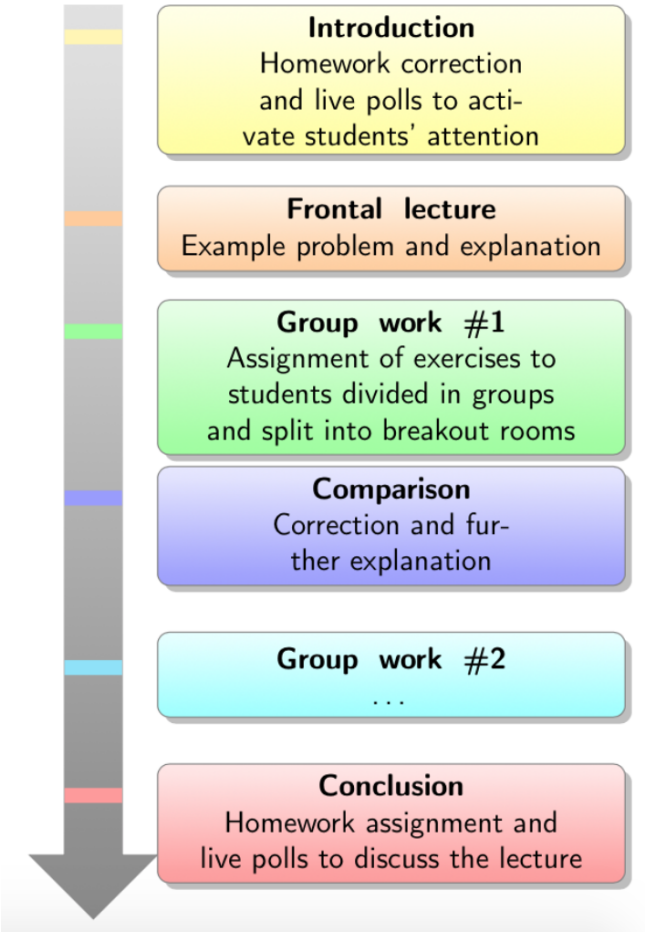
ROAR I - Lectures

Calendar:

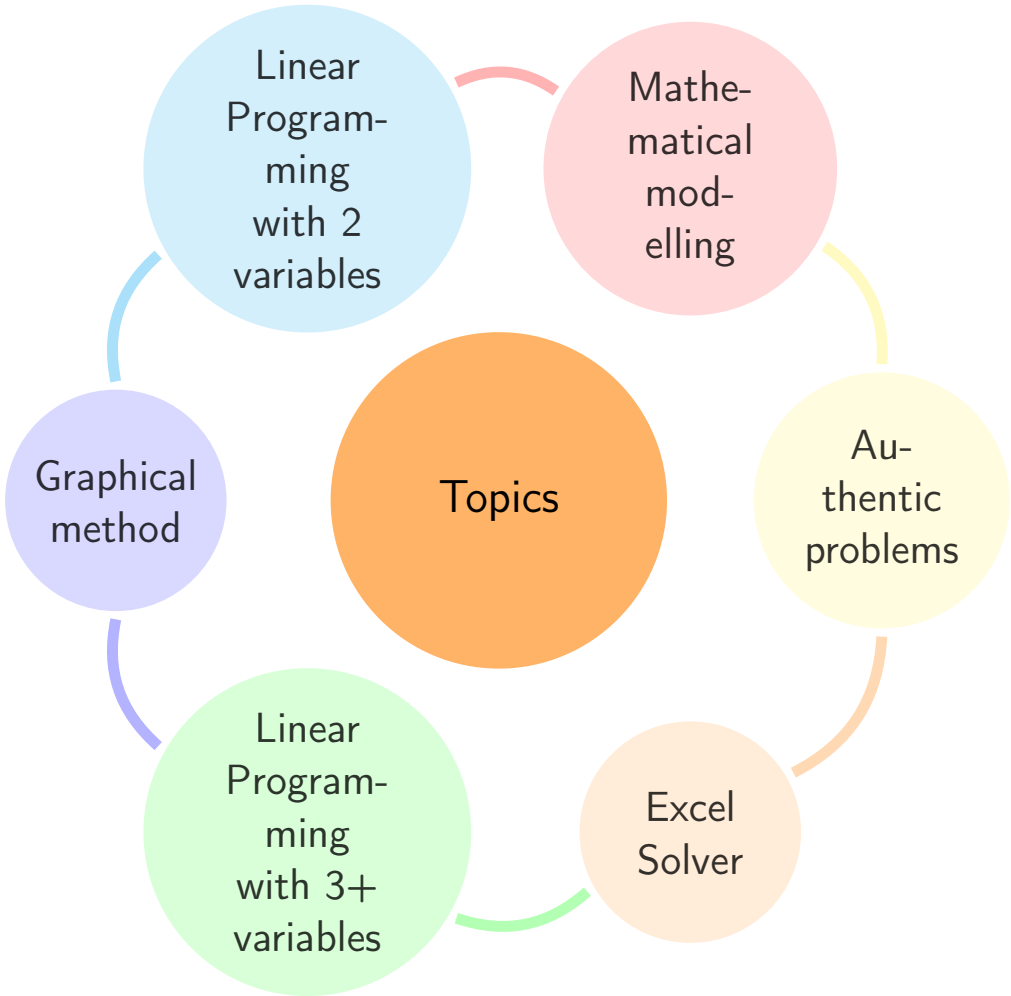
1. March 15 (5 hours)
2. March 27 (4 hours)
3. April 12 (5 hours)
4. April 24 (4 hours)
5. May 06 (2 hours)
6. May 13 (2 hours)

According to the pandemic emergency and the rules established by the Italian government, we had to rely on **distance learning** or blended form; only in the last lecture we were 100% onsite.

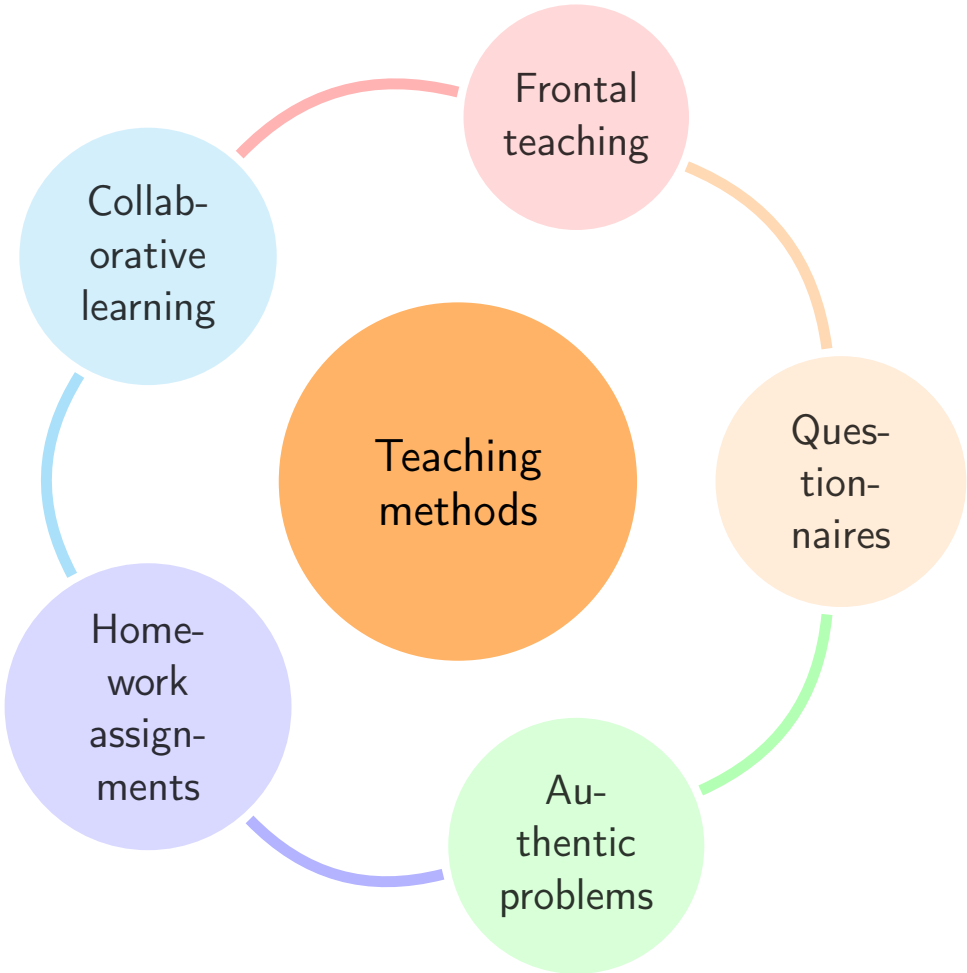
Template of a lecture:



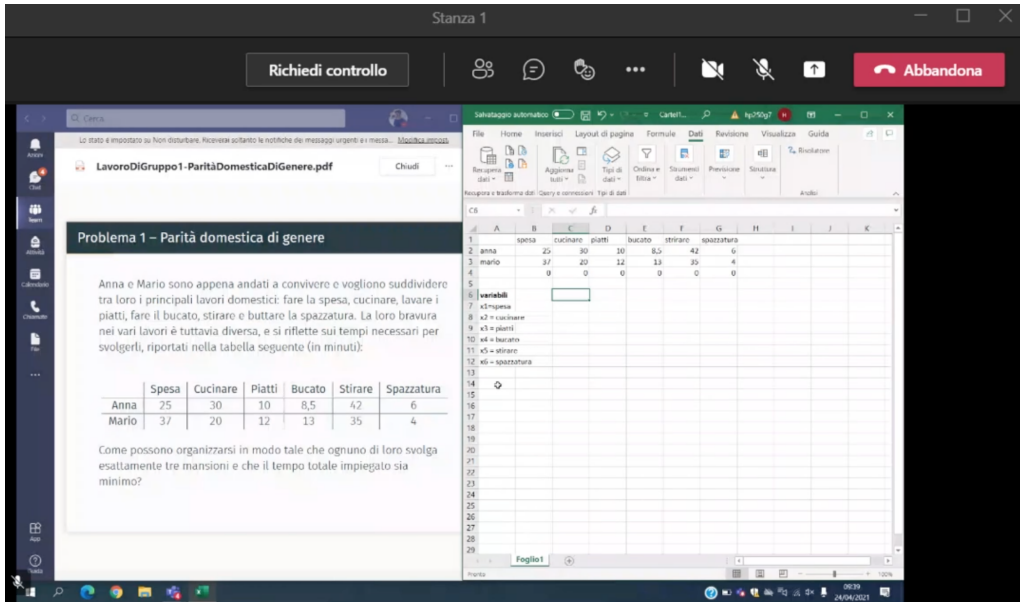
ROAR I – Topics

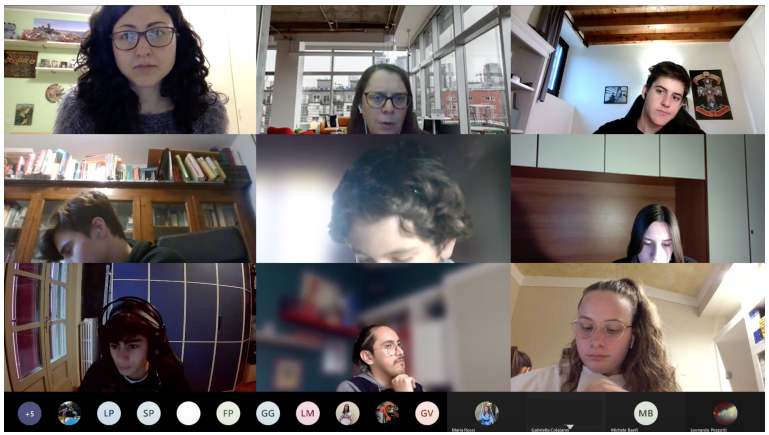


ROAR I – Teaching methods



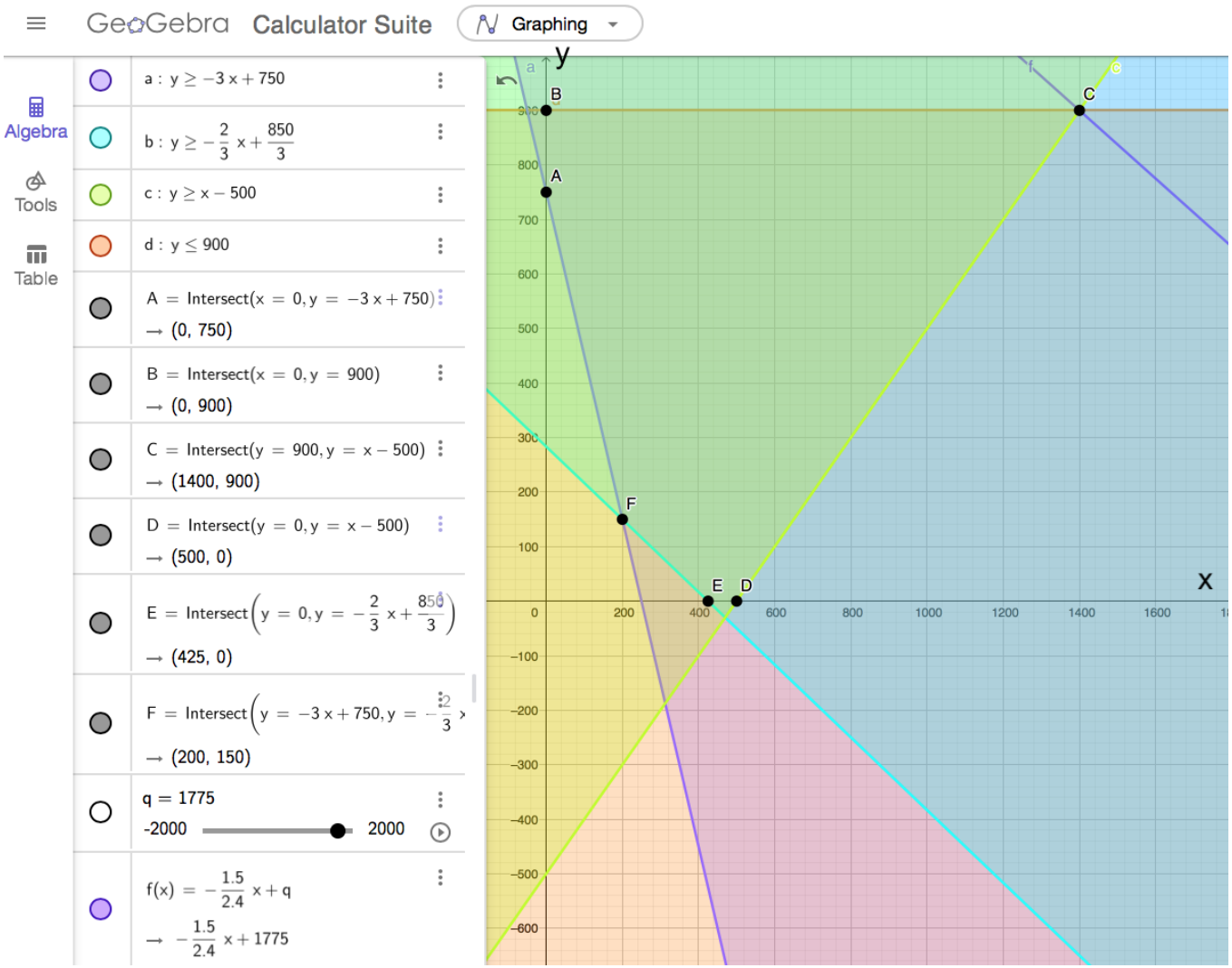
ROAR I - Distance group work



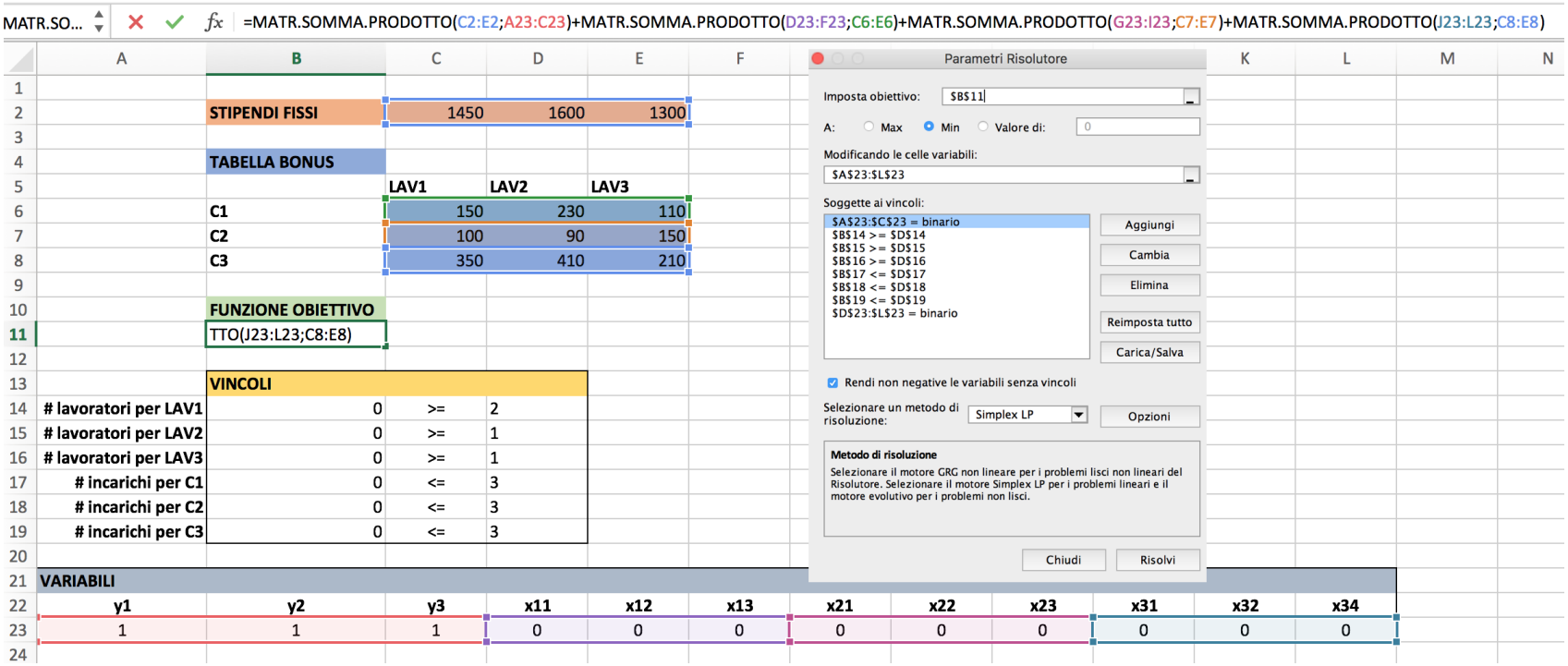


ROAR I – Digital technologies

GeoGebra

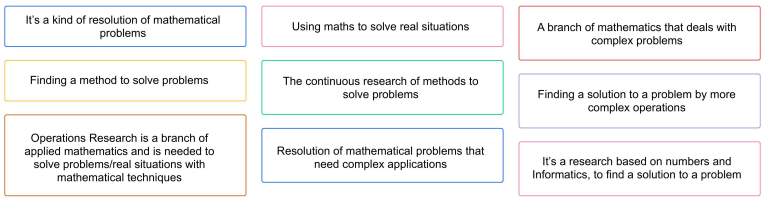


Microsoft Excel (Solver)

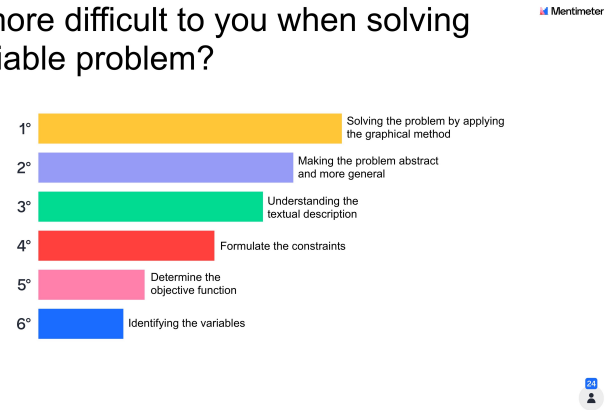


Mentimeter

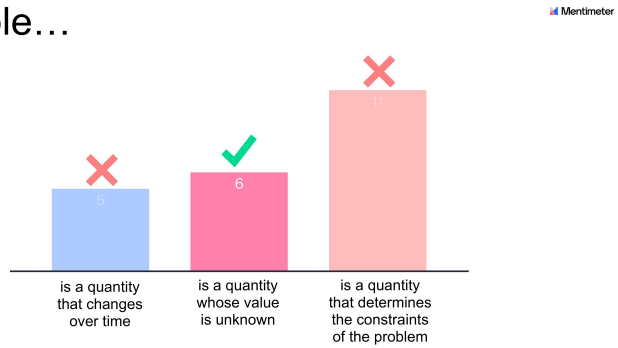
What do you think “Operations Research” is?



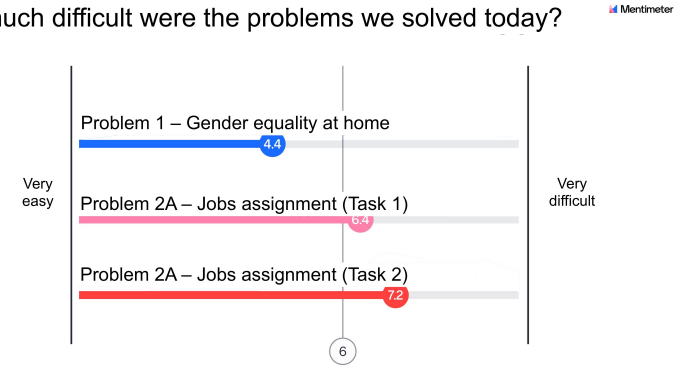
What is more difficult to you when solving a two-variable problem?



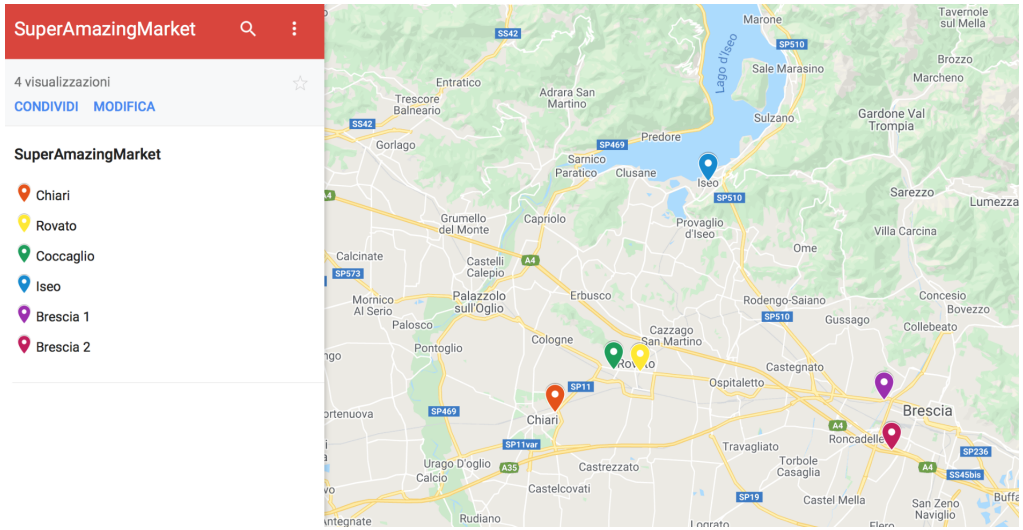
A variable…



How much difficult were the problems we solved today?



ROAR I – Authentic problems



"*Assume you are all members of the Operations Research area of SuperAmazingMarket, a supermarket chain in the province of Brescia. In particular, you are divided into five groups of five persons each. Every group will focus on solving a different problem related to the company activities. These problems are currently not being managed optimally, still being solved manually. In order to reach your goals, you are allowed to use the Internet and all the digital technologies you prefer. The results will have to be presented to the executive directors in the form of a presentation.*"

"*Every presentation has to include:*

- *an analysis of the problem description;*
- *a manual resolution to compute a feasible solution;*
- *the model formulation of the problem by applying Linear, Integer, or Mixed Integer Linear Programming;*
- *an implementation and resolution of the problem performed with Excel Solver;*
- *the textual description of an analogous problem that arises in a completely different context from the SuperAmazingMarket company.*"

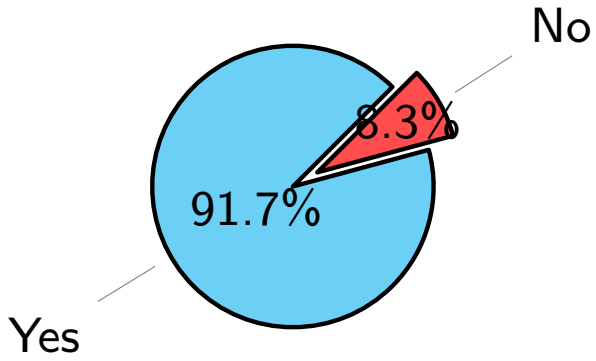
The **problems assigned** were about employees' shifts (*scheduling*), opening stores (*set covering*), cash funds (*cash management*), shelves management (*warehouse*), and gift baskets (*knapsack*).

ROAR I – Assessment

- Final presentation of authentic problems, **all solved**.
- Each group's presentation was evaluated in terms of:
  - group work;
  - analysis and deepening of contents;
  - knowledge and understanding;
  - exposition of the results.
- Each experimenter, each observer, and also the teacher graded each student by expressing a score from 1 (i.e., very poor) to 10 (i.e., excellent) for each aspect.
- Final score of a student = average of individual scores.

ROAR I – Feedback from students

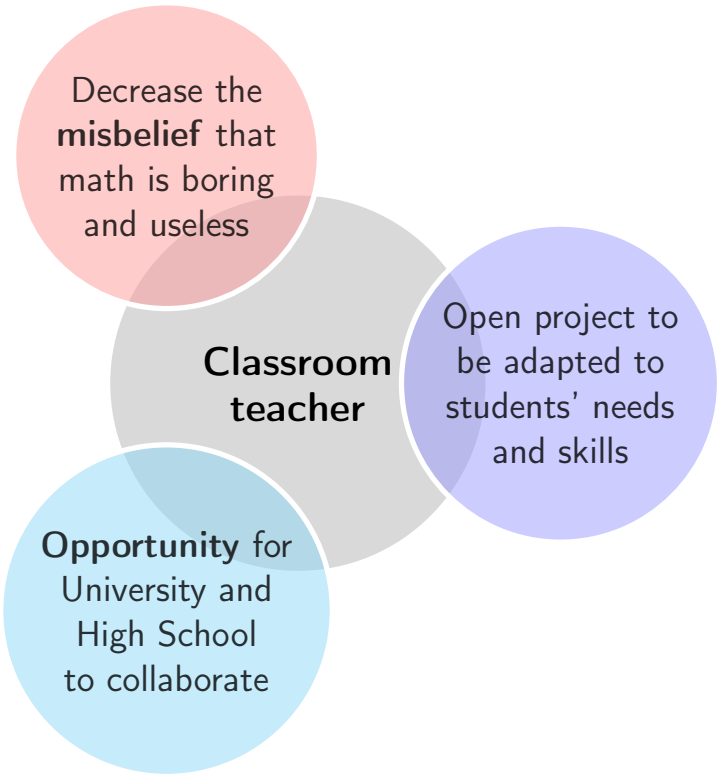
"Do you think that what you have learnt during this first year of ROAR will be useful to you in the future?"

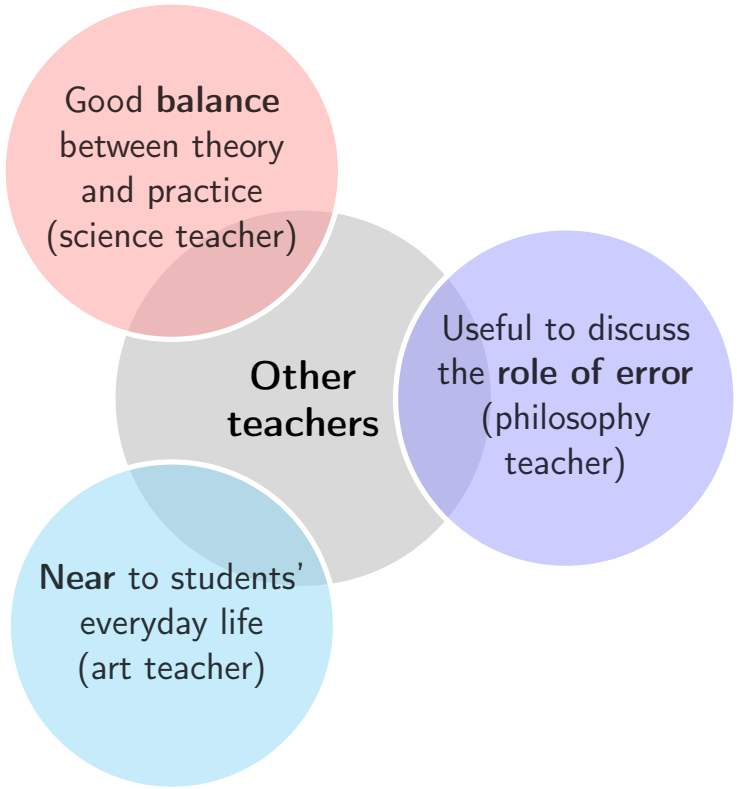


"ROAR gave me the chance to realize that mathematics and modelling are part of daily reality way more than I thought."

- *"We are now able to tackle some real situations that we could **not solve with just simple calculations**."*
- *"We could ascertain and experience that the theory learnt can be then concretized to face the real problems and needs of the working world. We moved **from just knowing to knowing what to do**."*
- *"This activity allowed us to always **work in teams**, confronting all the time and improving our relationships. Each of us could individually contribute to the resolution."*
- *"It helped us think **out of the box**."*

ROAR I – Feedback from teachers





On distance learning

Advantages:

- Opportunity for all observers to always attend the lectures, despite geographical distance.
- Greater number of observers than usual.
- Opportunity to record the lectures.
- Breakout rooms very suitable for work group.
- Live poll with Mentimeter.
- Sharing screens.

Disadvantages:

- Very much harder to bond with the class.
- Explanations more difficult to be followed by students, in terms of focus and attention.
- Webcam always on from Lecture 2, to be sure that students were following.
- From our side, very difficult time management, with pauses and technical issues to take into accounts.

Outline

Current work

G. Colajanni, A. Gobbi, M. Picchi, A. Raffaele, and E. Taranto, "*An OR-based Teaching Unit for Grade 10: The ROAR Experience, Part I*", INFORMS Transaction on Education (*working paper*).

Research questions from a didactic point of view:

1. Is it appropriate to include OR in ordinary mathematics lessons and thus propose complex authentic problems to students?
2. Do collaborative group work and the use of digital technologies foster students' development of modelling competence and the problem-solving process of authentic problems?

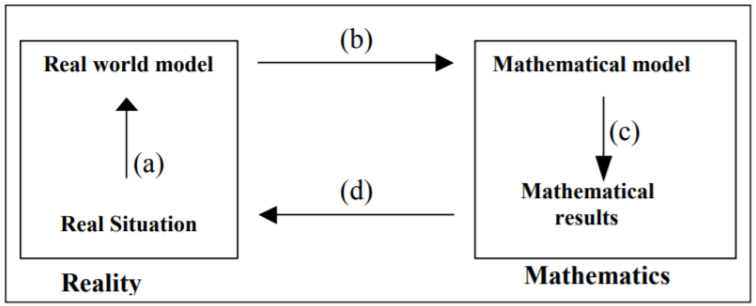


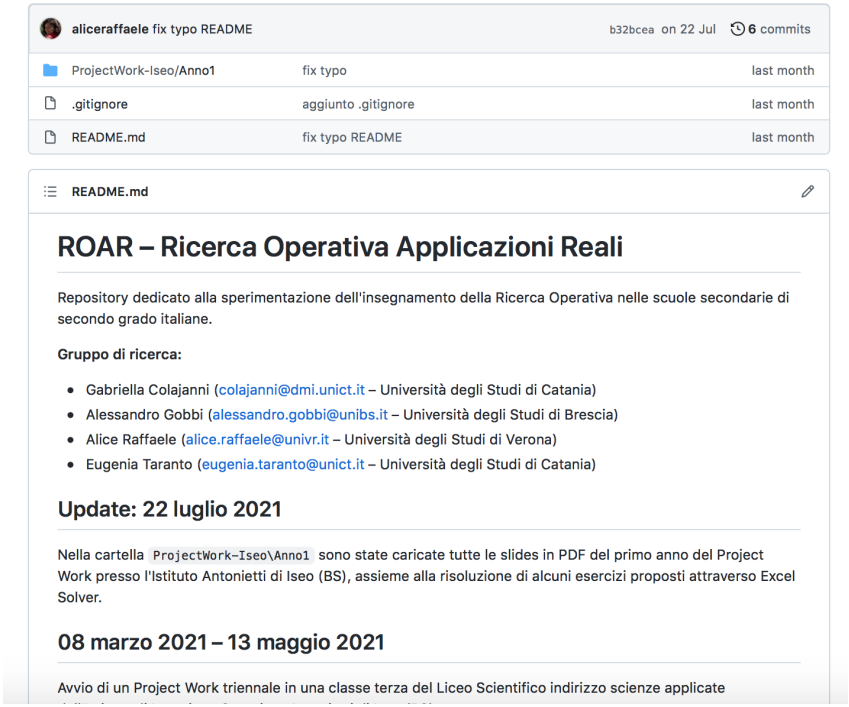
Figure: Modelling cycle (from Kaiser 1995, p. 68 and Blum 1996, p. 18).

3. In what ways do students feel that these activities have increased their understanding and appreciation of OR and/or Mathematics?

E. Taranto, G. Colajanni, A. Gobbi, M. Picchi, and A. Raffaele, "*Fostering students' development of modelling and problem-solving skills through Operations Research, authentic problems, and digital technologies in a collaborative environment*", Journal of Mathematical Education in Science and Technology (*working paper*).

Future work

- Winter/Spring 2022: **ROAR II**, addressed to the now Grade-11 class at IIS Antonietti.
- **Other experimentations** in other classes.
- **Repository** of all material related to ROAR to keep updated:



https://github.com/aliceraffaele/ROAR

A few references


Council of the European Union, *Council Recommendation of 22 May 2018 on key competences for lifelong learning*, Official Journal of the European Union, C 189/1, 2018.


Renato De Leone, Roberta Sagripanti, and Alberta Schettino, *La Ricerca Operativa nella scuola italiana e all'estero*, Periodico di Matematiche, Organo MATHESIS, 4(2):116–128, 2012.


Charles D. Garvin, *The potential impact of small-group research on social group work practice. Group work: Strategies for strengthening resiliency*, p. 51–70, 2001.


Gabriele Kaiser and Björn Schwarz, *Mathematical modelling as bridge between school and university*, ZDM, 38(2):196–208, 2006.


Gabriele Kaiser and Björn Schwarz, *Authentic modelling problems in mathematics education—examples and experiences*, Journal für Mathematik-Didaktik31(1):51–76, 2010.


Mogen Niss, *Applications and modelling in school Mathematics-directions for future development*, volume 3 (Development in School Mathematics Education Around the World), 1992.


Seymour Papert, Constructionism: *A New Opportunity for Elementary Science Education*, Massachusetts Institute of Technology, Media Laboratory, Epistemology and Learning Group, 1986.


Carlo Petracca, *Progetto Competenze. Progettare per competenze, unità di apprendimento, valutare e certificare, compiti di realtà*, Lisciani, Teramo, 2015.


Alice Raffaele and Alessandro Gobbi, *Teaching Operations Research Before University: A Focus on Grades 9–12*, Operations Research Forum 2(1):13, 2021.

Questions?