# PHYSICS EDUCATION RESEARCH IN ITALY AND THE BOLOGNA APPROACH

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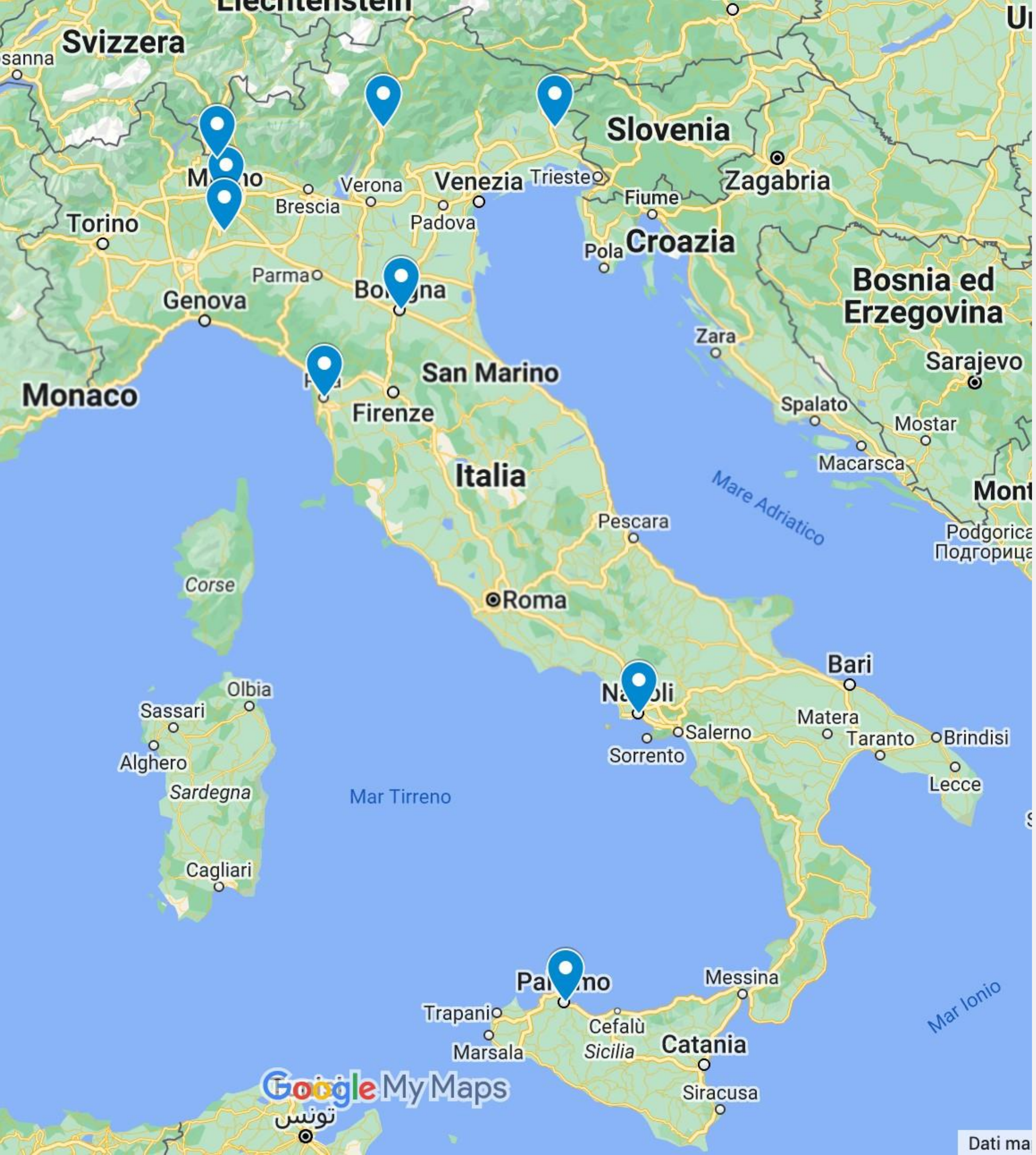
Create for STEM, 4/25/2023

ALMA MATER STUDIORUM
UNIVERSITÀ DI BOLOGNA




# PER-RESEARCH IN ITALY

Not a huge PER tradition in Italy (about 15 PhD students at the moment

Most of the research groups deal with things like

- rethink lab experiments within schools
- design of innovative teaching materials (e.g. visors)
- design of curricular textbooks

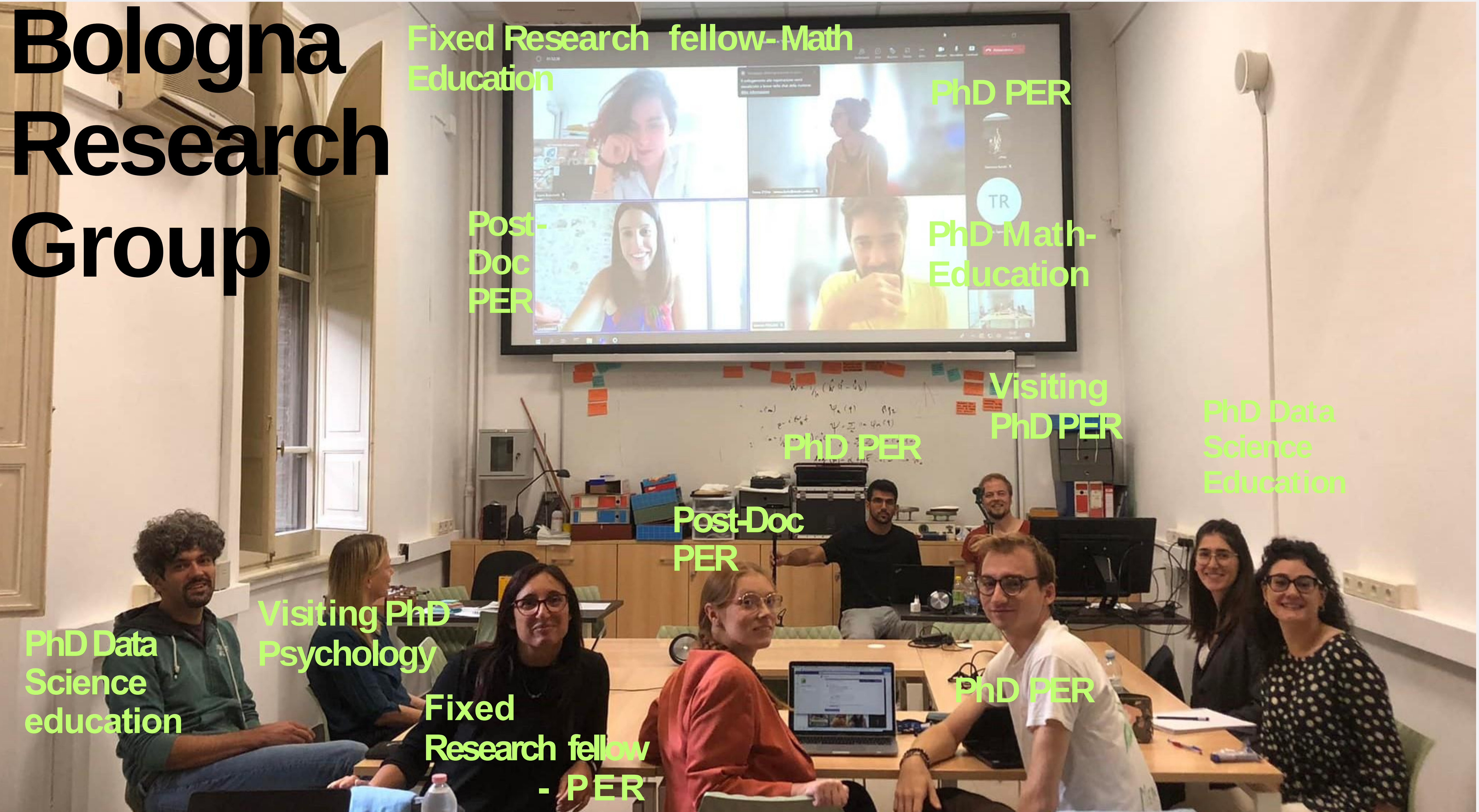
For what concerns methodologies they are mostly large scale questionnaires analyzed with

- clustering techniques
- structural equation modeling
- statistical inference

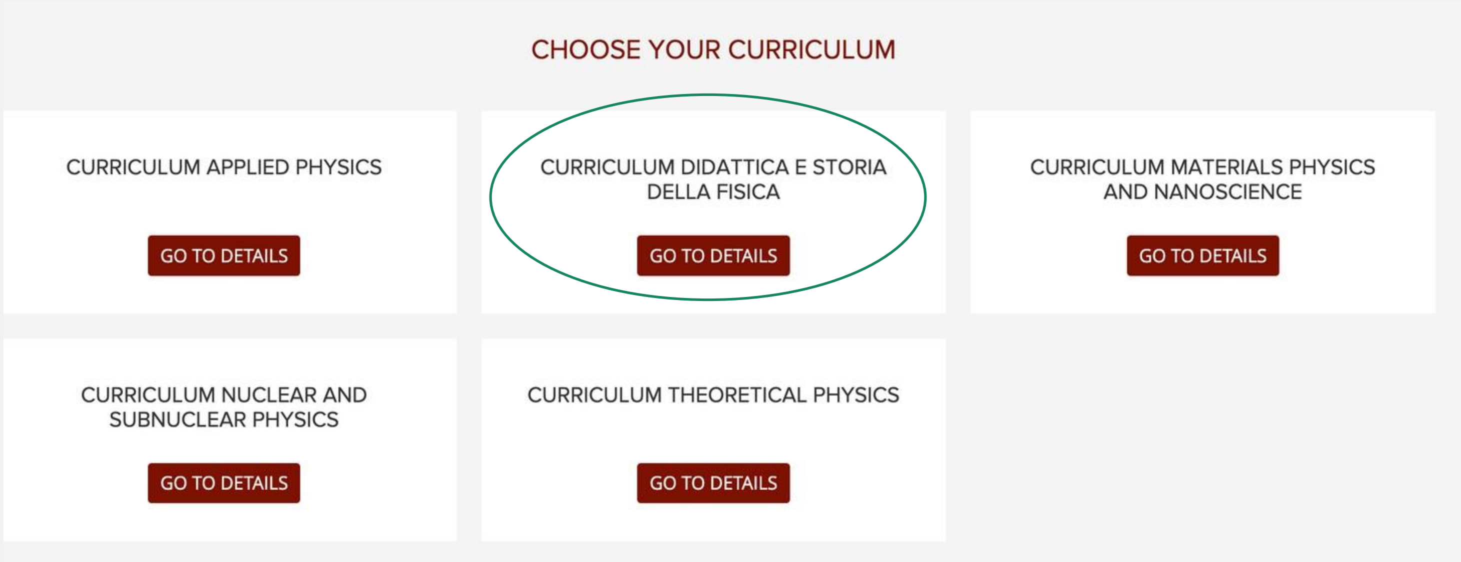
**Bologna research group.**
**By far the largest research group in Italy (5 PhD, 2 post-doc, 2 professors) led by professor Olivia Levrini.**

**The Bologna group is one of a kind within the Italian PER research context, in terms of aims, funding opportunities, research methods and kind of data analysis.**

# Bologna Research Group



# TEACHING "PHYSICS-TEACHING" IN ITALY




**Unibo Master Degrees**

We don't have Colleges of Teacher Education or Science Education, so Physics Education is always within Physics Departments.
We have in all the country just four master degrees programs (Napoli, Bologna, Roma, Pavia) and single courses in many more other universities, but most of graduate students come to Bologna from all over Italy.

Science Education consideration within disciplinary departments…(under construction)

# BECOMING PHYSICS TEACHER IN ITALY

- Temporal teacher (substitution, and so on…):
  - No title required, also undergraduates allowed

- Permanent teacher:
  - Bachelor and master degree in your discipline
  - Additional exams in Psychology, Pedagogy, Anthropology, Didactics (just one per each field)
  - Win a competition (not every year the government is able to orghanize them)
    - Three separate steps

| Classe di concorso | Numero posti |
|---|---|
| A020 – Fisica | 202 |
| A026 – Matematica | 438 |
| A027 - Matematica e fisica | 421 |
| A028 - Matematica e scienze | 366 |
| A041 - Scienze e tecnologie informatiche | 258 |

Ministero dell'Istruzione e del Merito

Home > Concorso ordinario scuola Secondaria > Concorso materie S.T.E.M. 2022 >

## Concorso materie S.T.E.M. 2022

153

10→35

18-08-1963

# BECOMING PHYSICS TEACHER IN ITALY

As a consequence:

- Many of the physics teachers do not have any kind of Science Education formation
- They are not necessarily asked to compensate this lack of competencies
- Teaching is more focused on *provide students with knowledge* rather than **guiding them through a learning where their views and ideas count.**

# *BOLOGNA APPROACH* TO SCIENCE (PHYSICS) EDUCATION

# EUROPEAN PROJECTS

- I SEE — It's your time to imagine the futures — Sept. 2016 – Aug. 2019
- IDENTITIES — Enlightening Interdisciplinarity in STEM for Teaching — Sept. 2019 – Aug. 2022
- SEAS — Sept. 2019 – Aug. 2022
- FEDORA — Sept. 2020 – Aug. 2023
- CLIMADEMY — CLIMAte change teachers' acaDEMY — Sept. 2022-

# KEY POINTS AND OBJECTIVE

We want to pursue a scientific (physics) learning that could be for students

- **Relevant:** students should feel that they are learning something close to them, to their lives
- **Meaningful:** students should feel that they are learning something engaging to them, and helpful to orient in decision makings
- **Authentic: i) personally authentic**: they can put their ideas and views in the content learning; **ii) scientifically authentic:** work on the detachment between school practices and scientific practices

Science Education

ISSUES AND TRENDS

**Disciplinary authenticity and personal relevance in school science**

Shulamit Kapon, Antti Laherto, Olivia Levrini

First published: 13 June 2018 | https://doi.org/10.1002/sce.21458 | Citations: 33

# PROCESS

Work on the discipline → Teaching practices → Appropriation → Identity development (?)

# WORK ON THE DISCIPLINE

- Study the knowledge and construct appropriate **design principles** (Duit et al., 2012), respecting disciplinary authenticity and exploiting the **productive forms of complexity** of knowledge

## The Model of Educational Reconstruction – a Framework for Improving Teaching and Learning Science[1]

Reinders Duit, Harald Gropengießer, Ulrich Kattmann, Michael Komorek & Ilka Parchmann

Chapter



Part of the Cultural Perpectives in Science Education book series (CHPS,volume 5)

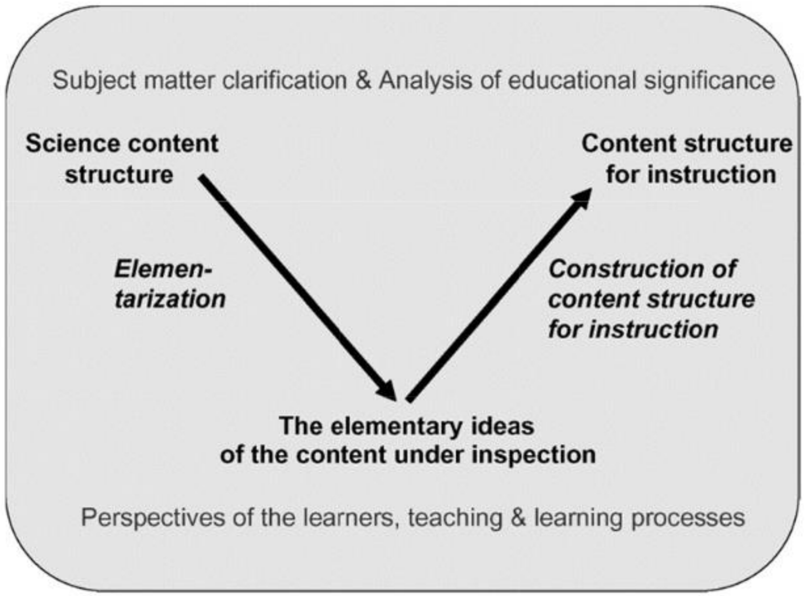



*Figure 4. Steps towards a content structure for instruction.*

Published: 24 March 2013

## Encountering Productive Forms of Complexity in Learning Modern Physics

Olivia Levrini & Paola Fantini

Science & Education **22**, 1895–1910 (2013) | Cite this article

- Examples of design principles (for thermodynamics intruction):
  - Multiperspectiveness
  - Multidimensionality
  - Longitudinality

# TEACHING PRACTICES

- Develop teaching practices which match the new shape of the knowledge content:
  - <u>Multiple positions within the content → Ask to consider multiple positions</u>
  - <u>Multiple dimension within the content → Develop activities where the different dimensions are compared</u>
  - <u>…</u>

Science Education

LEARNING

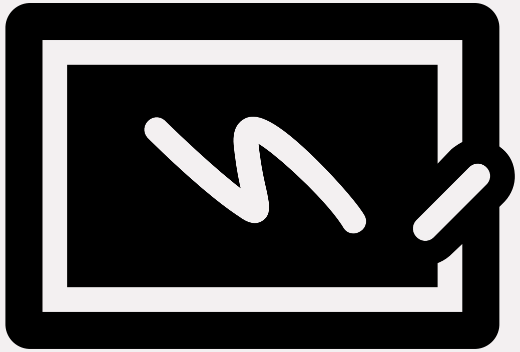
Science Education homepage

## Orchestration of classroom discussions that foster appropriation

Olivia Levrini, Mariana Levin, Paola Fantini, Giulia Tasquier

First published: 09 November 2018 | https://doi.org/10.1002/sce.21475 | Citations: 7

Set the conditions for students to position **themselves <u>towards the content and within the disciplinary boundaries</u>**



*<<Math is not an opinion, science is not an opinion!!!>>*

(my high school math teacher – and maybe yours too?)

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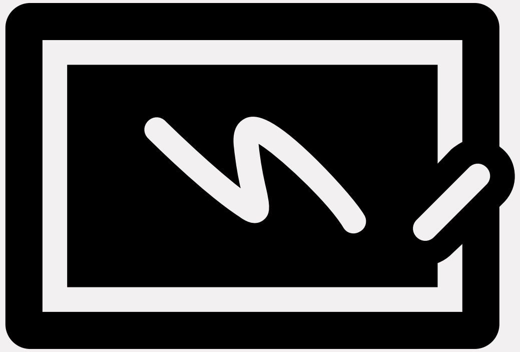

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(my high school math teacher – and maybe yours too?)

→

But science allows for many perspectives:

- QM or GR?
- Wave or particle?
- QM or Hidden variables?
- ...

# APPROPRIATION

Articles

**Defining and Operationalizing Appropriation for Science Learning**

Olivia Levrini, Paola Fantini, Giulia Tasquier, Barbara Pecori & Mariana Levin

Pages 93-136 | Accepted author version posted online: 06 Jun 2014, Published online: 09 Dec 2014

Download citation https://doi.org/10.1080/10508406.2014.928215 Check for updates

- The reconstruction toward a more rich and open knowledge, allows students to content ***appropriation***

*"Appropriation, in our study, implies students' discourse is*
*(A) an expression of a personal "signature" idea, (B) grounded in the discipline*
*(C) thick, in that it involves a metacognitive and epistemological dimension,*
*(D) non-incidental, in the sense of being consistently used throughout classroom activities*
*(E) a carrier of social relationships, in that it positions the student within classroom"*

# TOWARDS FEDORA

.Relevance

.Meaning

.Authenticity

*as objectives*

.Disciplinary grounded teaching

.Specific class practices

.Appropriation

*as instruction steps*

FEDORA

https://www.fedora-project.eu/

**“Future-oriented Science EDucation to enhance Responsibility and engagement in the society of Acceleration and uncertainty”**
(Grant agreement ID: 872841)

HORIZON 2020

European Commission

# FEDORA

FEDORA project aims to analyse the gap between science at school and science outside school by designing and implementing activities grounded on three pillars:

- the search for **new languages**
- an **interdisciplinary** approach
- the need to **futurize science education**

# FEDORA

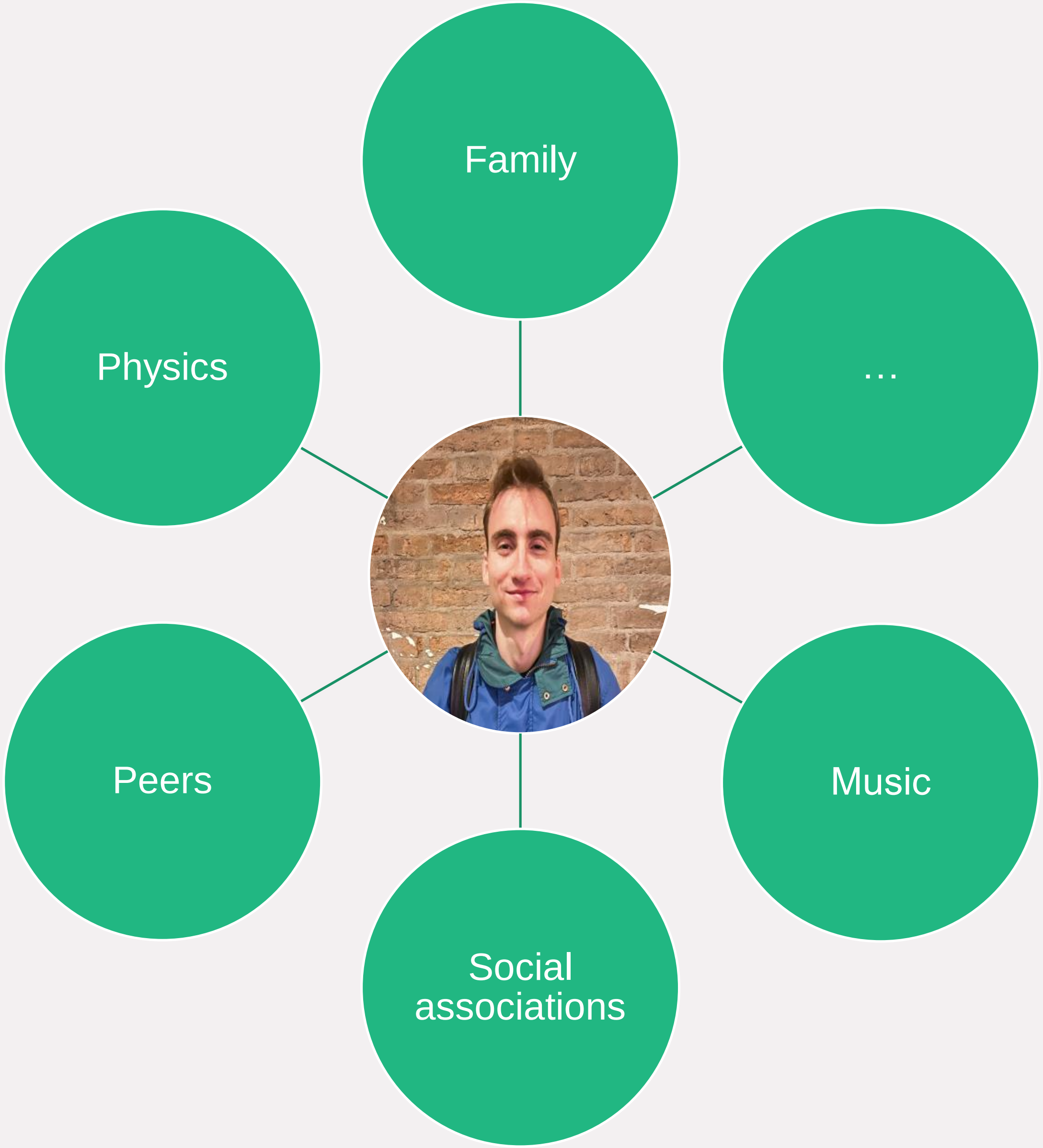
- **<u>New languages</u>**: sometimes the disciplinary language is not enough to let students appropriate the content. Merging the language of physics with other languages (art) can enhance to meaning of science content itself and provide multiple access-points.
- **<u>Interdisciplinarity</u>**: a clash between the hyper-specialised organisation of teaching in disciplines and the inter-multi-transdisciplinary character of innovation. Work at the boundaries of discipline to dismantle the silos-effect.
- **<u>Futurize science education</u>**: the discrepancy between atemporal teaching approaches and the need to support students to construct visions of the future by empowering actions in the present. Develop activities which foster future scaffolding skills

*"I almost feel like I can consider the language of writing and writing as the rhetoric of physics. And that is very nice because even writing itself even that very language needs rhetoric so anyway a code that goes beyond the word itself to better express concepts [...]"* (Italian teacher)

# FEDORA ACTIVITIES

| Name of the activities (year) | No. of repetitions |
|---|---|
| My city of the future (2022,2023) | 2 |
| Climate change at the museum (2022) | 3 |
| Mocku for change (2021) | 1 |
| Physics of clouds (2021) | 1 |
| Simulations of complex systems (2021,2022,2023) | 3 |
| Quantum Atelier and the second quantum revolution (2021,2022,2023) | 3 |
| Aerocene (2023) | 1 |
| AI (2023) | 1 |
| Kairos (2023) | 1 |
| AI Atelier (2023) | 1 |


# PHD RESEARCH: TOWARDS A NEW PERSPECTIVE ON DISCIPLINARY IDENTITY



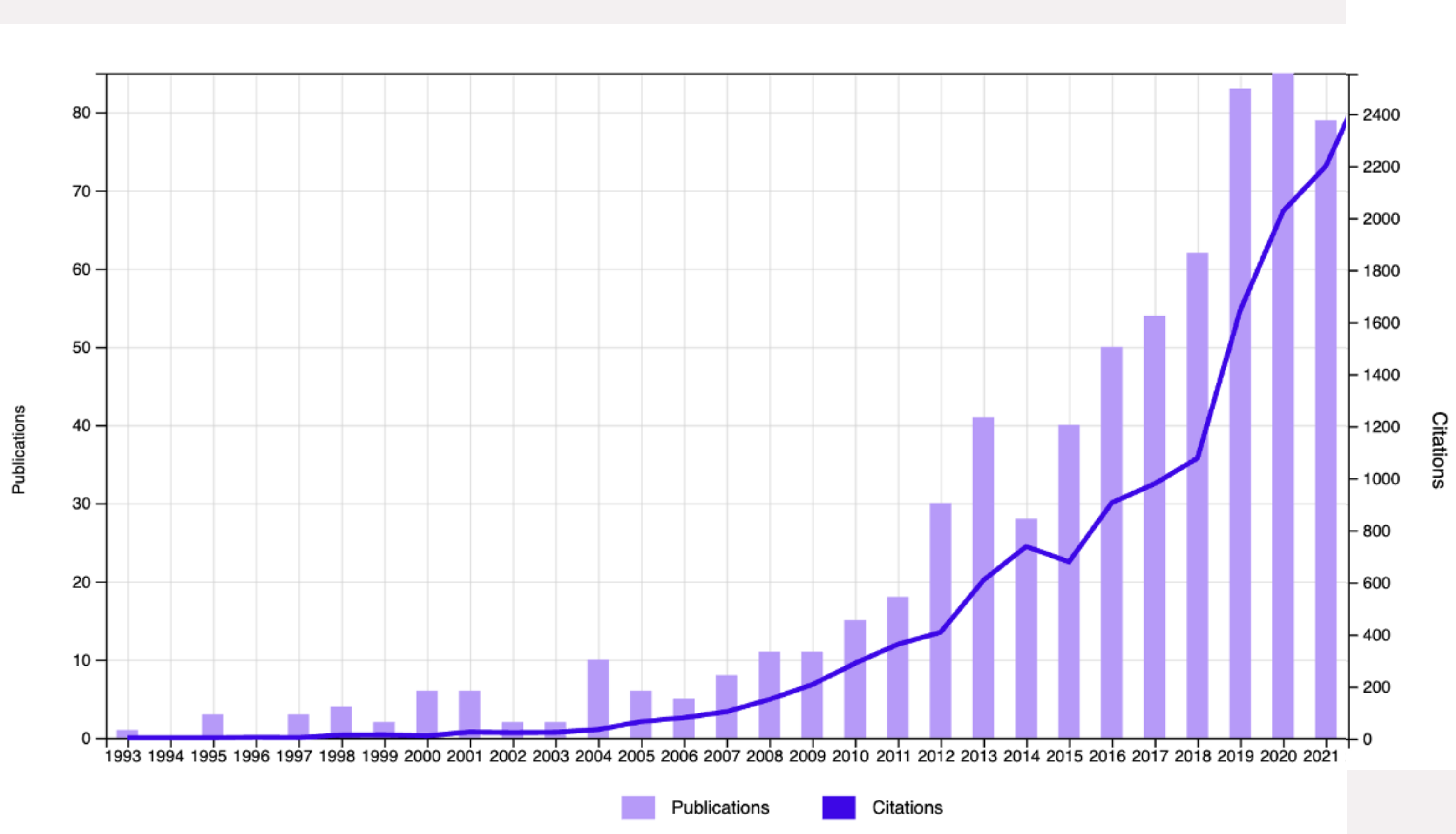

**Nexus of multi-membership (Wenger & Lave, 1991)**

- *How do I navigate through my multiple identities?*
- *What is the shape of these identities?*

In other words,

- What was the contribution of music in forming myself?
- What was the contribution of social associations in forming myself?
- ….
- What was the contribution of physics in forming myself?

# Research problem and general objective




Logical query on Web of Science ("identity" AND ("stem" OR "science" OR "physics" OR …)), then filtered within Science Education literature

- Growing need to deepen the relationship between identity and science, within Science Education research.
- The broad research concerning STEM- identity differs in terms:
  - **Conceptualization** of identity (as a lens? as a phenomenon?)
  - **Research methods** (qualitative, quantitative, mixed)
  - **Aims of the research** (deepen theoretical framework, elaborate new ones, provide suggestions for policymakers...)
  - ...

# Research problem and general objective

In what sense **science-identity**?

We can see (science) identity as **something always contested/negotiated between the self and the community of practice around him/her. It is not given in time but a continuously evolving spatial-temporal trajectory, which stand for the construction of the self.** (Wenger & Lave, 1991; Gee, 2000; Sfard & Prusak, 2009).

Identity in science education has been often conceptualized as **an operational lens** (Gee, 2000; Carlone and Johnson, 2007; Hazari et al., 2010) to study other issues such as power structures (Hazari et al., 2014), politics of recognition (Avraamidou, 2021), informal learning programs (Fracchiolla et al., 2020) and many more.

Typical dimensions of these STEM-identities as conceptual lenses are:

- *Competence*
- *Recognition*
- *Performance*
- *Interest*

# Research problem and general objective

Looking at the literature it emerges that "*science identities work can thus be regarded as relatively homogeneous*" (Danielsson et al. 2022) in terms of methodology (mainly small scale & qualitative) and aims (understand how and which identities are allowed within scientific teaching structures).

We interpret this homogeneity with blind/blank spots metaphor:

- **Blank Spot**: saturation of studies looking how *experiences of* performance, recognition and competence within scientific learning sustain/inhibit personal identity development

↓

SOCIO-POLITICAL FOCUS

- **Blind Spot**: very few studies looking how *experiences of* disciplines' features (in terms of epistemology, scientific practices and methods) sustain/inhibit personal identity development

↓

EPISTEMOLOGICAL FOCUS

# Research problem and general objective

“A key aspect in the lives of young is the search for **meaning and relevance**. They like areas where their voice is taken seriously, where their views count. Science and mathematics have an image of authority, at least as school subjects. Answers are either right or wrong. **There is no place for arguments and personal views**” (Sjoberg, 2001)

# Research problem and general objective

“A key aspect in the lives of young is the search for meaning and relevance. They like areas where their voice is taken seriously, where their views count. Science and mathematics have an image of authority, at least as school subjects. Answers are either right or wrong. There is no place for arguments and personal views” (Sjoberg, 2001)

But at the same time, we do see some relevance, some impact

"I think it is one of the greatest skills that I feel I have personally developed, to say this desire to question myself"

-

"I think that they are some of the competencies, the value of error, to be able to question your- self, that I think are fundamental in everyday life [...] in general for the person, for his development "

(Matteo, 23 y.o.)

"learning physics in a certain way, a very *strict* way and so when the formal part, the part of the *rigor*, the part of *truth* strongly emerges, you structure (to my opinion), and you take it out, a mindset which closes you rather than opening

-

"This in my opinion means to catch physics, not only catch the inquiry method, that surely is very useful, but also intimately structuring a person..."

(Nicolò, 25 y.o.)

## Research problem and general objective

Hence, we do recognize the importance of navigating within social scientific structures in forming science identity, but we aim to add other perspectives on science identity work, so to:

**Develop a theoretical construct from data collection and analysis, which may help in understanding how ALSO disciplinary (physics) epistemological features <u>can inhibit or sustain students' personal identity development.</u>**

# Theoretical backgrounds and research question

For developing the idea of **epistemic identity -** how disciplinary epistemology can trigger/inhibit the expression of personal issues, needs and (maybe) sustain an "evolution" of them - we need:

# Theoretical backgrounds and research question

For developing the idea of **epistemic identity -** how disciplinary epistemology can trigger/inhibit the expression of personal issues, needs and (maybe) sustain an "evolution" of them - we need:

1. A framework which allows to focus **more**[1] on epistemological features of discipline rather than the socio-political ones:


**<u>FRA to NOS Reconceptualization</u>**
(Erduran and Dagher, 2014):

- the nature of STEM disciplines is defined through resemblance, in the sense of agreement between observers, contexts

1- Of course it is not possible/reasonable a clear cut separation of these two nuances; we just consider to focus on this part of the discipline.

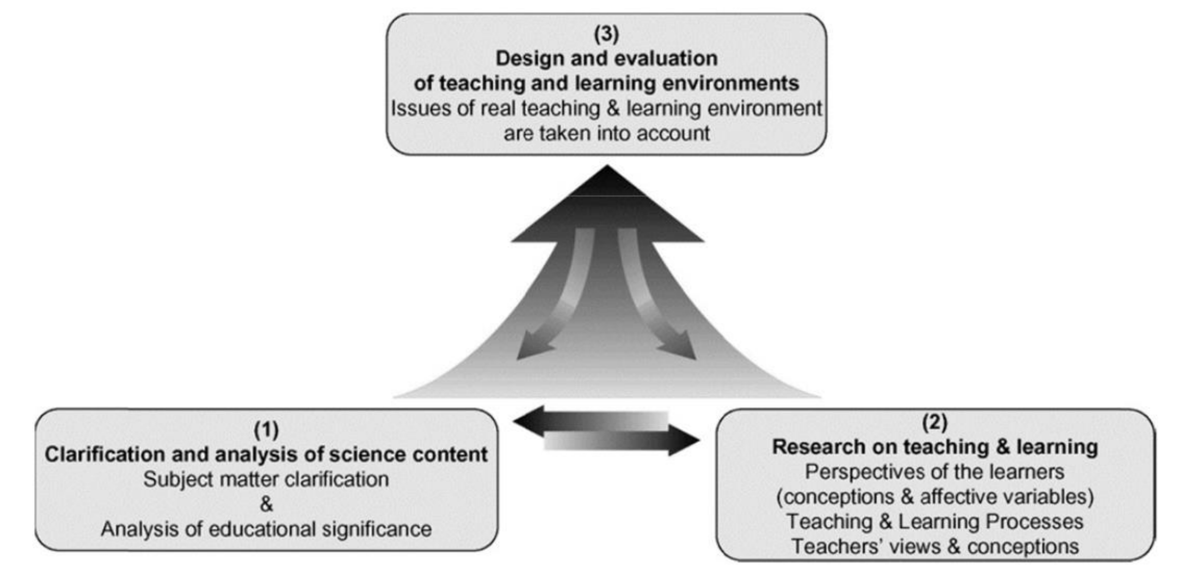
# Theoretical backgrounds and research question

For developing the idea of **epistemic identity -** how disciplinary epistemology can trigger/inhibit the expression of personal issues, needs and (maybe) sustain an "evolution" of them - we need:

2. A framework which allows to design teaching modules with the chance to handle and re-shape (e.g. physics) epistemology:

**Model of Education Reconstruction** (Duit et al., 2012):

- reconstruction of (science) content, that has "*to be transformed into a content structure for instruction*".
- the *re-construction* intends to exploit the depth of disciplinary contents structures and the richness of the methods and practices and aims implied by them.



# Theoretical backgrounds and research question

Given the two theoretical frameworks, we present our broad Research Question:

RQ:
"*What epistemological types of knowledge, and what kind of educational reconstruction leave room for the development of personal identity in physics learning?*"

By **designing activities, collecting data and analyzing them** we aim to provide multiple ***local*** answers which can contribute to the general research objective:

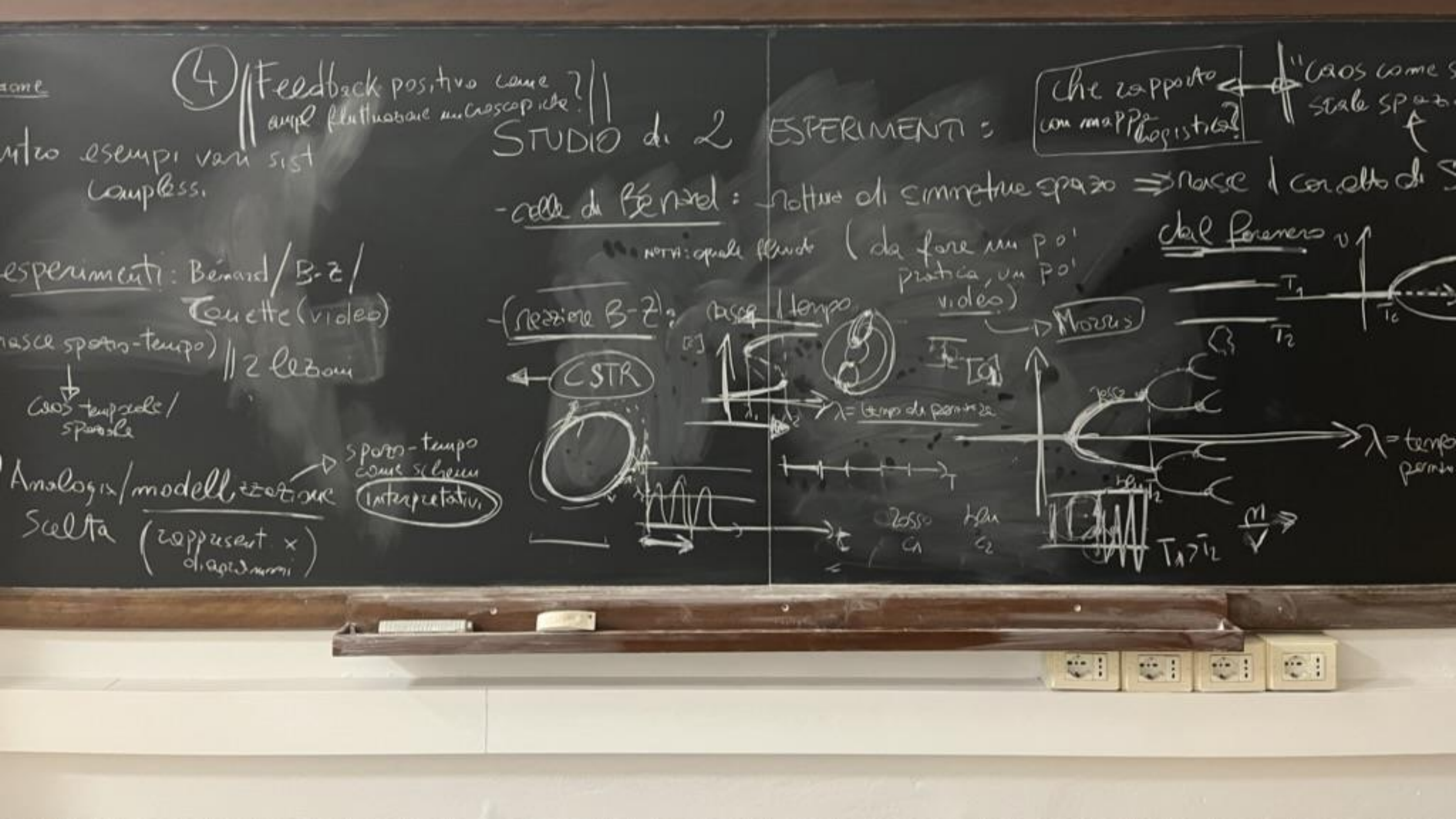
- developing a theoretical construct for **epistemic identity**

# EXAMPLES OF EDUCATIONAL RECONSTRUCTION:
# - FISICA DELLE NUVOLE
# - KAIROS

# RECONSTRUCTION OF PHYSICS COMPLEX SYSTEM

## Why complex systems?

“The epistemological structure of the complexity can be a source of words and epistemic forms of reasoning that can stimulate critical and systemic thinking, needed to navigate today's society. Dealing with them can train to understanding the complexity of systems around us (natural, social and economic ….). […] Ultimately the nature of the concepts treated in the perspective described, can help to build conceptual structures, models and metaphors to orient oneself in today's society, the society of complexity and uncertainty” (P. Fantini)


(4) Feedback positivo come ?
STUDIO di 2 ESPERIMENTI :
Che rapporto con mappe logistica?
esempi vari sist complessi
esperimenti : Bénard / B-Z / Couette (video)
nasce spazio-tempo)
2 lezioni
caos temporale / spaziale
Analogia / modellizzazione
Scelta
spazio-tempo come schemi interpretativi
- celle di Bénard : rottura di simmetrie spazio
nasce il concetto di
dal fenomeno
(da fare un po' pratica, un po' video)
- reazione B-Z : nasce il tempo
CSTR
λ = tempo di permanenza
Morris
$T_1$
$T_2$
$T_1 > T_2$
λ = tempo

# TWO EXAMPLES

| LA FISICA DELLE NUVOLE | KAIROS |
|---|---|
| Grade 9 | Grade 10 |
| March – May 2021 | March – May 2023 |
| Basic concepts of complex systems | Basic concepts of complex systems |
| Creating writing of essays (in groups) | Creative writing of theatrical acts and scenes (individual wiriting) |
| Focus on the spatial complexity | Focus on the temporal complexity |
| - | Laboratory lessons |

# FISICA DELLE NUVOLE + KAIROS


Physics of clouds ("Fisica delle nuvole") poster

4 (1hr. each) lectures on complex systems and their properties, **chosen and reconstructed by physics teacher upon a MER approach**.

Concepts presented were:

- Circular causality (negative and positive feedbacks)
- Deterministic chaos
- Emergent properties
- Micro-macro scale approach
- Irreducibility
- Unpredictability

# KAIROS

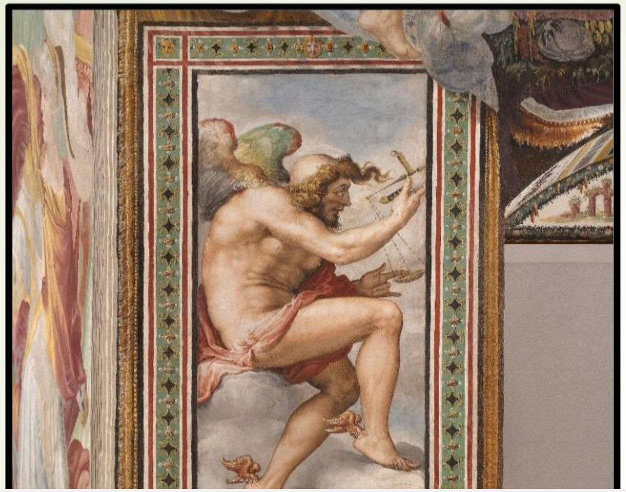
We wanted to highlight the ***emergence property*** highlighting how spatial and temporal structures emerge through a chaotic behaviour (**deterministic chaos).**

From the spatial/temporal patterns, it is possible to extract some key concepts of the complexity paradigm that have been shown to generate new knowledge in diverse disciplinary fields:

- Philosophy (Deleuze & Guattari)
- Literary criticism (Morson)
- Strategic management field (VUCA- Volatility, Uncertainty, Complexity, Ambiguity)
- …

Benard cells

B-Z reaction




ARGO LAB
Power


HOLLISTER

# SOME CONSIDERATIONS

- Starting from a condition in which there are no space-time structures, we see the emergence of space structures (cells, stripes, rings) or time structures (periods). Both processes are seen as bifurcations from an unstable state into two new stable states (e.g. two directions of convection, two colors), which finally lead to a chaotic regime, as the superposition of space and time "patterns" at different space and time scales
- Hence, bifurcation and chaos, which define emerging space-time structures of these two phenomena, become analytical tools used to study other phenomena and generate new knowledge within the discipline (Ising model, magnetization, etc.) and outside the discipline.
- This is what we mean for educational reconstruction; to show how scientific epistemological features emerge, study them, translate them "outside" the discipline, reporting and enhancing their meaning through new languages and show their potentialities as analytical tools in other contexts, but also as personal tools.

# EXPLOITING NEW LANGUAGES

- In the second part of the module students were asked to write, **setting** the stories within a complex system, **referring** to the epistemological features presented, **respecting** the narratological constraints.

- Use different narrative sequences (dialogues, monologue, description)
- Choose a beginning sequence
- Make use of narrative techniques and inspirations (e.g. humour in Pirandello or complexity in Calvino)

*"Writing as a betrayal but also empowerment of the complexity meaning. "* (teachers)

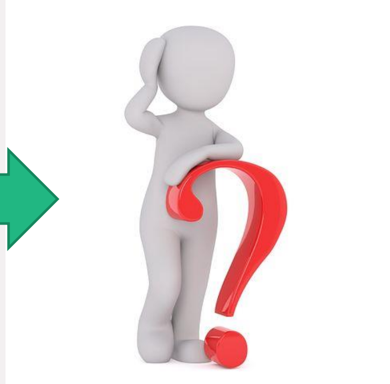
# FINDINGS


- On the one hand students re-ported with idiosyncratic language the epistemological features of complex systems discussed in class, in terms of[1]
  - methods
  - aims
  - knowledge
  - values

- On the other hand they re-ported:
  - personal issues
  - emotions towards complex systems epistemology and how to deal with it

**through the voices and thoughts of essays' characters.**

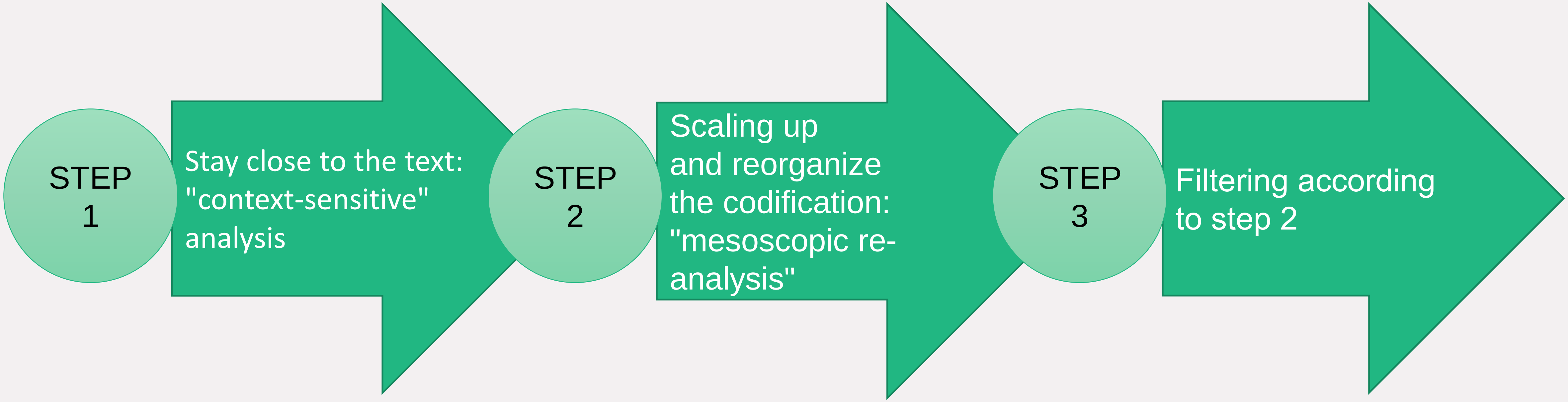
NON-EXPECTED
in every essay there are personal issues related to identity and its construction + epistemic emotions



1-Erduran and Dagher, 2014

# DATA ANALYSIS

- Given the nature of data (6 essays), we found natural to pursue a **qualitative thematic analysis** (Braun and Clarke, 2006).
- This is coherent with the aim of developing a theoretical construct for epistemic identity; indeed we follow a procedure informed by Grounded Theory Approach (Glaser and Strauss, 1967).



# FINDINGS

Hence we can say that:

1. a specific choice of *educational reconstruction* (made by physics teacher), focusing on some of the epistemological features of complexity (such as the multiperspectives or the different scales of phenomenona in complex systems)

AND

2. the instrument of creative writing with its constraints

- **brought students to express, reconceptualize, take new perspective and become more aware** of a particular personal need: find a balance between the self (unique, distinct) and the group (family, peers).

"*(we wrote them) in a period when however we had to cope and we had to relate so much to our own personal reality and much less in our relationship with others [...]* ***personally I thought a lot during those months about the relationship with others and the relationship with myself and I think you can also perceive from the themes*** *the fact that personal reality was a highlight because by not having a relationship with the other the conception of ourselves is amplified and is constantly being questioned*"(Monica)[1]

"***we put ourselves in the place of the cloud, so in the end we told precisely ourselves inside that cloud … so writing about complexity through a cloud that is already a complex structure anyway turned into something simple because we were talking about us***"(Carla)

"*So this text also served very much as a dialogue between us, to figure out just how we wanted it to represent us*" (Monica)

"*I almost feel like I can consider the language of writing and writing as the rhetoric of physics. And that is very nice because even writing itself even that very language needs rhetoric so anyway a code that goes beyond the word itself to better express concepts […]*" (Italian teacher)

1-pseudonyms

# CONCLUSIONS

We see this activity as a practical example where, **by acting on the content reconstruction and not only on instructional strategies,** it was possible to open **up "space" for students' expression**, to give voices and images to personal demands and needs.

Reconstructing physics epistemology, with the help of creative writing**, *"authorized"* students' identities to emerge and at the same time sustained them with new tools.**

In this sense physics epistemology became a scaffolding for personal issues development: **EPISTEMIC IDENTITY work as steps in the construction of the self, inspired by the learning of knowledge structures.**

# AMBITIOUS SCIENCE TEACHING IN ITALY

# AIMS OF THE RESEARCH

- **Characterize and describe** the implementation of the US framework “Ambitious Science Teaching” in an italian context, with undergraduate students.

- Study the potentialities offered by the framework implementation, in fostering knowledge ***appropriation*** (Levrini et a., 2015) and ***identity development*** by working with real scientific practices.

# MODULE STRUCTURE

**1st - 2nd - 3rd lesson**

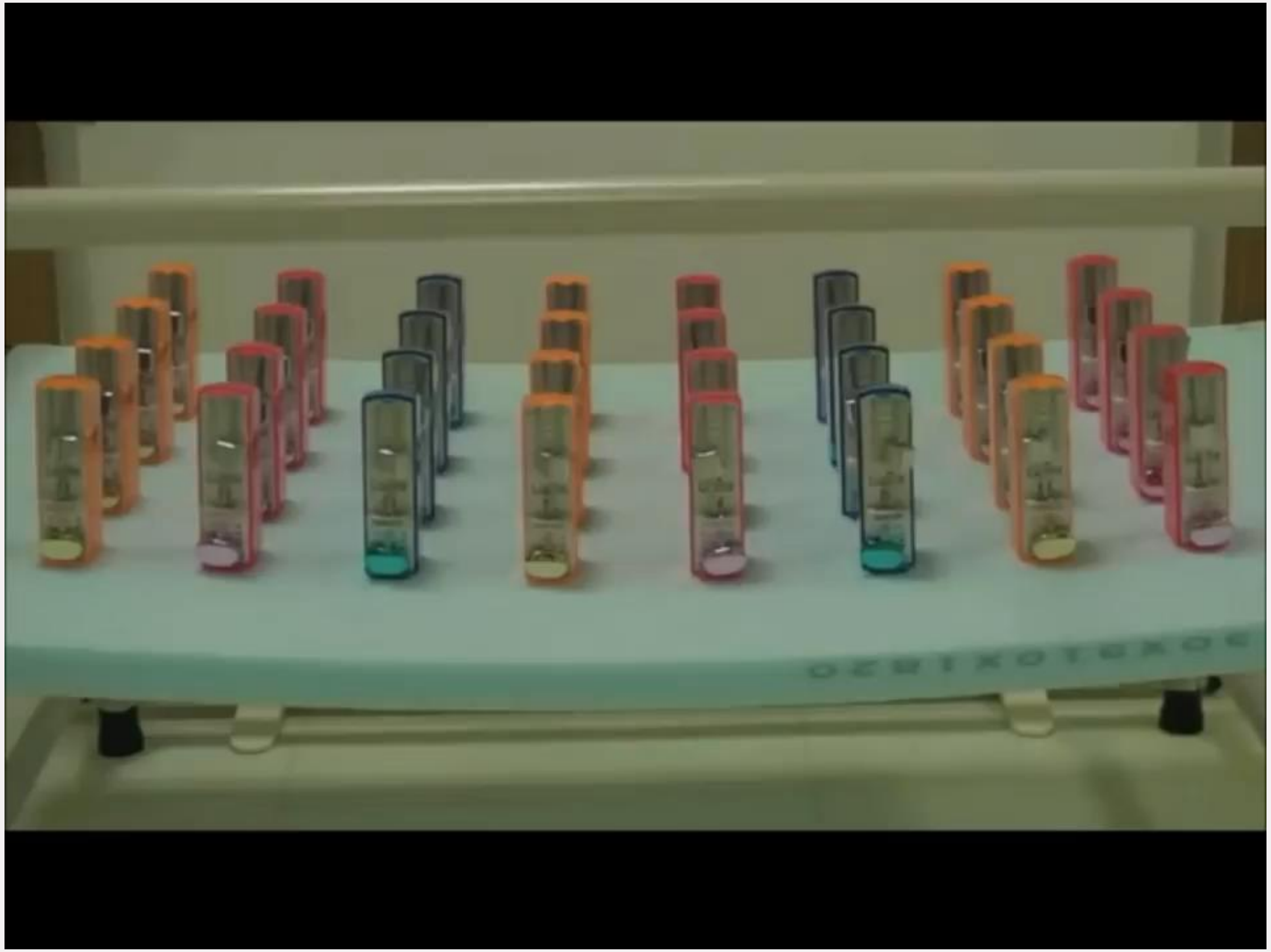
- lectures and discussions regarding AST practices.

**4th - 5th lesson**

- modelization activity: metronomes synchronization.

**6th lesson**

-the groups presented their teaching module.



# METRONOMES SYNCHRONIZATION

**Phenomenon:** metronomes placed on a rigid surface, started one after the other: as time passes, they get to synchronize.

**Explanation:** Transmission of linear momentum through the surface -> redistribution of average momentum across the surface -> oscillation in synchrony.

**Modelization:** Kuramoto model (1975), evolution of oscillators coupled together with different initial phases. For metronomes, pendulum = oscillator and coupling = vibrations transmitted through surface.

$$\frac{d\theta_i}{dt} = \omega_i + \frac{K}{N}\sum_{j=1}^{N}\sin(\theta_j - \theta_i)$$

Dynamic is driven by two terms: proper frequency and coupling term. Force that drives an oscillator to assume same phase and frequency as others: depends on phase difference between oscillators and on parameter K, strength of the coupling.

# MODULE

**1st - 2nd - 3rd lesson** -> lectures and discussions regarding AST practices.

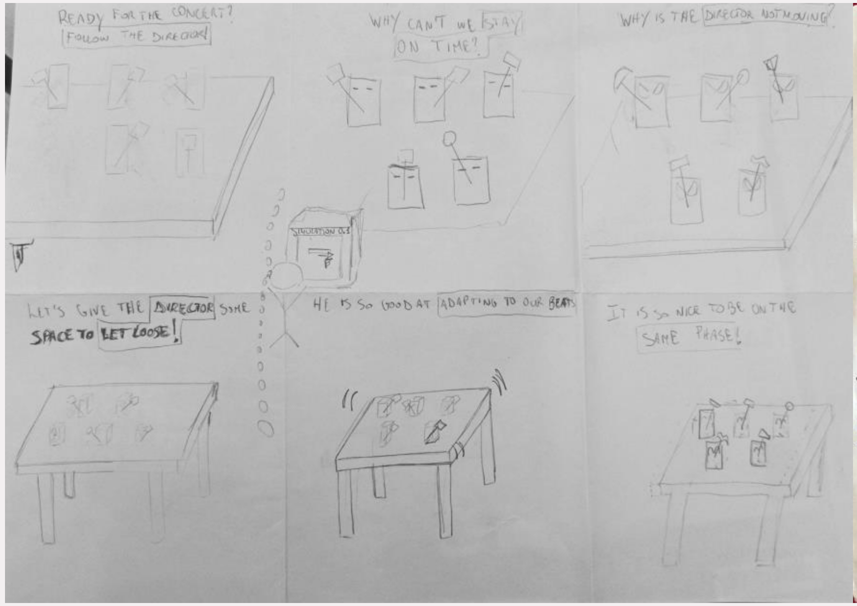
**4th - 5th lesson** -> modelization activity.

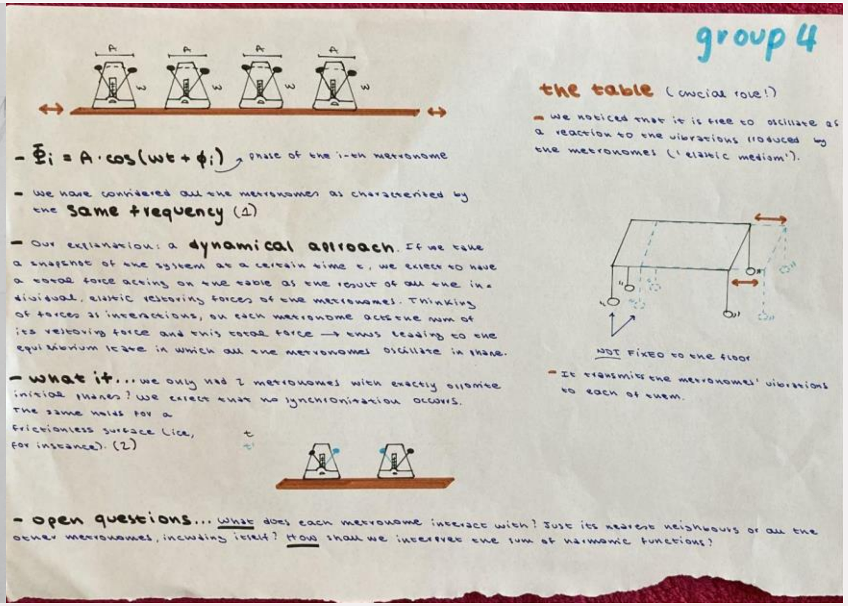
**6th lesson** -> the groups presented their teaching module.

Students were guided to:

1. Watch a video presenting the phenomenon.
2. Formulate a model explaining the phenomenon.
3. Exchange the models and argument choices and explanations.
4. Revision the models by "testing" them in a virtual simulation.
5. Participate in the discussion of a final model formulation.

# MODELS PRODUCED DURING THE ACTIVITY




Key points of the final explanation:

1. The table links only if there is (sufficient) friction.
2. Momentum is exchanged in both directions (feedback effect).
3. Opposite phases synchronize in antiphase.
4. Table dynamic driven by a group of metronomes with similar behavior.
5. Mass of table relevant (it must not be too massive).
6. Initial conditions: same frequency, different phases and amplitudes.
7. Frequency of table reaches frequency of metronomes; final amplitude is an average of initial amplitudes.

Group 3 model: **creative** approach; metronomes are musicians and table the director. Comic sequence.

Group 4 model: **analytical** approach; realistic details and gradual explanations.

# RESEARCH QUESTIONS

**RQ1:** *How did students react and what dynamics emerged in this AST implementation?*

**RQ2:** *What tools did the AST offer to students to become agents of their knowledge construction?*

# INITIAL SOURCES OF DATA

1. **Description** of the Physics Teaching Lab course class with the help of Prof Tasquier, the course's professor of reference.
2. Video **recordings** of the activities.
3. **Teaching materials**.
4. Student **artifacts**: several jamboards, schemes of the modelization, teaching units designed at the end of the module.

# CRITERIA FOR NEW DATA COLLECTION (1)

According to recordings, jamboards and impressions of teachers, a high engagement was present and students seemed to resonate with the framework principles.

Hence we wanted to:

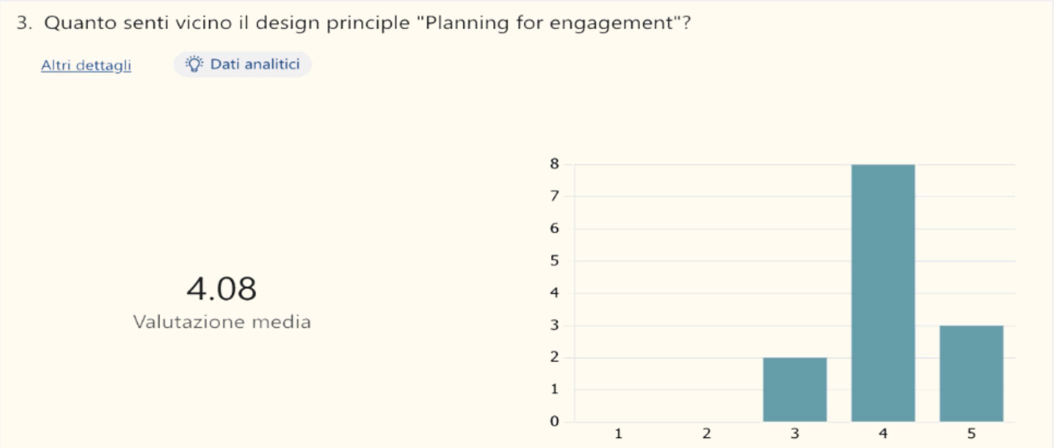
- Have a comprehensive picture of the class.
- Investigate the acceptance of the framework principles and the level of *appropriation.*
- Investigate group-dynamics and the role of personal contributions in the construction of the explanatory model.

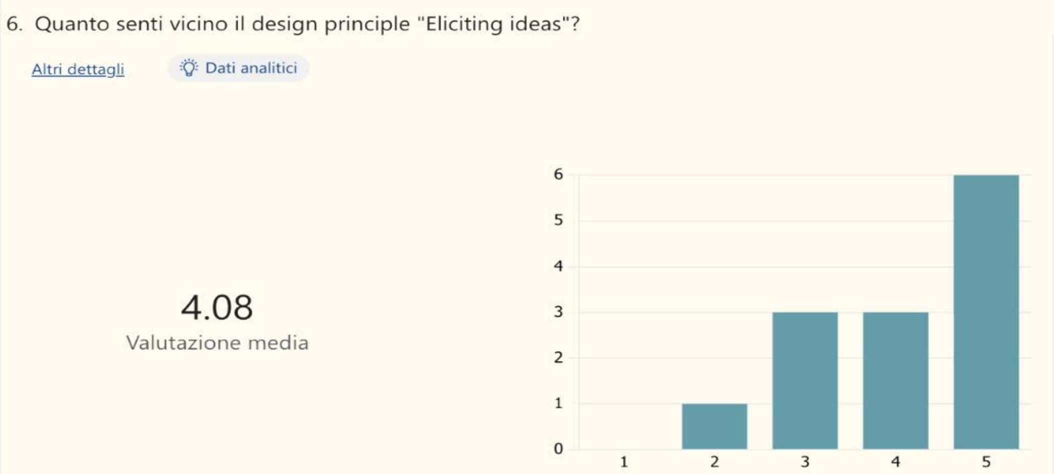
We choose to submit a **questionnaire** with 11 open questions and 29 close questions.

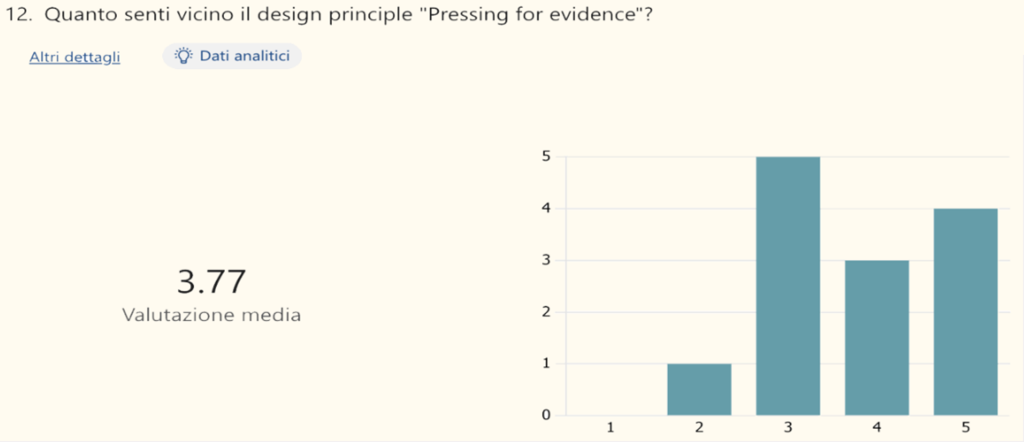
# QUESTIONNAIRE OUTCOMES

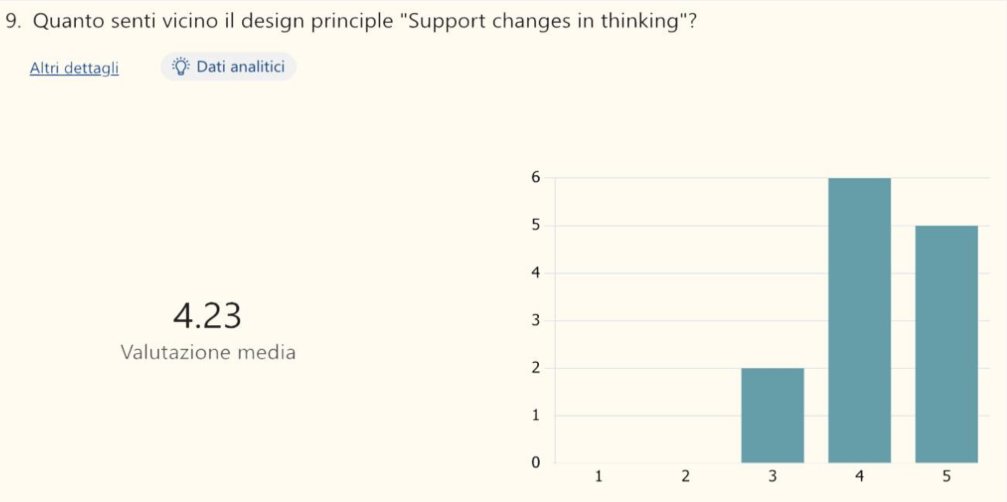
Framework practices were:

1. **Accepted by students**:
   - More than 69% of the students (N=13) perceived 3 principles close to themselves. For the 4th principles the percentage decreases to 54 %.
   - Referred to practices with adjectives as: *stimulating, ambitious, engaging, innovative.*



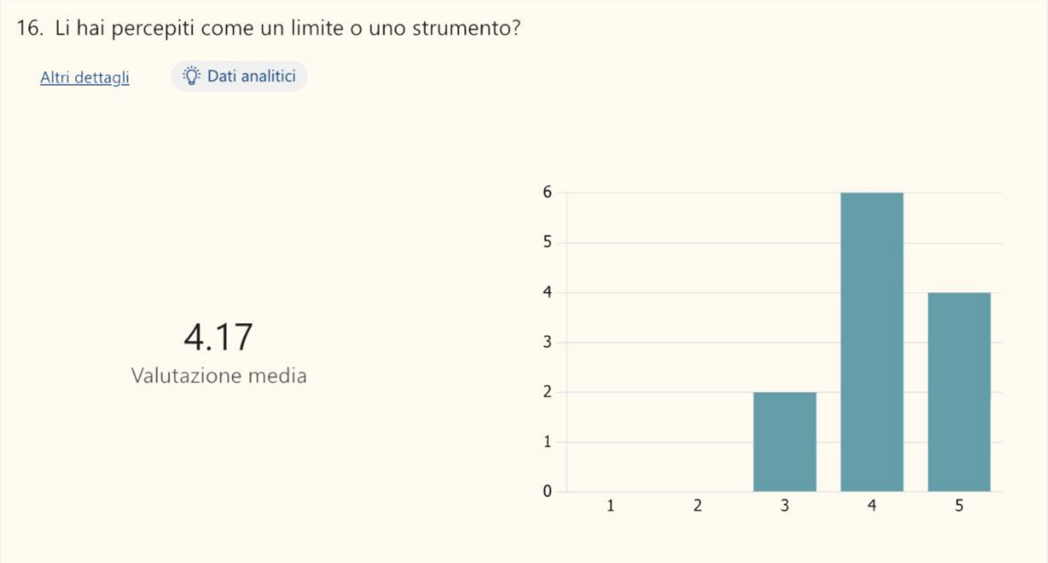



# QUESTIONNAIRE OUTCOMES 2

2. **Understood**: students systematically refer to a *safe place* condition in the class, highlighting one of the main design goals of the framework.

3. **Appropriated**: 89% reported that principles were an instrument more than a limitation in developing the explanatory model; all groups mapped principles into the design of their unit modules.




In addition it emerges that:

- Students looked critically at the framework: simulating **scientific practices** triggered *awareness* of their value as **citizenship skills**.

# CRITERIA FOR NEW DATA COLLECTION (2)

Deepen the analysis on students':

- Explanatory models.
- Perception of the teaching setting.
- Views of the relationship between scientific practices and citizenship skills.
- Personal approach to knowledge during the modeling process.

This led to a structured **interview protocol** (11 questions), with 6 students (2 females/4 males) out of the 13 who answered the questionnaire.

# INTERVIEWS ANALYSIS

- **Codification** (**Nvivo** software) with 6 categories.
- **Intercoding reliability test** to check the effectiveness of the categorization.

| | Kappa | Agreement | A and B | Not A and Not B | Disagreement | A and Not B | B and Not A |
|---|---|---|---|---|---|---|---|
| Safe Place | 0.9337 | 99.25 | 5.66 | 97.59 | 0.75 | 0.47 | 0.29 |
| Scientific Practices | 0.5736 | 97.11 | 2.07 | 95.04 | 2.89 | 1.29 | 1.61 |
| Citizenship Skills | 0.1362 | 98.48 | 0.13 | 98.35 | 1.52 | 0.56 | 0.96 |
| School-Society Gap | 0.5573 | 97.33 | 1.78 | 95.55 | 2.67 | 1.68 | 0.99 |
| Personal Knowledge | 0.4644 | 94.87 | 2.45 | 92.41 | 5.13 | 1.07 | 4.06 |
| Positioning Toward Knowledge | 0.1376 | 95.06 | 0.46 | 94.6 | 4.94 | 3.87 | 1.07 |

# EPISTEMIC AGENCY

Students **felt free to express ideas**, without judgement.

They systematically recognized the practices held in the activity as close to **real scientific practices.**

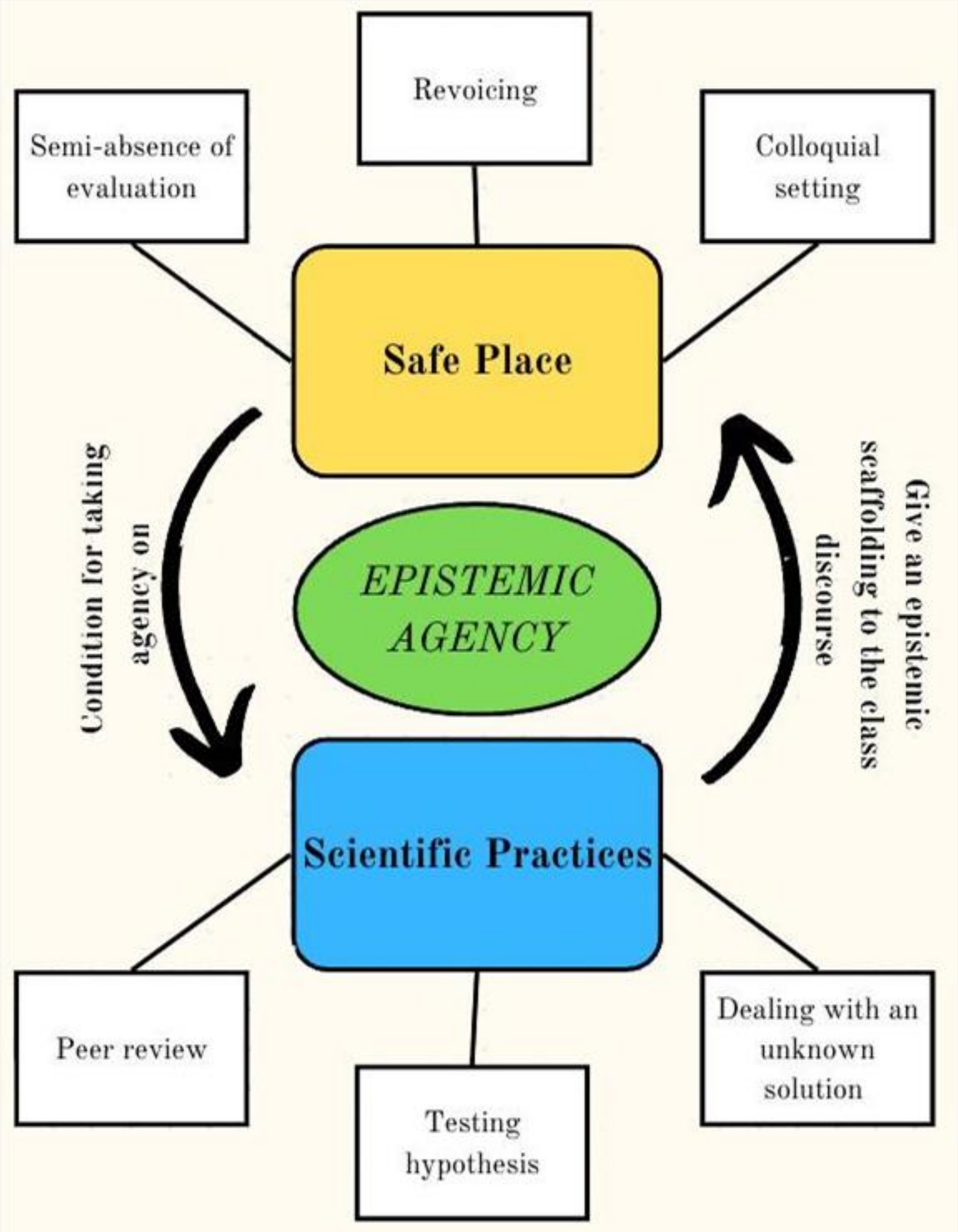
The real scientific practices gave the chance to act on the knowledge,
and the safe place set the students as agents.

EPISTEMIC

AGENCY

This dualism compensates two possible **critical** issues:

- Agency contrasts **the fear generated by an unfamiliar topic and approach**.
- The epistemic scaffolding given by the practices fills the **classroom discourse** with meaning and scientific knowledge.



# SCHOOL-SOCIETY GAP

Additionally, scientific practices were recognized by students as valuable even **outside the scientific context**.

Answers describe them as triggering ***citizenship competences***.

*“is a way to develop reasoning skills outside of school as well.”*

It seems that fostering real scientific practices at school, allows students to *recognize* ***independently*** the *transversal* value of these practices.

*"I think eventually students have more awareness of what it means to do science and feel more part of the scientific community. This could also increase the scientific awareness of the citizenship."*

# CONCLUSIONS

**RQ1:** ***How did students react and what dynamics emerged in this AST implementation?***

The results answer to **RQ1**:

- Showing that the framework was *accepted, understood and appropriated* by students.
- Describing the dynamics and the reactions to the framework principles, that took place in the classroom during the activity.

**RQ2:** ***What tools did the AST offer to students to become agents of their knowledge construction?***

The results answer to **RQ2:**

- Explaining how the framework goal of *epistemic agency* was achieved thanks to the **dualism** of *safe place* and *scientific practices*.
- Displaying how, working with **real scientific practices** at school, is it possible to reduce the gap between school science and real science and develop awareness on the gap between school and society.

# REFERENCES


- Danielsson, A.T., King, H., Godec, S. *et al.* The identity turn in science education research: a critical review of methodologies in a consolidating field. *Cult Stud of Sci Educ* (2023). https://doi.org/10.1007/s11422-022-10130-7
- Gee, J. P. (2000). Identity as an Analytic Lens for Research in Education. *Review of Research in Education*, *25*, 99. https://doi.org/10.2307/1167322
- Carlone, H., & Johnson, A.C. (2007). Understanding the Science Experiences of Successful Women of Color: Science Identity as an Analytic Lens. *J Res Sci Teach* 44, 1187-1218
- Hazari, Z., Sonnert, G., Sadler, P. M., & Shanahan, M.-C. (2010). Connecting high school physics experiences, outcome expectations, physics identity, and physics career choice: A gender study. *Journal of Research in Science Teaching*, n/a-n/a. https://doi.org/10.1002/tea.20363
- Hazari, Z., Lock, R., Cass, C. & Beattie, C.. (2014). Obscuring Power Structures in the Physics Classroom: Implications for Student Engagement and Physics Identity Development. *J Res Sci Teach*, 52(6), 10.1002/tea.21214
- Avraamidou, L. (2021). Identities in/out of physics and the politics of recognition. *J Res Sci Teach*, 59(1), 10.1002/tea.21721
- Fracchiolla, C., Prefontaine, B., & Hinko, K.A. (2020). Community of practice approach for understanding identity development within informal physics programs. *Phys. Rev. Phys. Educ. Res.* 16, 10.1103/PhysRevPhysEducRes.16.020115
- Tasquier, G., Barelli, E. (2023). FEDORA materials' effectiveness to develop thinking and future-scaffolding skills and to foster aware, responsible and proactive engagement with science: results and hypotheses from the first round implementations - Deliverable 4.2 (V1.0). Zenodo. https://doi.org/10.5281/zenodo.7519166
- De Zuani F., D'Orto, E., Fantini, P., Tasquier, G., Levrini, O. "Design of activities questioning the *lack of relevance* of science at school and its distance from society challenges" (accepted), Frontiers in Education
- Erduran, S. & Dagher, Z. (2014). Reconceptualizing the Nature of Science Education: Scientific Knowledge, Practices and Other Family Categories, Springer
- Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*, *3*(2), 77–101. https://doi.org/10.1191/1478088706qp063oa
- Glaser, B. G. & Strauss, A. L. (1967). The Discovery of Grounded Theory. Strategies for Qualitative Research. Chicago: Aldine.
- Glaser, B. G., & Strauss, A. L. (2010). *The discovery of grounded theory: Strategies for qualitative research* (5. paperback print). Aldine Transaction
- Anfara, V. A., Brown, K. M., & Mangione, T. L. (2002). Qualitative Analysis on Stage: Making the Research Process More Public. *Educational Researcher*, *31*(7), 28–38. https://doi.org/10.3102/0013189X031007028
- diSessa, A. A. (2002). Why "conceptual ecology" is a good idea. In Reconsidering conceptual change: Issues in theory and practice (pp. 28-60). Springer Netherlands.

Grazie.