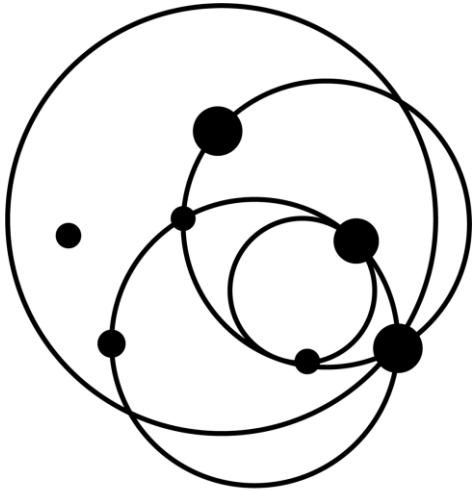

FEDORA

The Quantum Atelier Project: Results from an interdisciplinary experience between art and science

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FEDORA - Future-oriented Science EDucation to enhance Responsibility and engagement in the society of Acceleration and uncertainty This project received funding from the European Union's Horizon 2020 Research and Innovation program under Grant Agreement n° 872841 www.fedora-project.eu

Quantum Atelier Project

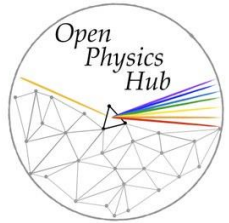
Where:
The school context: «Liceo A. Einstein», a scientific high school based in Rimini (Italy)

The collaboration between the University of Bologna and the school: I SEE, SEAS, FEDORA and CLIMADEMY projects.

When:

- September-October 2021: PLS course on the Second Quantum Revolution
- November 2021-May 2022: Quantum Atelier project

In collaboration with:



FEDORA

Development of an open-schooling and future-oriented model to enable creative thinking, foresight and active hope as skills needed in formal and informal science education.

H2020 project coordinated by the University of Bologna (September 2020-August 2023)

Partnership: University of Bologna; Kaunas University of Technology; University of Helsinki; University of Oxford; Teach the Future; formicablu

The three dimensions of the project's actions and research:

- *Interdisciplinarity*
- *Narratives and Languages*
- *Futurizing Science Education*

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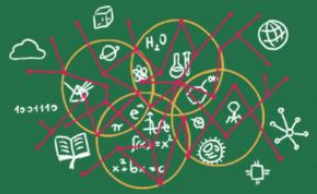
We worked on 3 main dissonances:

1. 

Organization of teaching in disciplines
VS
Interdisciplinary character of innovation

2. Formalized languages of science education in formal contexts
VS
New languages, narratives and arts

3. 

A-temporal oriented teaching
VS
Need to construct visions of the future

Our research was based on:

Literature in science education research

&

Corpora of texts produced by hundreds of students' and experts' surveys

The outcoming results of our studies tailored recommendations for:

Open-schooling networks

Instruction designers

Policymakers

Policy institutions

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

FEDORA: the Second Quantum Revolution course

Our need: *Find new personal and meaningful narratives and languages to talk about the Second Quantum Revolution*

The three dimensions of the project's actions and research:

- *Interdisciplinarity*
- *Narratives and Languages*
- *Futurizing Science Education*

- **The Second Quantum Revolution course**
- **Quantum Atelier project**

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Quantum Atelier Project

At the end of the Second Quantum Revolution, the QA project started as an extracurricular course carried out by 4 teachers (1 literature teacher and artist, three math and physics teachers) and 6 students.
The group reflected on new possible narratives to talk about some aspects of the quantum revolutions and the potential role of art.

The project ended with the production of three artworks.

At the end of the project, we interviewed three out of six students to understand how students lived the interdisciplinary experience. In particular, the research question to which we aim to contribute is

RQ

If and How does the interdisciplinary experience of Quantum Atelier could promote a personally meaningful understanding?

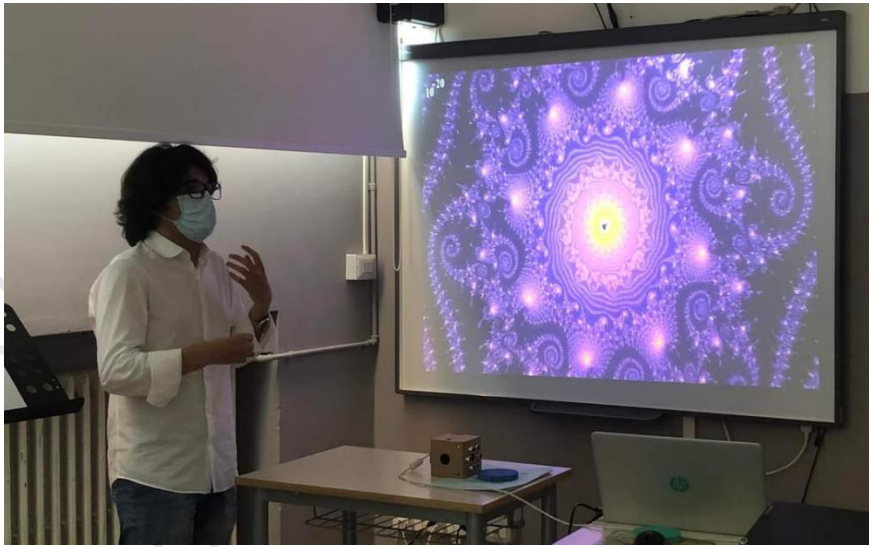
The Data and the analysis

As source of data we used:

- A focus group carried out at the end of the Second Quantum Revolution course
- The final collective interview to three out of the six students (Arturo, Carlo and Andrea);
- The written texts realized by the students to participate to an art-science contest

The analysis:
To contribute to RQ1, we carried out an analysis based on grounded theory using the framework elaborated by Levrini et al. (2015)

Quantum Atelier Project: The artworks



Title: $|\psi\rangle$

Represented theme: time-evolution of a state, relationship between the system and the observer and effect of quantum measurement.
"[...] evolving system. And then both for... for technical aspects, however for the awareness of our skills in the field of programming, we decided to adapt it and therefore considering the continuous evolution of the focus on the interaction with the system [...] we decided to put more emphasis on the action of the observer on the system."

"Translation": the temporal evolution of the system has been simulated through evolving fractal, the interaction with the system takes place with a sensor next to which is placed a button to emphasize the direct action of the observer on the system, the collapse (effect of measurement) is represented with the return of the fractal to an initial state.

Quantum Atelier Project: The artworks

Title: *Maze*

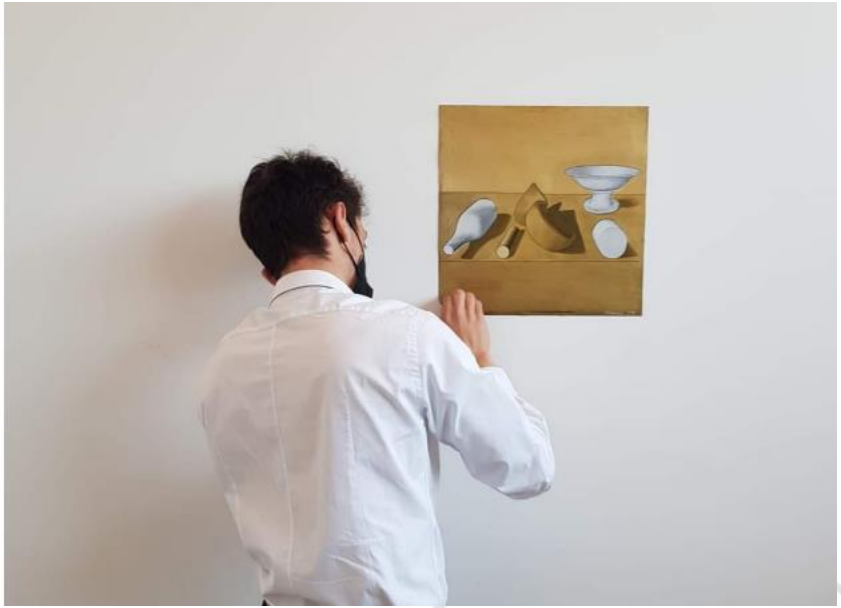
Represented theme: superposition principles, interaction observer-system and effect of quantum measurement.

"Translation": the idea of quantum state is reproduced through representational art and, in particular, a work of Kandinsky.
"*Representational art as a basic concept is traced back... um... connects well to the superposition principle because in general already in the pictorial conception of the painting... different layers overlap...*".
Through the interaction with the touch screen (interaction system-observer), it is possible to observe the effect of the quantum measurement

Quantum Atelier Project: The artworks

Title: *Apparence*

Represented theme: the change of the relationship between knowledge and reality, knowledge in relation to the subject.



"Translation": Roberto Longhi provides an interpretation of Morandi's work through a story by Proust: "a sinking of the gaze in which the shape of objects seems to lose importance". For this reason, they propose a Morandi's still life that stands on the threshold between visible and invisible. Through the technique of augmented reality, they "simulate this vanishing of the fixity of perceived reality and let emerge the text of Proust from which we started, thus alluding to a "beyond", to a more complex reality, where matter could manifest itself in the way that the investigation of quantum research lets us glimpse. The physical description of the world is 'authorized' by quantum physics not to correspond to our daily experience: the new theoretical framework becomes a gateway to a culturally revolutionized world, in front of which disappears any expressive constraint that tries to 'capture'."

The appropriation construct

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. [...] *The lack of personal meaning and the image of eternal truth and correct answers put off more young people today than before*. (Sjøberg, 2001, p. 21)

We believe that science education and the construction of (inter-) disciplinary knowledge can and should play an important role in the construction of personal identity.

"Appropriation is a complex and reflexive process of transforming scientific discourse (scientific words and utterances) so as to embody it in one's own personal story, respecting disciplinary rules and constraints. The process of transformation involves one populating scientific discourse with one's own intentions, idiosyncratic tastes, and purposes in order to make it sensible not only for oneself but also with respect to one's way of participating in the social context of the class" (Levrini et al., 2015, p.99).

The interdisciplinary experience promoted the appropriation of the content

A. developed around a set of words or expressions repeated several times and linked together so as to express an authentic, *idiosyncratic signature idea*; this idea is recognizable as authentic and idiosyncratic because it is different from student to student in terms of, for example linguistic choices and the tone;

B. *disciplinarily grounded* (i.e., the idiosyncratic idea is used by the student as a tool for selecting pieces of disciplinary knowledge and coordinating them in a way meaningful from a physical point of view, namely, by respecting the rules and the constraints of the game of physics);

C. *thick* (i.e., the idiosyncratic idea involves a metacognitive dimension [what learning physics means for me] and an epistemological one [what image of physics makes sense to me]);

D. *nonincidental* (i.e., the idiosyncratic idea can be traced back to the student's reactions in different classroom activities, and, hence, it can be recognizable within a personal story that can go beyond the duration of a single episode);

E. the *carrier of social relationships* (i.e., the idiosyncratic idea places the student within the class community and, vice versa, the development of the idiosyncratic idea was inseparable from the classroom dynamics).

The interdisciplinary experience promoted the appropriation of the content

The case of Carlo

His discourse is characterized by the repetition of some expressions (**Marker A**) like "*finding a correlation*", "*figuring out the mechanism*", "*giving the reasoning within*", and "*seeing geometrically what happens*", "*see geometrically*". For him, the knowledge is formally encoded, and the understanding consists in grasping the mechanism inside as well as in seeing geometrically ("*see geometrically*", "*a geometric representation in my opinion is always the best*", *"more geometric is the type of representation and the easier it is for me to understand")* that allows him to "*automatically*" understand since it evokes nature and what he constantly sees: namely known shapes (*I see a shape... It's almost like it's already in my mind")*. Carlo gave major evaluations to the geometrical, the logical, and the circuital representations, but he need for multiple representations to activate personal reasoning mechanisms ("*if a geometric representation is combined with the formalization... it allows [me] to understand the reason why that thing is represented in that way. For me, it's the best way to understand things.")*.

The active participation and the repetition of expressions like "*in my opinion*" and "*for me*" suggest that Carlo took an active part during the focus group and give us information about social relations (**Marker E**). In particular, he often took the position of contrarian ("*I think it's the exact opposite*", "*I start so I don't have against anyone*."), highlighting that his social position was very personal, always enriching the group discussion.

This suggests that Carlo's signature idea is nonincidental (**Marker D**). The constellation of representations encountered during the course has nurtured and satisfied his learning needs favoring the activation of personal mechanisms of reasoning.

The interdisciplinary experience promoted the appropriation of the content

The case of Carlo

Carlo's signature idea is perfectly embodied in his artwork: he chose a painting by Kandinsky that embodied the return to the simplest shapes and colors after the artistic movements of impressionism and expressionism. The choice of this painting recalls his need of recognizing and tracing back a concept to shapes and colors ("*seeing and understanding everything through the eyes so in my opinion the shapes, colors...*", "*I see a shape...*"). They allow him, immediately and naturally, to understand a concept because they are already in Carlo's mind ("*It's almost like it's already in my mind*", "*if the shape is made in the correct way... I still get to understand the concept*"). He chose representative art to represent the concept of the superposition state also because the superposition is "*already in the pictorial conception*". In Carlo's words "*Representative art is based on the... It connects well to the superposition principle because in general already in the pictorial conception of the painting... different layers overlap or anyway... [it] is always the sum of a certain number of things* [...]".

The painting choice that embodies Carlo's signature idea is grounded in disciplinary knowledge (**Marker B**): the superposition principle as a linear combination of the states of a system can be reconceptualized, metaphorically, as the overlap of the different layers in the painting surface.

The interdisciplinary experience promoted the appropriation of the content

The case of Carlo

The "irrational channel" on which an artwork is based and understood for Carlo is a very good way to shed light on the shift of paradigm from classical to quantum probability, from classical to quantum logic (**Marker B**). In Carlo's words "[the channel with which it allows to communicate the work of art] *is not so much emotional and emotional but rather irrational because... We also talked about it in the course when... when we were exposed to the concept of probability that... we lose that... that perception we have always had of binary logic to enter into a probabilistic logic. Similarly, our reason* [reason understood as our *system of values or our way of conceiving reality*] *at this time, as we understood society or as we think about logic itself, is mostly deterministic and binary so... in this case... just in this specific case to explain something that escaped from that... from that pattern of reason, to use something that eluded reason in itself was a great way of representing it...*"

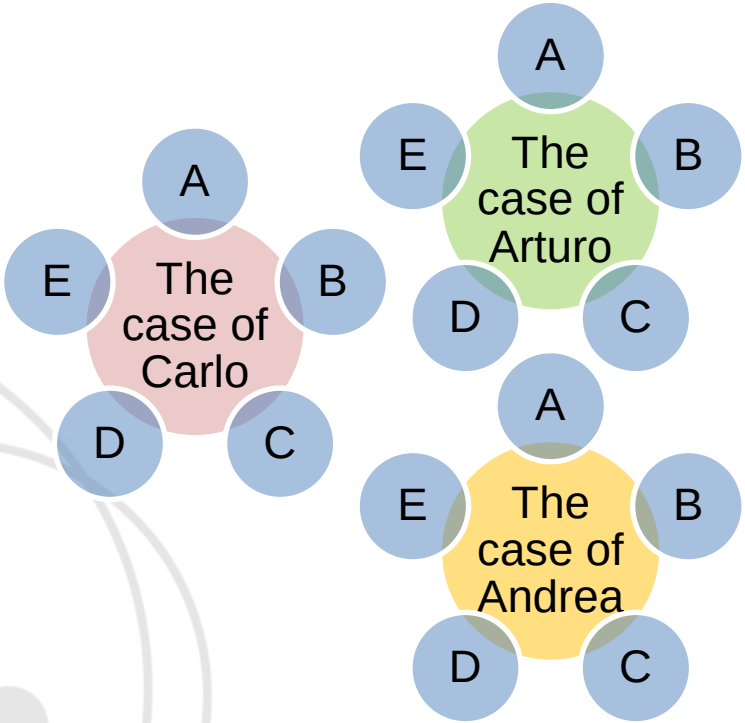
The interdisciplinary experience promoted the appropriation of the content

The case of Carlo

Finally, Carlo's signature idea is also thick (**Marker C**) because it is bearer not only of what learning physics means for him ("*see geometrically*", alongside more representations) but also of the image of physics he has: physics as formal knowledge that, however, can be traced back to nature through shapes. The final interview allows us to enrich Carlo's signature idea. At the beginning, he said "*I understand [a concept] more from a geometric or conceptual point of view*." The conceptual perspective to which Carlo refers to consists of the ri-elaboration, in the interdisciplinary art-science space, that led him to conceptually elaborate the superposition principle and the passage from classical to quantum logic. The two concepts are reconceptualized as a superposition of layers in the artwork and as an irrational element due to the fall of the scheme of values representing the "*classical reason*". At the end of the interview, when we asked students to think a word to describe the relationship between science and art, Carlo said: "*The fact that [physics] is practically applicable in every field in the sense... with a little ingenuity*... [...] *with a little care you can get... makes it clear that [physics] is the matrix of things and that you can connect very easily that is... Anyway, [in quotation marks] it is ubiquitous*." Physics is a "*matrix*", it is everywhere. It is thus elevated to thinking tool, in this case, also to re-read and populate a representation of meanings and rework it to bring out the deep personal meaning attributed to some basic concepts of quantum physics.

Conclusion

This analysis showed the impact on students' learning of the interdisciplinary art-science experience.



The presence of the 5 markers in students' narratives suggests that the art-science experience engaged them in complex and reflexive processes of transforming scientific discourse (scientific words and utterances) so as to embody it in their own personal story, populating it with personal intentions, idiosyncratic tastes, and purposes "in order to make it sensible not only for oneself but also with respect to one's way of participating in the social context of the class".

Conclusion

This analysis showed the impact on students' learning of the interdisciplinary art-science experience.

Students' reactions

Knowing themselves through the interdisciplinary experience
This Quantum Atelier project will remain in my memory as something very positive because it made me... allowed me to analyze my skills, to adapt them to something I wanted to accomplish and then be able to adapt the project and skills to make them... reach a meeting point. [...] even this here is another aspect that I will keep strongly as a great memory... the need to adapt the level of explanation in order to better involve the public... (Arturo)

Feeling at home in the interdisciplinary experience
I really enjoyed working in this way [between the technical, philosophical, conceptual and artistic dimensions] *also because it is the way I am more and more comfortable* (Andrea)

The presence of the 5 markers in students' narratives suggests that the art-science experience engaged them in complex and reflexive processes of transforming scientific discourse (scientific words and utterances) so as to embody it in their own personal story, populating it with personal intentions, idiosyncratic tastes, and purposes "in order to make it sensible not only for oneself but also with respect to one's way of participating in the social context of the class".

The experience gives students room to express themselves and their ideas proving to be **inclusive and enriching.**
The way in which the 3 students talked about the experience highlights the significance of the interdisciplinary experience for reflecting and grasping more deeply the theme and, in particular, the concepts they represented as well as for promoting the awareness and the development of personal skills (such as technical ones) and nurturing personal identities.

THANKS for the attention

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