

# IDENTITIES

Enlightening  
Interdisciplinarity  
in STEM  
for Teaching



## QUESTIONING INTERDISCIPLINARITY WITHIN TEACHER EDUCATION: A MODULE ON THE EVOLUTION OF COVID-19 PANDEMIC

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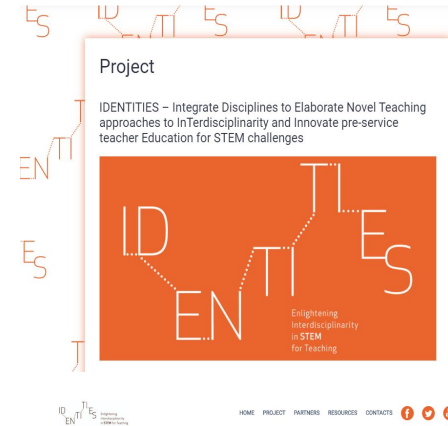
## Goals of the IDENTITIES project

*Integrate Disciplines to Elaborate Novel Teaching approaches to InTerdisciplinarity and Innovate pre-service teacher Education for STEM challenges*

**Design of innovative and transferable teaching modules** to be used in the context of teacher education

- with special focus on the **links between Physics, Mathematics and Computer Science.**
- to provide participants with **professional skills** to work on the analysis, design and implementation of **interdisciplinarity at secondary school.**

## IDENTITIES



<https://identitiesproject.eu/>

## Goals of the IDENTITIES project

Mixing and integrating different theoretical perspectives in mathematics, physics and computer science education.

- 1) **every discipline is valued** with its own epistemological and methodological identity
- 2) experts in didactics of each discipline are involved in a process of **co-design and co-teaching**
- 3) two **types of interdisciplinary topics**:
  - a) **Interdisciplinary curricular topics**
  - b) **Advanced STEM topics**

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## 1. Needs for preservice teacher education to approach interdisciplinarity

- Need of introducing students in scientific **activities asking for disciplines' interaction**
- Difficulties on **transposing into school the disciplinary interactions** that can be often observed in scholarly practices outside school (mathematical ecology, epidemiology, etc.) **and existence of important constraints in secondary school institutions** (prevalence of monodisciplinary curricula, their fragmentation, time restrictions, lack of new epistemologies in school for interdisciplinarity)



## 2. Interdisciplinary culture to build, that respects disciplinary identities

- Opportunities for **interdisciplinary research in education**
- Opportunity for **new school epistemologies** thanks to a new generation of teachers

## 2. Design of a teacher education instructional proposal for interdisciplinarity

### Main theoretical frameworks and tools

- As general methodology for the **design of teacher education instructional proposals**:
  - The **Study and Research Paths for Teacher Education** (SRP-TE) as proposed in the framework of the Anthropological Theory of the Didactics (ATD)
- As tools to be shared to analyse **disciplines and interdisciplinary relationships**:
  - **Taxonomy about interdisciplinarity** (Thomson Klein, 2010)
  - **Boundary objects and boundary crossing mechanisms** (Akkerman & Bakker, 2011)

## Interdisciplinarity

*Taxonomy of interdisciplinarity (Thompson Klein, 2017; 2010)*

“Multidisciplinarity involves encyclopaedic, additive juxtaposition or, at most, some kind of coordination, but it lacks intercommunication and disciplines remain separate [...]. **True interdisciplinarity is integrating, interacting, linking, and focusing.** [...]. Transdisciplinarity is transcending, transgressing, and transforming” (Thompson Klein, 2010) “transcends the scope of disciplinary worldviews through an overarching synthesis” (ibid., 2017)

“Interdisciplinary thinking is understood as the capacity to integrate knowledge and modes of thinking from two or more disciplines or established areas of expertise to **produce a cognitive advancement in ways that would have been impossible or unlikely through single disciplinary means**” (Crujeiras & Jimenez-Aleixandre, 2019).

## Interdisciplinarity and disciplines

The term “discipline” contains the Latin root “discere”, whose meaning is to learn. **Disciplines are re-organizations of the knowledge** with the scope of teaching it.

Students, whilst building their knowledge, should also develop epistemic skills, like problem solving, modelling, representing, arguing, explaining, testing, sharing, evaluating the correctness of a reasoning/an argument.

From this perspective, **disciplines can still play a relevant educational role**, provided that they are explicitly pointed out as **forms of knowledge organization historically developed and grounded on specific epistemologies**

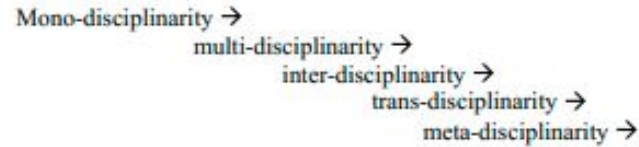
## FRA “wheel” (Family Resemblance Approach; Erduran & Dagher, 2014)





## From “Interdisciplinary mathematics education” handbook (Ch. 3 - Roth & Williams)

**Fig. 3.1** The spectrum of interdisciplinarity in problem solving, after Williams et al. (2016)



‘**interdisciplinary**’ mathematics involves various sorts of conjunction of mathematics with other knowledge:

- one or more **other disciplines** (e.g. when mathematics is used as a tool within a science)
- just **extra-mathematical, even ‘everyday’ knowledge** (as in mathematical modelling of traffic flows)

“Genuine ‘inter’ disciplinarity emerges, when **mathematics interacts with other disciplines to become something new and different** (e.g. when mathematics, statistics and sociology become a new, hybrid ‘quantitative reasoning’, or in mathematical-physics, and mathematical-biology).”

## From “Interdisciplinary mathematics education” handbook (Ch. 3 - Roth & Williams)

‘meta-disciplinarity’ : awareness of the nature of the discipline or disciplines involved.

- when one becomes **aware of the root disciplines**—including mathematics—in their relation and difference within inquiry, e.g. when the nature of ‘using evidence’ in history and in science becomes contrasted.
- the **epistemic qualities of the disciplines** become clearer, **conscious theoretical control** of the disciplines becomes possible.

This kind of **meta-knowledge** can emerge from **reflection on the relationship of mathematics or other disciplines with other knowledge** at any point on the above spectrum [...]

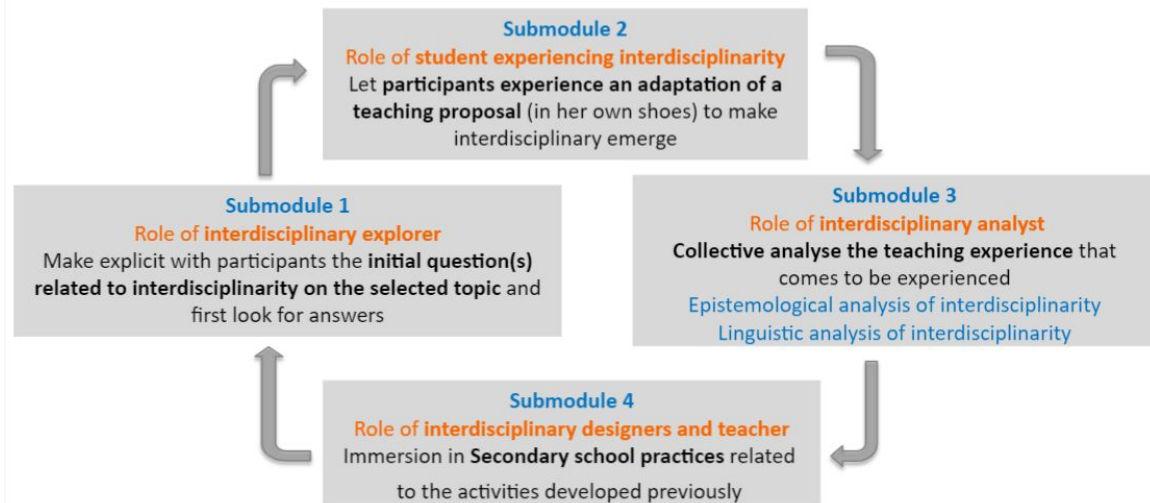
it may be desirable to think of a beyond-disciplinarity which is not only ‘meta’ in the above sense, but which we will term ‘**knowingly un-disciplined**’, i.e. **to some extent freed from the disciplines that bind problem-solving and inquiry to disciplinary norms and their limits** (Williams, 2016).

## The module structures: commonalities

The modules have a similar **general structure** described in terms of submodules, based on an adaptation of the SRP-TE model;

Participants are asked to adopt different roles:

- Becoming “explorers”
- Becoming “students”
- Becoming “analysts”
- Becoming “designers and teachers”



Adaptation of the submodules' structure of the Study and Research Paths for Teacher Education (Ruiz-Olarría, 2015; Barquero, Bosch & Romo, 2018)

## Study and research paths for teacher education (SRP-TE)

### ASSUMPTIONS CONCERNING SRP-TE

- SRP-TE could be an appropriate transition **didactic device** towards the **new pedagogical paradigm of questioning the world** (Chevallard 2015), avoiding a visiting works approach in TE
- TE programmes may take into account **professional questions** that emerge from the teachers' practice (Cirade 2006, Bosch & Gascón 2009), placing them at the core of TE programmes
- Introduce **didactic knowledge** as a tool to approach these professional questions and to raise new question, not a set of (dogmatic) answers

## Study and research paths for teacher education (SRP-TE)

Previous research shows how **SRP-TE seems to be useful** tool to:

- Enable teachers' **epistemological and didactic questioning of dominant paradigm** (What does it exist? What can it be done differently? What new epistemological and didactic tools are needed?)
- Transpose **research tools to teaching practice tools** for the epistemological and didactic analysis
- Help teachers **progress in the critical issue of identifying institutional constraints** hindering a **change of paradigm** in current school systems

## TE in the paradigm of questioning the world

The herbartian schema (Chevallard, 2004)

- Group of **students**  $X$  and study **supervisor(s)**  $Y$
- They start from a **question**  $Q_0$  (the ‘generating’ question)
- They should elaborate their own (collective) **answer**  $A^\heartsuit$  to  $Q$
- To elaborate  $A^\heartsuit$ , the didactic system is seen to create the milieu  $M$ :

The milieu is composed by **derived questions**  $Q$ , bodies of knowledge  $A^\diamond$  (**labeled answers**), other **works**  $W$  and **collection of data**  $D$ :

$$[ S(X; Y; Q_0) \curvearrowright M = \{A_1^\diamond, A_2^\diamond, \dots, A_m^\diamond, W_{m+1}, W_{m+2}, \dots, W_n, \cdot\} \hookrightarrow A^\heartsuit \\ Q_{n+1}, Q_{n+2}, \dots, Q_p, D_{p+1}, D_{p+2}, \dots, D_q \}.$$

## TE in the paradigm of questioning the world

- QUESTIONS:** What are the possible initial questions  $Q$ ? Where do they come from? How are they selected? Why are they to be approached? How to formulate them? What assumptions underlie their formulation? What new questions can be derived? Etc.
- ANSWERS:** What are the available answers  $A_j^\diamond$  for (in-service or pre-service) teachers? Where do they come from: didactics research, other disciplines, etc.? How are they made accessible (didactic transposition)? How are they validated? Etc.
- MILIEUS:** What possible milieus  $M$  can be used to deconstruct and reconstruct  $A_j^\diamond$  till obtaining  $A^\heartsuit$ ? Etc.
- ECOLOGY:** What conditions are needed to plan TE and to be carried out? How to set them up? What constraints hinder them? Etc.

## Initial questions related to interdisciplinarity to address as 'explorers'

### Submodule 1

#### Role of interdisciplinary explorer

Make explicit with participants the **initial question(s) related to interdisciplinarity on the selected topic** and first look for answers



- The initial questions can be of different nature:
- Closer to the role of the discipline and of their interaction related to the topic addressed in the module, such as:  
*How have the different disciplines address a certain topic? How have these disciplines interacted to address certain problems or questions related to the topic?*
  - Closer to the teaching profession, such as:  
*How can interdisciplinarity practice can be transposed into Secondary school classrooms?*



## Submodule 2

### Role of **student experiencing interdisciplinarity**

Let **participants experience an adaptation of a teaching proposal** (in her own shoes) to make interdisciplinary emerge



## Submodule 1

### Role of **interdisciplinary explorer**

Make explicit with participants the **initial question(s) related to interdisciplinarity on the selected topic** and first look for answers

## Experiencing interdisciplinarity under the role of student

- Participants are asked to work in groups and experience themselves some activities related to the interdisciplinary topic
- This work in groups requires an active participation working in group, reporting, exposing and debating your work
- This submodule is crucial to build together a shared *milieu* to 'talk' and 'analyse' (inter)disciplinary practice



### Submodule 1

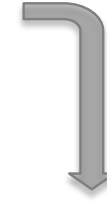
#### Role of **interdisciplinary explorer**

Make explicit with participants the **initial question(s) related to interdisciplinarity on the selected topic** and first look for answers

### Submodule 2

#### Role of **student experiencing interdisciplinarity**

Let **participants experience an adaptation of a teaching proposal** (in her own shoes) to make interdisciplinary emerge



### Submodule 3

#### Role of **interdisciplinary analyst**

**Collective analyse the teaching experience** that comes to be experienced

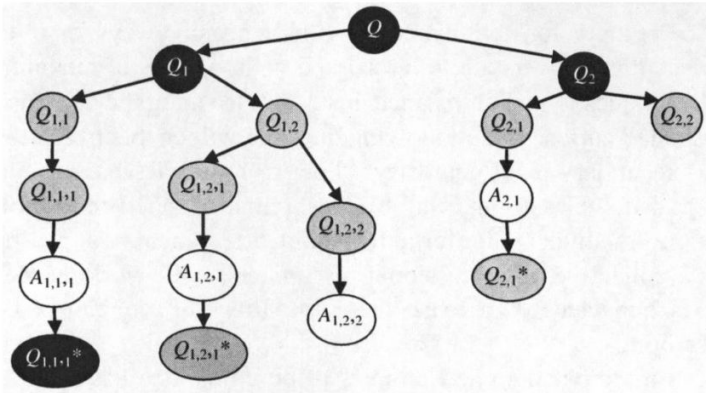
Epistemological analysis of interdisciplinarity

Linguistic analysis of interdisciplinarity



### Progression on the tools to become interdisciplinarity analyst

- Instruments to help and progress on the interdisciplinarity analysis: *Guides for the interdisciplinary analysis* or *Analytics grid for disciplinary and interdisciplinary features* or...
- Video recorded lecture + Q&A sessions



Winsløw, Matheron, & Mercier (2013). Study and research courses as an epistemological model for didactics. *Educational Studies in Mathematics*, 83, 267–284.

**Q:** You are given data showing the development of the size of a population of geese on an island, over a period of time. How can we predict its size at a later time?

**Q<sub>1</sub>:** ... discrete models, population size  $x_n$  given at times  $t = nt_0$  where  $t_0$  is fixed ("generation")

**Q<sub>1,1</sub>:** ... assuming that a generation depends only on the previous one :  $x_{n+1} = f(x_n)$

**Q<sub>1,1,1</sub>:** ... assuming constant relative growth:  $x_{n+1} = (1+k)x_n$

**A<sub>1,1,1</sub>:** Malthusian model,  $x_n = (1+k)^n x_0$

**Q<sub>1,1,1</sub>\*:** The answer  $A_{1,1,1}$  is unrealistic as growth is unlimited. How can assumptions be modified – what about other models of type  $x_{n+1} = f(x_n)$ , where  $f$  is a  $C^1$ -function?

**Q<sub>1,2</sub>:** ... assuming that the  $n$ th generation  $x_n$  depends on the  $d$  previous ones :  $X_{n+1} = f(X_n)$ , where

$$X_n = (x_{nd}, x_{nd+1}, \dots, x_{nd+d-1}) \in \mathbb{R}^d$$

**Q<sub>1,2,1</sub>:** ... assuming linear model  $X_{n+1} = AX_n$  where  $A$  is a  $d \times d$ -matrix

**A<sub>1,2,1</sub>:** After  $n$  periods:  $X_n = A^n X_0$

**Q<sub>1,2,1</sub>\*:** How does  $A^n$  behave? Stability as  $n \rightarrow \infty$ ?

**Q<sub>1,2,2</sub>:** ... assuming affine model  $X_{n+1} = AX_n + b$  where  $A$  is a  $d \times d$ -matrix and  $b \in \mathbb{R}^d$ , what happens?

**A<sub>1,2,2</sub>:** After  $n$  periods:  $X_n = A^n X_0 + \sum_{k=0}^{n-1} A^k b$  (stable as  $n \rightarrow \infty$  under some conditions)

**Q<sub>2</sub>:** ... continuous modeling the population size as a continuous function:  $x(t)$  where  $t$  is time

**Q<sub>2,1</sub>:** assuming constant relative growth:  $x'(t) = kx(t)$

**A<sub>2,1</sub>:** Exponential growth,  $x(t) = be^{at}$  (in particular, unlimited growth)

**Q<sub>2,1</sub>\*:** ... How about relative growth with upper bound:  $x' = kx(K - x)$  (logistic model)

**Q<sub>2,2</sub>:** How about other continuous models, like  $x' = f(x, t)$ , or higher order ODE models?

**Fig. 2** Outline of SRC designed and experimented by Barquero et al. (2007)

## Akkerman & Bakker (2011)

Boundary people

Boundary object

Boundary crossing  
mechanisms

## Boundary object

- Ambiguous nature
- Interpretative flexibility
- They belongs to *both* one world *and* another (multivoicedness)
- They also reflects a nobody's land, belonging to *neither* one *nor* the other world (unspecified quality)

## Boundary crossing mechanisms

**Identification** (“What are the disciplinary contributions to the definition of the epidemiological models?”)

**Coordination** (“How can the shared concept of model establish a communicative connection between the disciplines involved?”)

**Reflection** (“Has the interaction among the disciplines at the boundary enriched the disciplines?”)

**Transformation** (“Has the disciplines’ interaction on epidemiological models contributed to found interdisciplinary modelling practices?”).

## Online International Summer school in June 2021

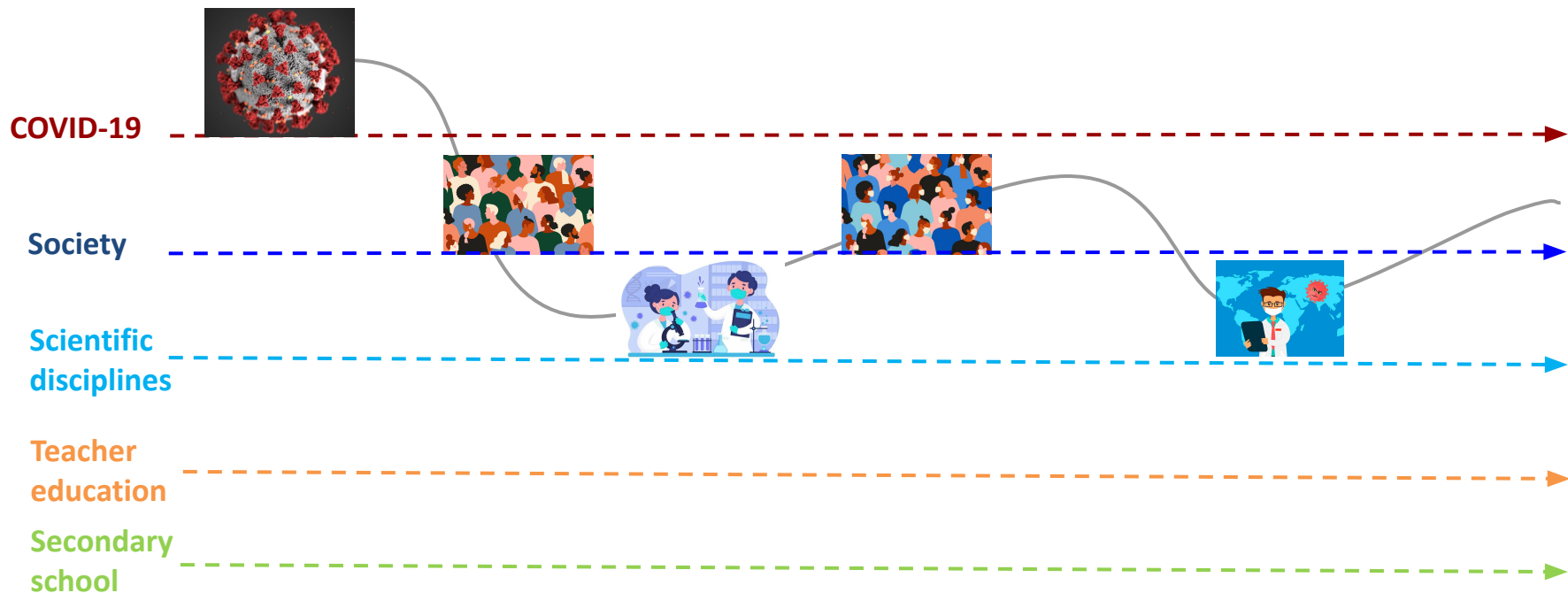
- two **types of interdisciplinary topics**:
  - **Interdisciplinary curricular topics**
  - **Advanced STEM topics**
- About two days and a half devoted to one module of each type of interdisciplinary topics
- Along each module implementation, experiencing and using some tools for the **epistemic** and **linguistic analysis of interdisciplinarity**.

Online IDENTITIES Summer School 2021

admin - News, Research, Teaching - April 20, 2021



## Interdisciplinarity at the service of the Society: decoding COVID-19 evolution





## Research questions

RQ1) Which questions can be formulated to promote interdisciplinary reflections on the topic of COVID-19 evolution?

RQ2) Through which kind of activities can these questions be posed to prospective teachers to address the topic of COVID-19 evolution from an interdisciplinary perspective?

## RQ1) Which questions can be formulated to promote interdisciplinary reflections on the topic of COVID-19 evolution?

1) **Topic-specific questions (TSQs)**, related to the issue under study:

*How can we characterize the evolution of COVID-19 in Spain or in Italy in 2020? What can be done to make the vaccination campaign against COVID-19 effective?*

2) **Meta-reflection questions (MRQs)**, that aim to trigger a deeper epistemological reflection on the TSQs (epistemological focus is on interdisciplinarity, identifying the disciplinary contributions as well as the ways in which disciplines interact):

*How have the different disciplines contributed to the societal understanding of the evolution of COVID-19?*

*On which levels have the disciplines interacted facing this challenge? Are there disciplines more legitimated to address some particular questions than others? Have the disciplines changed through their interaction?*

## Research questions

RQ2) Through which kind of activities can these questions be posed to prospective teachers to address the topic of COVID-19 evolution from an interdisciplinary perspective?

### Submodule 1

#### Role of interdisciplinary explorer

Make explicit with participants the **initial question(s) related to interdisciplinarity on the selected topic** and first look for answers

Science and interdisciplinarity  $\longleftrightarrow$  Society  
 $\longleftrightarrow$  Teacher Education  $\longleftrightarrow$  Secondary school

### Initial questions related to interdisciplinarity Interpreting the evolution of COVID-19

Q<sub>0.1</sub>: How have the S-T-E-M disciplines interacted to investigate the evolution of COVID-19? What answers have been given and how have their advances spread to society?

Q<sub>0.2</sub>: What role has each discipline play and how can we analyse interdisciplinarity when addressing complex issues related to the evolution of COVID-19?

Q<sub>0.3</sub>: How can this interdisciplinary practice transposed and disseminated into secondary schools?

## Submodule 1

### Role of interdisciplinary explorer

Make explicit with participants the **initial question(s) related to interdisciplinarity on the selected topic** and first look for answers

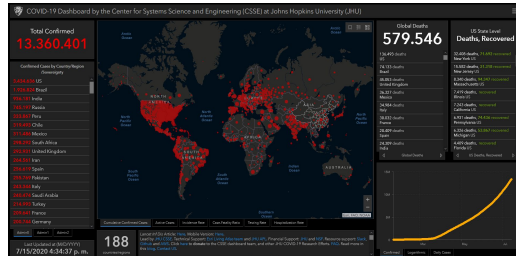
Science and interdisciplinarity  $\leftrightarrow$  Society  
 $\leftrightarrow$  Teacher Education  $\leftrightarrow$  Secondary school

Teacher education for interdisciplinarity  
 Module about modelling coronavirus evolution

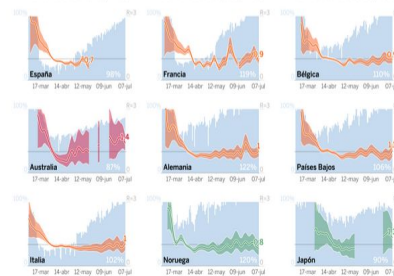
## Activity proposed in submodule 1, as interdisciplinary explorers

- Analysis of a selection of news about the scientific contributions to the understanding of COVID-19 evolution

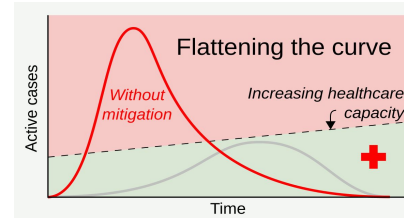
March 2020



What is the number of confirmed cases of COVID-19 in different countries? What does it mean that number of infected people grow exponentially?

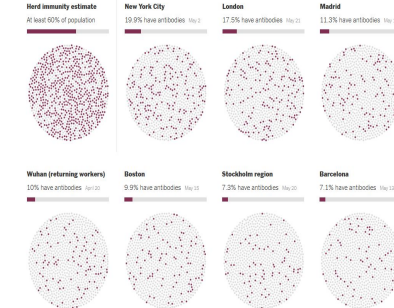


What is R? Which models are used? How is R defined?



How to forecast when will the curve reach its maximum? What does it mean to flatten the curve?

June 2021



What model simulation can tell us about effects do the different socio-political decisions

### Submodule 1

#### Role of **interdisciplinary explorer**

Make explicit with participants the **initial question(s) related to interdisciplinarity on the selected topic** and first look for answers

Science and interdisciplinarity  $\longleftrightarrow$  Society  
 $\longleftrightarrow$  Teacher Education  $\longleftrightarrow$  Secondary school

Teacher education for interdisciplinarity  
Module about modelling coronavirus evolution

## Activity proposed in submodule 1, as **interdisciplinary explorers**

- Analysis of a selection of news about the scientific contributions to the understanding of COVID-19 evolution
- Collecting students' answers through the **1<sup>st</sup> guide of analysis of interdisciplinarity**
  - Which have been the **main questions** that the research community has been addressing?
  - Which **disciplines** can be detected that have contributed to the discussion?
  - Which **tools and disciplinary knowledge** can be detected through the answers provided?
  - Which **specific terminology** was used for the dissemination of the questions addressed and answers provided? Which was known, which one new?
- Group discussion on the **evolution of different issues** asked in the 1<sup>st</sup> analysis of ID

#### Collection of news

- News 1** - More than 599,000 people have died from coronavirus in the US - [Actualized]  
<https://www.washingtonpost.com/graphics/2020/national/coronavirus-us-cases-deaths/>
- News 2** - Coronavirus: How maths is helping to answer crucial covid-19 questions - (13/02/2020)  
<https://www.newscientist.com/article/2233386-coronavirus-how-maths-is-helping-to-answer-crucial-covid-19-questions/#ixzz6x1fRkAsI>
- News 3** - How epidemics like covid-19 end (and how to end them faster) - (20/02/2020)  
[https://www.washingtonpost.com/graphics/2020/health/coronavirus-how-epidemics-spread-and-end/?hpid=hp\\_graphics\\_pop\\_b](https://www.washingtonpost.com/graphics/2020/health/coronavirus-how-epidemics-spread-and-end/?hpid=hp_graphics_pop_b)
- News 4** - Why outbreaks like coronavirus spread exponentially, and how to "flatten the curve" - (14/03/2020)  
<https://www.washingtonpost.com/graphics/2020/world/corona-simulator/>
- News 5** - Mathematics of life and death: How disease models shape national shutdowns and other pandemic policies - (25/03/2020)  
<https://www.sciencemag.org/news/2020/03/mathematics-life-and-death-how-disease-models-shape-national-shutdowns-and-other>
- News 6** - Mathematical models help predict the trajectory of the coronavirus outbreak. But can they be believed? - (3/05/2020)  
<https://www.seattletimes.com/seattle-news/health/mathematical-models-help-predict-the-trajectory-of-the-coronavirus-outbreak-but-can-they-be-believed/>
- News 7** - When it rains it pours: COVID-19 exacerbates poverty risks in the poorest countries - (4/05/2020)  
<https://unctad.org/news/when-it-rains-it-pours-covid-19-exacerbates-poverty-risks-poorest-countries>
- News 8** - Five ways to ensure that models serve society: a manifesto - (24/06/2020)  
<https://www.nature.com/articles/d43586-020-03812-9>

## Submodule 1. Role of interdisciplinary 'explorer'

- **Big group sharing:**
  - Participants report the results of their analysis on the news - vertical analysis of the MIRO board.
  - If you see any relation between your analysis and the analysis presented of any of the news, please share these thoughts with the rest of participants.
- **Group discussion** about the **evolution of the news throughout time** - horizontal analysis of the MIRO board
  - Evolution on the questions addressed
  - Evolution on the S-T-E-M disciplines intervening
  - Evolution on the answers provided
  - Evolution on the tools and disciplinary knowledge
  - Evolution on the specific terminology





**“HOW MANY”**  
questions

Issues of **quantity**

about numbers of the epidemics:  
number of cases, deaths, countries,  
vaccinations...

**“WHY”**  
questions

Issues of **explanation**

exponential increase of the curve,  
modelling the epidemic, second wave

**“WHAT/HOW”**  
questions

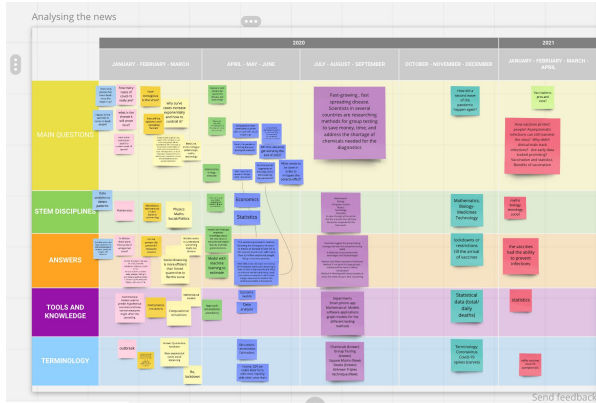
Issues of **description**

about the nature of the disease: infectivity,  
what happens to asymptomatics, what  
protection do vaccine provide

**“WHAT TO DO”**  
questions

Issues of **decision-making**

testing, creation of models for  
prediction, vaccination strategies



## About the disciplines intervening and their interaction

- Most of questions were difficult to be addressed by only one discipline, most of them call for the interaction among disciplines
- What, who and how a discipline is defined?

## About the the tools, knowledge and terminology used

- Important “key-word” were detected
  - Raw data
  - Validity of data
  - Models
  - Simulation of models
  - Simulation of scenarios
  - Predictions
  - Contrast and validation of the simulation against reality
  - ... among others....

- **About the evolution on the disciplinary tools and knowledge**

- Mathematical models
- Use of mathematical models to predict hypothetical scenarios and to know how control measures might affect the spreading
- Mathematical simulations / Computational simulations
- Approach / Explicit and Implicit assumption / Uncertainty
- Economic models / Mathematical models / Other models / Validation / Contrasting
- Experiments / Mathematical Models / Software applications / Graph models for the different testing methods
- Statistical data (total/ daily deaths)

**model as a  
key-word**

## Submodule 2

### Role of **student experiencing interdisciplinarity**

Let **participants experience an adaptation of a teaching proposal** (in her own shoes) to make interdisciplinary emerge, **distributed into some particular “lines of inquiry”** about the Covid evolution

- Work in group on the three lines of ID inquiry (4 students each) following the guides [2h]
- Preparation of the group sharing [30 min]

### 1<sup>st</sup> interdisciplinarity line of inquiry.

**Delimiting the system to look at and formulate hypothesis about the behaviour and evolution of the pandemic**

What can data reveal about the evolution of COVID-19? What hypothesis can we address? How data can help us to enquire into our hypothesis?

### 2<sup>nd</sup> interdisciplinarity line of inquiry.

**The role of models in studying the evolution of the pandemic**

What is the role of models and of modelling in investigating the evolution of COVID-19? Which are the aims and uses that we can give to models?

### 3<sup>rd</sup> interdisciplinarity line of inquiry.

**Simulating scenarios to make decisions on social restrictions**

How can computational simulations support decision-making processes about future actions in the context of the pandemic (from political, economic, medical, etc. perspectives)? What is their validity and function?

## 2<sup>nd</sup> interdisciplinarity line of inquiry

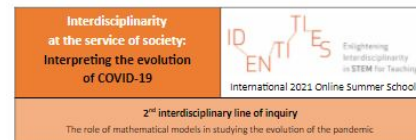
### The role of mathematical models in studying the evolution of the pandemic

#### Main question to address

What is the role of models and modelling in investigating the evolution of COVID-19?

#### Available media and resources

- Worksheet explaining the 2nd interdisciplinarity line of inquiry
- Databases:
  - First\_Wave\_Data.xlsx (February\_March\_April; Early\_May)
- Two videos to learn the basics of Excel and GeoGebra works
- Presentation template to expose your work



#### INTRODUCTION

The emergence of the COVID-19 pandemic has put the scientific community in the spotlight of society as a whole. Their studies have been one of the main tools for establishing measures to address the situation and have had a direct impact on daily life. Good examples are statistical analyses to extract relevant information from data, the development of mathematical models to make predictions, and computational simulations to understand virus diffusion.

In this second submodule we will focus on the second topic: **modelling to make predictions**. Based on the evolution of the number of COVID-19 infections accumulated in Spain during the first wave, we propose that you model these data with the goal to make predictions for the days following the first wave.

The generative question of the module that will guide your investigation as students in this interdisciplinarity line is the following:

*What is the role of models and modelling in investigating the evolution of COVID-19?*

#### PART 1: Presentation of the interdisciplinarity line of research

To get started, we suggest you answer these questions in order to define a little bit the task proposed:

*What does it mean to model some data?*

*What is a model? What is a "good" model? What would be a "good" model for understanding the evolution of COVID-19?*

*What can be the goals of modeling some data? That is, what do we intend to study when modeling the actual data on the evolution of COVID-19?*

#### PART 2: Research development

Once you have discussed the questions, we ask you to propose, in groups, a "good" model to understand the evolution of COVID-19. Specifically, we propose that you **model the cumulative number of infected people during the first wave to make predictions** for the following five days.

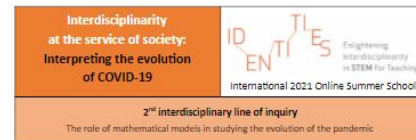
## 2<sup>nd</sup> interdisciplinarity line of inquiry

### The role of mathematical models in studying the evolution of the pandemic

#### What and how to expose your work and answers?

To share your work, we ask you to prepare three slides to show the rest of the groups the work you have done, each slide focusing on one of the following three aspects:

1. What were the **main questions** you investigated about?
2. **Which model** have you chosen? What are its characteristics? Why do you think this is a "good" model?
3. **What forecasts** does this model offer for the first days of March?



#### INTRODUCTION

The emergence of the COVID-19 pandemic has put the scientific community in the spotlight of society as a whole. Their studies have been one of the main tools for establishing measures to address the situation and have had a direct impact on daily life. Good examples are statistical analyses to extract relevant information from data, the development of mathematical models to make predictions, and computational simulations to understand virus diffusion.

In this second submodule we will focus on the second topic: **modelling to make predictions**. Based on the evolution of the number of COVID-19 infections accumulated in Spain during the first wave, we propose that you model these data with the goal to make predictions for the days following the first wave.

The generative question of the module that will guide your investigation as students in this interdisciplinarity line is the following:

*What is the role of models and modelling in investigating the evolution of COVID-19?*

#### PART 1: Presentation of the interdisciplinarity line of research

To get started, we suggest you answer these questions in order to define a little bit the task proposed:

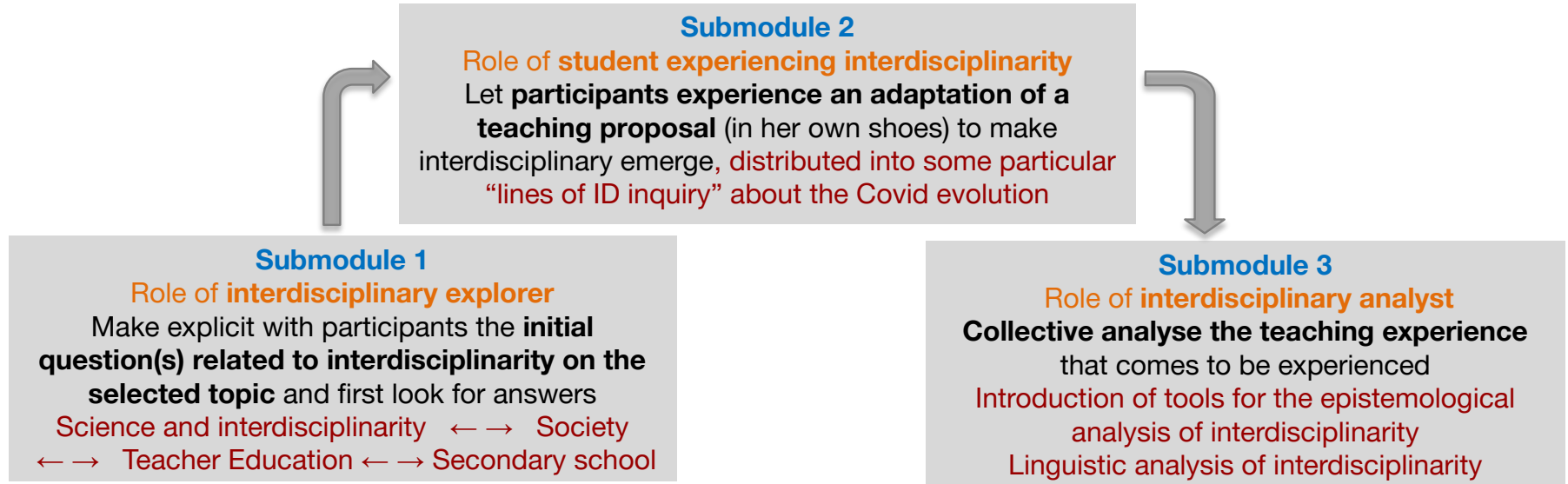
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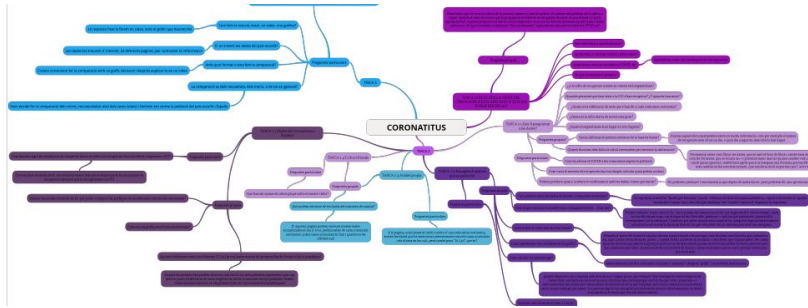
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## Main instruments transferred to assume the role of ID analyst

- **Maps of questions and answers** [Winsløw, Matheron, & Mercier, 2013] to sketch the process followed through the dialectics between the questions addressed and the answers obtained in L1, L2 and L3.
- Mix groups working on the **2<sup>st</sup> guide of analysis of interdisciplinarity**: detection of boundary objects and description of boundary crossing mechanisms [identification, coordination, reflection and transformation]



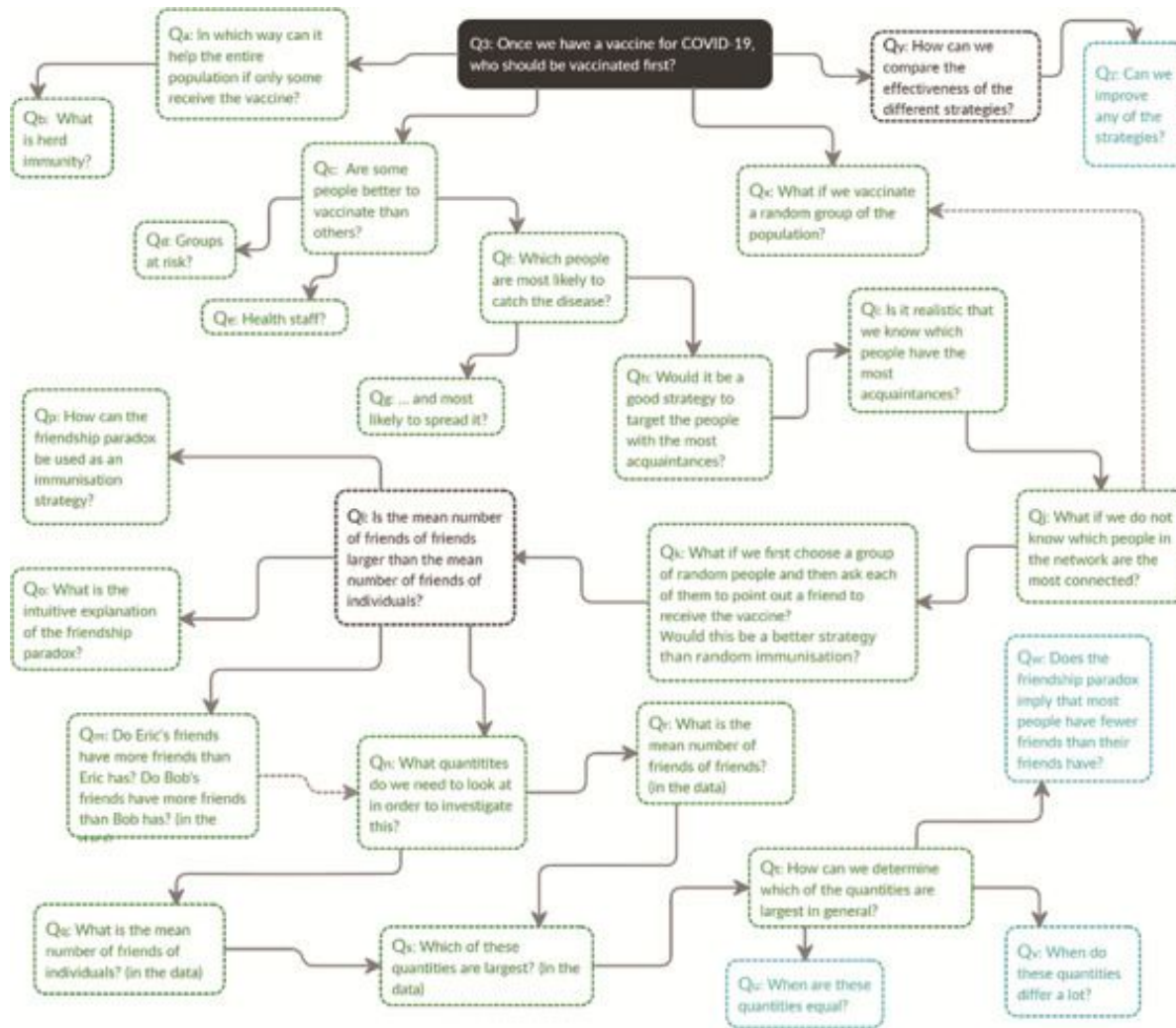
## Questions-answers map

as tool for the  
epistemological analysis of  
the activity

## Submodule 3. Role of interdisciplinary analyst

- Construction in group of the **questions and answers map** for each line of inquiry, starting from given initial questions:
  - Make explicit the **questions** you were addressing and the **link** they established among them
- Big group sharing and comments to highlight links among the lines.





## Module on the evolution of the COVID

### SESSION 3: Analysing interdisciplinarity as analysts

Jensen, M., & Winsløw, C. (2021). Questioning corona-a study and research path. *Teaching Mathematics and its Applications: An International Journal of the IMA*, 40(2), 154–165.

<https://doi-org.sire.ub.edu/10.1093/teamat/hrab003>

## Line of interdisciplinarity 2 about models: a preliminary case study

## 2<sup>nd</sup> interdisciplinarity line of inquiry: analysis of the group discussion (one Engineer, one CS, one Physicists)

E: How do you want to address this? What **does it mean to model some data?**

J: Is this a kind of **validation**, right? So what is a model is the next question, but the **data is something that you already have**, something that has already happened so **model the data is a way to confirm that your model works in reality** that has already happened.

V: I think it's more something that helps you to understand **how to organize a lot of data** that you have, because **something is happening but you can't visualize it without a model**.

E: Well, I think that the **optimization of data is very important in a model** because in a model **you see the data all together and not one by one**, and also it's easier to see the **results**, you see how it goes through time. through other parameters that you have, it's easier to see the dependence between your data.

## 2<sup>nd</sup> interdisciplinarity line of inquiry: analysis of the group discussion

V: You **contextualize**, I think, the data.

J: But they're asking for modeling data. This could be kind of **processing data**. Modeling data is.... well, we have to **set what modeling data means**. I think that processing data is for group 1.

E: mmm OK you are asking about the questions what is the role of modeling? [...] We were thinking about **what does it mean to model.. this is a general question that is all through the module we are doing, so I think this is the last we are gonna answer**. What is a model and what is the role of models in the evolution of COVID 19 is actually the last question to answer since we need to do the process to see the role. **We have to do the steps: step A “to make a model”, then we will be able to give an answer, through our experience**, about the role of a model and modeling in the investigation. They ask us to make a model. **they give us data.. they ask us to make a process**.

## 2<sup>nd</sup> interdisciplinarity line of inquiry: analysis of the group discussion

E: So for you modeling data is just to make an image and not analyze them, not process them? So put them in another point of view,

J: It's having **a numerical model which will fit the data you already have**. You know for instance we have a wave, from the past, we have the data of the infection of the previous months. So we gonna do **a model in order to fit the evolution of this past months**. So it's not taking those data and try to distinguish. We are gonna do a model in order to fit it. This will help us to understand what has happened.

E: We are just discussing, I agree with you. **I am trying to find how we can write it**. Valentina what's your point of view?

V: I agree with your point. For me model is also contextualize data, try to **find the most suitable them for organizing data in order to analyze them later**.

## 2<sup>nd</sup> interdisciplinarity line of inquiry: analysis of the group discussion

E: I am “Googling” it.

Berta: **this general question is very general and you can address it in very different ways.** So I think it would be very important if one of you to **take notes of the questions that you are raising.** Here you are raising a lot of questions: what to model means for us, what do we ask to a model, is model more linked to process data or to fit data, or to give tools to predict data? The aim is not to try to answer these big questions, it's impossible somehow, so take notes of your discussion and... if there was **a group in parallel they would have followed another trajectory.** This is the first thing. The second is: you have this Excel file, with real data. **You can open it and then do what you are proposing with this data.**

## *2nd line of inquiry: The role of models in studying the evolution of the pandemic*

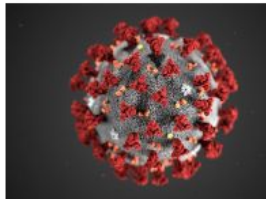
To share your work, we ask you to prepare three slides to show the rest of the groups the work you have done, each slide focusing on one of the following three aspects:

1. What were the **main questions** you investigated about?
2. Which **model** have you chosen? What are its characteristics? Why do you think this is a "good" model?
3. What **forecasts** does this model offer for the first days of March?

## Main question: Role of Models

*What is the role of models and modelling in investigating the evolution of COVID-19?*

- The type and form of models depend on the **phase of the epidemic**.
- **Before an epidemic**, used for planning and identifying critical gaps and prepare plans to detect and respond in the event of a pandemic.
- **At the start of a pandemic**, we are asking questions such as: (i) where and how did the pandemic start, (ii) risk of its spread in the region, (iii) risk of importation in other regions of the world, (iv) basic understanding of the pathogen and its epidemiological characteristics.
- **As the pandemic takes hold**, we begin investigating: (i) various intervention and control strategies, (ii) forecasting the epidemic incidence rate, hospitalization rate and mortality rate, (iii) efficiently allocating scarce medical resources to treat the patients and (iv) understanding the change in individual and collective behavior and adherence to public policies.
- **After the pandemic starts to slow down**, we are interested in developing models related to recovery and long-term impacts caused by the pandemic.(social - economic - cultural)



Source: "Mathematical Models for COVID-19 Pandemic: A Comparative Analysis"

<https://link.springer.com/article/10.1007/s41745-020-00200-6>



## Sub - questions addressed

- **What do we mean by the modeling data?**
  - Data modeling defines not just data elements, but also their structures and the relationships between them
- **What is a model? What is a "good" model? What would be a "good" model for understanding the evolution of COVID-19?**
  - Model is a tool in order to reproduce/represent in a simple way a reality process in order to understand it..
  - A "good" model about Covid-19 takes under consideration:  
time, number of the infected, geographical space.
  - We agreed on some "good" qualities the model has to present:
    - generalization, workable, simplicity,
    - The model suits data and is able to make a good prediction.
    - Takes under consideration the "end user"
- **What can be the goals of modeling some data? That is, what do we intend to study when modeling the actual data on the evolution of COVID-19?**

The goals could be to predict the evolution of number of covid in the early days of May

- **A question we addressed during our investigation and was not in the "module" was :**

**What do we mean by the word analysing and the word processing data ?**

**Data processing:** A series of actions or steps performed on data to verify, organize, transform, integrate, and extract data in an appropriate output form for subsequent use.

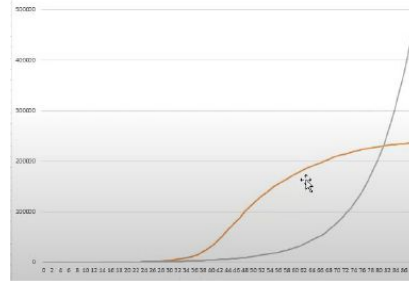
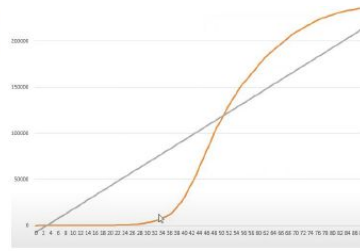
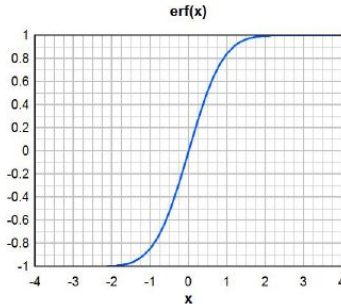
**Data Analysis** involves actions and methods performed on data that help describe facts, detect patterns, develop explanations and test hypotheses.

# Model Chosen for cumulative evol

- Linear nor exponential fit qualitatively
- We chose **Error function**

In mathematics, the **error function** (also called the **Gauss error function**)

$$\operatorname{erf} z = \frac{2}{\sqrt{\pi}} \int_0^z e^{-t^2} dt.$$

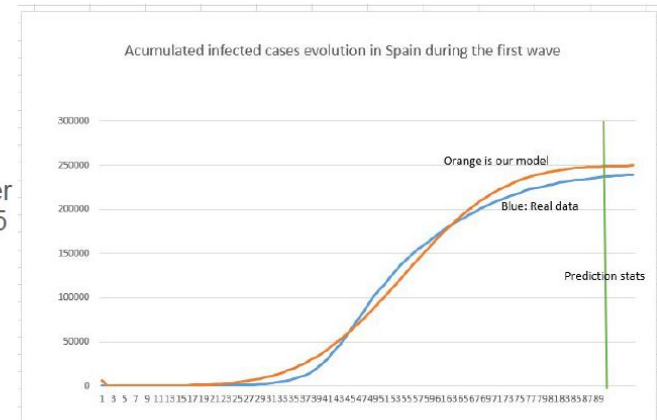


## Predictions

- Although some discrepancies, the **general behaviour** is obtained
- However, the model **overpredicts** the number of infections for the next 5 days.
- A **qualitative** approximation is obtained, rather than quantitative

Module on the evolution of the COVID

Submodule 4: Thinking as designer and teacher



## Why COVID-19 Models Don't Predict the Future

<https://youtu.be/wKOsIhIFt6U>

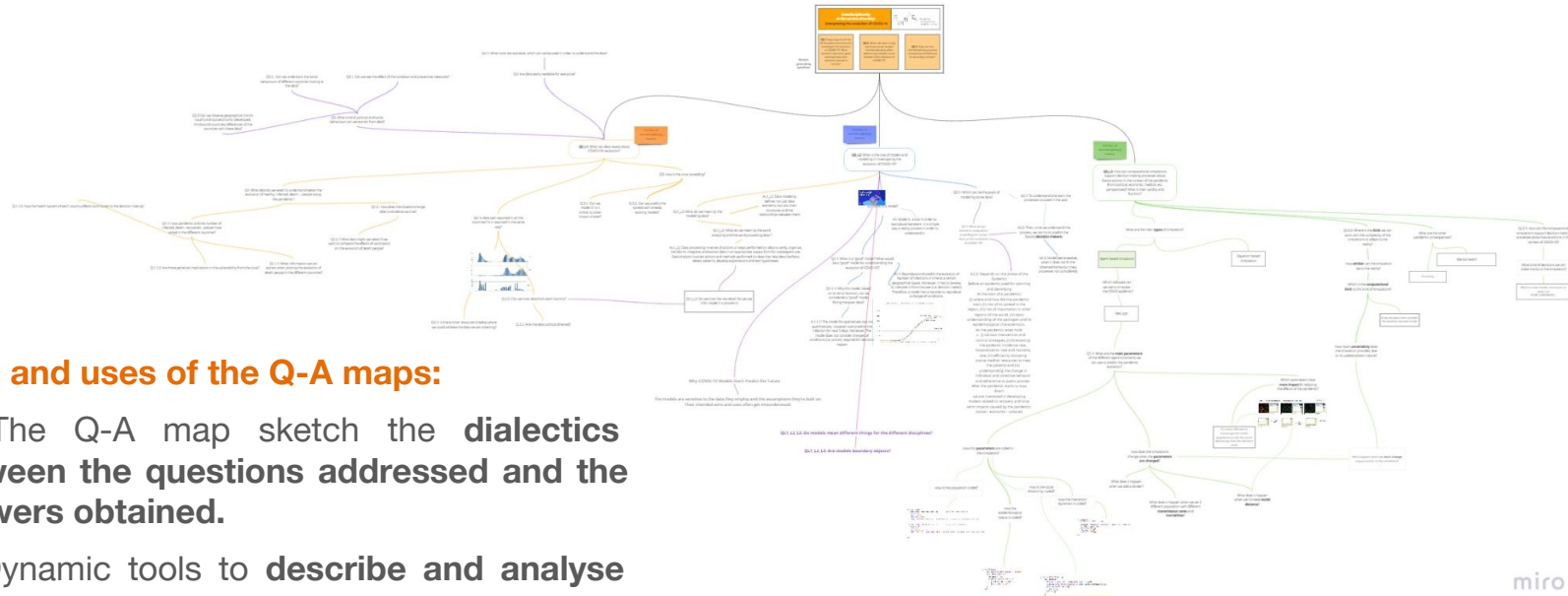
***“To understand what epidemiological models can tell us, it helps to first understand what they can’t.”***



*The models are sensitive to the data they employ and the assumptions they're built on. Their intended aims and uses often get misunderstood.*

***Food for thought: Why is so freaking hard to make a good covid-19 model?*** <https://fivethirtyeight.com/features/why-its-so-freaking-hard-to-make-a-good-covid-19-model/>

- Examples of questions-answers map elaborated by the students



### Role and uses of the Q-A maps:

→ The Q-A map sketch the **dialectics** between the questions addressed and the answers obtained.

→ Dynamic tools to **describe and analyse** the knowledge at stake

**Q0\_L2:** What is the role of models and modelling in investigating the evolution of COVID-19?

### Uses of the Q-A maps:

→ Tool to detect **intersections among the lines of ID inquiry**

→ Tool to detect possible **boundary objects** (Q, A, terminology, methods, etc.)

→ Giving rise to “meta-reflection” questions about ID



Q1: What is a model?

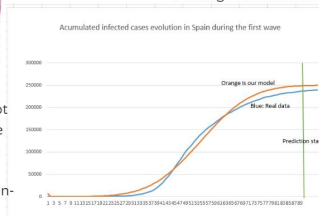
A1: Model is a tool in order to reproduce/represent in a simple way a reality process in order to understand it.

Q1.1: What is a “good” model? What would be a “good” model for understanding the evolution of COVID-19?

Q1.1.1: Why this model, based on an error function, can be considered a “good” model fitting the given data?

A 1.1.1: The model fits qualitatively but not quantitatively. However over-predicts the infection for next 5 days. Moreover, The model does not consider changes of conditions (i.e. unlock) required for decision-makers

A1.1: Reproduce and predict the evolution Number of infections in time at a certain geographical space. Moreover, it has to be able to interpret it from the user (i.e. decision maker). Therefore, a model has to be able to reproduce a change of conditions.



**QL1\_L2\_L3:** Do models mean different things for the different disciplines?

**QL1\_L2\_L3:** Are models boundary objects?

Q2.1: What is a model?

QL1\_L2: What do we mean by the modelling data?

AL1\_L2: Data modeling defines not just data elements, but also their structures and the relationships between them

QL1\_L2: What do we mean by the word analysing and the word processing data ?

AL1\_L2: Data processing: A series of actions or steps performed on data to verify, organize, transform, integrate, and extract data in an appropriate output form for subsequent use. Data Analysis involves actions and methods performed on data that help describe facts, detect patterns, develop explanations and test hypotheses.

QL1\_L2: Do we trust the raw data? Do we use it for model or to process it

## Conclusions and discussion

The **SRP-TE model** enriched with **Boundary “objects”/Boundary crossing mechanisms + epistemological analysis of disciplines and interdisciplinary connections** worked as a good framework that supported meaningful interdisciplinary co-design and provided didactic tools to discuss with students.

The main **interdisciplinary innovations** concerns the **choice of the *milieu*: news and raw data**, that must be investigated in a relevant way with **questioning processes that should be relevant also from other disciplinary points of view (not only mathematics)**, as well as the lines of inquiry.

The **lines of inquiry are oriented to interdisciplinary interactions**: based on potential **boundary “objects”** to trigger **meta-reflections about disciplines** through boundary crossing mechanisms. The milieu must be enriched to lead to **authentic discussions from all the disciplinary points of view** (see the MODEL case!)

The potential is **explored in a very different way with all mathematicians or people with different backgrounds**.

## Conclusions and discussion

### About the progress of teachers-in-training on analysing interdisciplinarity

- Initial absence of coherent notions, concepts, discourses and tools to talk about and to analyse ID
- Change of roles (explorers-students-analysts-designers-teachers) seems to facilitate sharing a rich *milieu* between teachers-in-training and educators
- Specific tools for the epistemological description of the disciplinary and ID knowledge at stake seems to be necessary to → Questions-Answers maps
- Progression of the “Guides for ID analysis” seems a fruitful device to make the questioning about ID progress, but some open questions:
  - When to introduce specific moments to reflect on disciplinary identities?
  - How the progression on submodules 1-3 will facilitate the immersion into secondary school?



## Limitations and future developments

- Some students identified **disciplinary boundaries** in a “naive” way (e.g. computer science as the science that “provides us the applet”; physics as the science that “sets the scientific method”).
  - This finding seems to be more present when students do not go deep in the analysis of specific conceptual tools but remain on a *higher-order level of discussion* → introduce specific moments of instruction in which an agreement on the disciplinary identities is reached among instructors and participants
  
- However, most students were aware of the **change in their understanding of boundary objects** that experienced throughout the module
  - “At the beginning these concepts had different meaning depending on the background of each participant but, during the discussions, this meaning was mixed with the other meaning, leading to a final understanding.”



## Limitations and future developments

The **role of experts is very important and co-teaching necessary** since the phases of **elaboration of questions and validation in real-time** needs experts from the different disciplines (also experts in didactics have very often an implicit disciplinary perspective....and need interdisciplinary education!)

The **institutionalization** was carried out well in the first phase (summarize the news in order to move forwards in the disciplinary/interdisciplinary questioning) while after the **Submodules 2+3 it remained very open**. Maybe too much? What is a good way to end up?

# IDENTITIES

Enlightening  
Interdisciplinarity  
in STEM  
for Teaching