Virtual School: Learning to Teach Physics in a Virtual Community of Practice

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Abstract
This research explores the impact a Virtual Community of Practice (VCoP) within the international *Virtual School* pilot project aimed at providing future secondary-school physics teachers with authentic teaching experiences. The *Virtual School* serves as a platform to connect future teachers with real schools and pupils, creating a unique educational environment to develop professional identity and competencies. This paper reports on part of the project engaging eight preservice or early-career teachers, two mentors, three researchers, and forty-eight secondary school pupils. Pre and post semi-structured interviews were employed to collect data, exploring the participants' experiences and perceptions. The findings reveal significant impacts of the VCoP on the understanding of professional identity and the disciplinary teacher practices of participants. By participating in this digital community, they have developed expertise, bridging the gap between theoretical knowledge and real-classroom dynamics. This study highlights the potential of VCoPs to shape the training of secondary-school physics teachers, offering new avenues for teacher education in the digital age.
Keywords*:* teacher education, virtual community of practice, teaching physics, teacher competences, professional identity.

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Introduction

Having a good education enhances young members of society's employment opportunities as well as their overall health and wellbeing (Redecker, 2017). Education should be equally accessible to each and every student, regardless of their cultural or socioeconomic background. Unfortunately, educational disadvantage is a significant problem (Fullan, 2020), which the spread of the Covid-19 pandemic boosted across all levels. Students' difficulties were intensified by limited interactions with teachers and peers, and by the loss of the benefits of practical work, which impacts the quality of STEM teaching and learning (Bjurholt & Bøe, 2023). The Science, Technology, Engineering and Mathematics (STEM) field is particularly vulnerable as many students struggled in these subjects even before the pandemic (e.g., O'Brien, 2021). This is a relevant problem throughout all levels of education, as incoming preparation has been shown to be a major predictor of students' performance in STEM university courses, especially in Physics (Burkholder et al., 2022).

On the other hand, many teachers described valuable experiences gained from online teaching that they would incorporate into their regular teaching. These include home experiments, demonstrations, and simulation tools such as PhET simulations. These innovative practices have the potential to enhance STEM education, provided that teachers are provided with adequate resources and platforms for exchanging expertise within the physics teaching community (Bjurholt & Bøe, 2023). Tens of millions of students are enrolled in fully virtual schools around the world (Fullan, 2020) indicating that online teaching and learning and the related teacher education are a necessity that will persist.

The *Virtual School* (VS) project originated in Australia, by the Monash University, in 2020. Due to the pandemic restrictions, ensuring future teachers the possibility to gain experience in the field by means of a teaching placement has been particularly challenging (Fullan, 2020). The Virtual School project aimed to transform this challenge into an opportunity by engaging preservice teachers in virtual internships targeted at supporting disadvantaged high school students. In 2022, the VS project was adapted to the Italian context thanks to a joint seed funding project between Monash University and the University of Padua (Authors Phillips et al., 2023). In the context of UniPD, a small Virtual Community of Practice of preservice and early-career physics teachers was set up, with the shared domain of interest being the design and delivery of online physics lessons for high-school students. This paper focuses on the Italian pilot with the underlying research question of how this experience might support the development of participants' professional identity as physics teachers.

Theoretical background

2.1 Teacher communities of practice

The term "community of practice" was coined by J. Lave and E. Wenger while studying apprenticeship as a learning model (Lave and Wenger, 1991). According to the definition by Wenger (2002, p.4), communities of practice (CoPs) are "groups of people who share a concern or a passion for something they do and learn how to do it better as they interact regularly". CoPs are characterized by three fundamental elements: a common domain of interest; a community, substantiated by the relationships and interactions among the members; and the practice, consisting in a shared repertoire of resources, knowledge, and experiences. They can accommodate members with different levels of expertise and degrees of participation (Wenger, 2002).

CoPs have been identified as one of the most effective professional development frameworks also in the context of teacher training. Successful teacher CoPs can have positive impacts on teaching practice and student achievement (Vangrieken et al., 2017). While CoPs are useful for both preservice and in-service teacher training, we focus here on their value for preservice and early-career teachers. These two phases of a teacher's career are, in fact, strictly connected, as novice teachers need support during their transition from initial teacher education to their actual engagement in the profession (Wei et al., 2021; Etkina, 2010). The need for such support becomes even more pronounced in the present historical and social context, characterized by volatility, uncertainty, complexity, and ambiguity (Hadar et al., 2020). CoPs can afford early-career teachers with opportunities to engage in three key processes: representation of practice (envisioning teaching activities while eliciting decision-making processes); decomposition of practice (opportunities of breaking down the complexity of teaching activities) and approximation of practice (acting out the practice of teaching in a controlled way and experiencing productive failure – see Kavanagh et al., 2020). Furthermore, CoPs can offer occasions of interaction between novice and expert teachers, which have proved to be very important to shape teachers' identity (McLaughlan, 2021; Kirkby et al., 2018).

The notion of CoP has been extended to the virtual context, serving as a conceptual framework for studying online networks of teachers (Ghamrawi, 2021). Virtual CoPs (VCoPs) have become even more popular after the Covid-19 pandemic. In organizing and facilitating VCoPs, the differences between online settings and face-to-face settings - mainly in terms of interactions that are fostered - must be considered (McLaughlan, 2021). Nevertheless, participating in VCoPs has been reported to lead to better teaching practices, especially related to remote teaching (Ulla & Perales, 2021; Ghamrawi, 2021). VCoPs have been described also in the context of physics teacher training (e.g., Nadeau et al., 2020).

2.2 CoPs for preservice and early-career physics teacher education

CoPs as a key component of initial and early-career teacher training are supported also in the context of STEM and specifically of physics (Etkina et al., 2010; Etkina et al., 2017).

Physics teachers are part of a disciplinary culture characterized by transmissive teaching methods, abstracted content, overcrowded curriculum, and high complexity (Frågåt et al., 2021; Etkina et al., 2017). Consequently, they need opportunities to engage with student-centered practices, informed by the findings of Physics Education Research (PER) (Frågåt et al., 2021; Fischer & Kauertz, 2021; Milner-Bolotin, 2018). These opportunities are met in teacher training programs that encompass three elements (Etkina et al., 2017):

- Apprenticeship-based practice, involving brief teaching tasks followed by opportunities for reflection.
- Coursework focussed on the teaching and learning of physics.
- Nurturing from a rich and diverse community of practice, involving experienced teachers, faculty, and previous graduates in the program.

Being in such a community increases the likelihood that future teachers are socialized into the profession in an environment that fosters good habits (Etkina et al., 2017), empowers them as reflective practitioners (Criswell et al., 2018), and reinforces physics teacher identity.

The lens of identity has been used in the literature to frame and examine instances of novice physics teachers implementing good practice (e.g., Wei et al., 2021). It is a comprehensive construct shaped by the interplay of knowledge, skills, beliefs, and dispositions. It is determined by three main factors (Avraamidou, 2014):

- Personal: personal histories, beliefs, emotions, and attitudes.
- Social: the relationships within the different professional communities to which the teacher belongs, including both the scientific community (physicists) and the physics teachers' community.
- Situational: the contexts in which physics teachers operate (e.g., teacher training programs) and their features.

It is therefore important to consider both the teachers' individual dispositions and trajectories, the communities in which they are involved, and the type of experiences they are exposed to.

The formation of a physics teacher identity entails shaping an idea of what it means to be a “good” science teacher (Avraamidou, 2014). This not only drives teachers’ actions but also prepares them for lifelong learning (Etkina et al., 2017). Findings in the literature suggest that novice teachers tend to highlight dimensions related to content transmission and, to some extent, pedagogical elements (Salazar López & Nardi, 2021; Frågåt et al., 2021). Notably, those with limited classroom experience tend to place less emphasis on the role of relationships, and internships can be decisive in reshaping their perspective (Salazar López & Nardi, 2021). These findings underscore the need for teacher training programs that effectively integrate science content knowledge with pedagogical knowledge, providing teachers with collaborative spaces for professional development rooted in research.

2.3 Identity and Epistemic Frame Theory

Among the different ways of understanding and studying teachers’ identity, in this work we adopt Epistemic Frame Theory (EFT). EFT was proposed by Shaffer (2006a) to describe the pattern of associations among skills, knowledge, and other cognitive elements that characterize groups of people who share similar ways of framing, investigating, and solving complex problems. These elements can be understood as the components of an "epistemic frame” (Shaffer, 2006a).

The concept of “frame” was developed by Goffman (1974) to indicate a set of organizational principles that structure our perception of what is happening and is important during an activity. The term “epistemic” is grounded in Perkins’ (1992) description of epistemology as “knowledge and know-how concerning justification and explanation” (p. 85). Shaffer (2006b) extends this notion defining epistemology as “a particular way of thinking about or justifying actions, of structuring valid claims” (p. 32). Epistemology is domain-specific, as students of different subjects belong to different subcultures and may differ in their attitudes toward teaching (Grossmann & Stodolsky, 1995).

Online teaching encompasses a series of roles and competencies, that are arguably underpinned by combinations of the elements of an epistemic frame (e.g., Boettcher & Conrad, 2021; Cleveland-Innes, 2019; O'Brien & Fuller, 2018). The roles and competencies identified by the literature can be summarized into nine dimensions:

1. Teacher as content deliverer (Boettcher & Conrad, 2021).
2. Teacher as relationship manager (Cleveland-Innes, 2019).
3. Teacher as technology user (Farmer and & Ramsdale 2016 and more).
4. Teacher as workload manager (Goodyear et al., 2001).
5. Teacher as designer (Farmer & Ramsdale, 2016; Goodyear et al., 2001).

6. Teacher as critic (Cleveland-Innes, 2019) – which was operationalized as critical thinker.
7. Teacher as innovator (Cleveland-Innes, 2019; Goodyear et al., 2001).
8. Teacher as leader (O'Brien & Fuller, 2018).
9. Teacher as student expert (Boettcher & Conrad, 2021; Cleveland-Innes, 2019).

Studying teachers' discourse about their role in a teaching experience therefore provides insights into their epistemic frames and how they understand their teacher identity.

The Virtual School project

The *Virtual School* project originated in 2020 at Monash University, Australia, in response to the pressing challenges of educational disadvantage, particularly in the STEM field, which were further amplified by the COVID-19 pandemic. The project's main objective was to address the difficulties faced by students and student-teachers in STEM subjects. To tackle this issue, the *Virtual School* project engaged preservice teachers in virtual internships, offering a unique learning environment where they could interact with mentors, researchers, and experienced teachers, while also reaching the students' needs through online lessons. Through the process of designing and delivering interactive online sessions, the participants developed a deeper understanding of integrating technology into STEM teaching and learning, thereby shaping their identities as future STEM educators.

The Virtual School concept was further developed through a joint research effort between Monash University and the University of Padova (UniPD) in Italy in 2021-2022. Taking into account the specificities of the Italian context, the UniPD side of the project involved both preservice and early-career physics teachers, as explained in further detail in the following section. Participants were engaged in creating remedial physics lessons for students in their first year of secondary school during the early post-pandemic times. By fostering a digital community of practice, the project aimed to strengthen the professionalism of Italian teachers in the beginning phase of their career, also as a response to the current lack of opportunities for preservice internships, which limits the opportunities for them to engage in valuable experiences and feedback before entering the profession.

In the Australian context, the project in 2021-22 identified key areas of the Victorian Certificate of Education curriculum that were historically poorly answered in end of year examinations. Hence, the project engaged preservice secondary school teachers to design and realize interactive lessons online covering the content for each of these areas. The seven one-hour classes and the final two-hour one were delivered by pairs of preservice teachers under the supervision of a qualified and registered mentor teacher.

In the Italian context, the participants co-designed, co-delivered and reflected on cycles of eight physics lessons realized in collaboration with local secondary schools, closely interacting with experienced teachers (mentors) who identified the core disciplinary areas that needed intervention.

The study

This research is an exploratory case study on the impact of a VCoP for preservice and early-career physics teacher training. We hypothesised that, through the Virtual School experience, teachers' epistemic frames on professional identity could be altered and, that they could develop their conceptions of what it means to be a good physics teacher. We identified the following research question:

How can a virtual community of practice influence physics preservice and early-career teachers' epistemic frames about their professional identity?

4.1 Context, participants and setting

Differently from the Australian context, in Italy there is currently no specific degree program for prospective secondary school teachers. While the legislation in this regard is changing the paper is being written, at the time of designing the project the so-called "24 CFU" initial teacher training scheme applied. Teacher were required to get a degree in the subject (in this case, Physics or Mathematics or Astronomy), plus 24 ECTS ("CFU" in Italian) in anthropo-psycho-pedagogical subjects. These could include courses on physics education, which were however not compulsory. The problem therefore arose of defining the profile of Italian participants so that they corresponded to a profile of "preservice" teacher. A related problem was recruiting a sufficient number of participants, as the Virtual School experience was not part of any compulsory programme, and we could not grant credit for participation.

As a trade-off solution, we decided to recruit participants from students in their final year of physics, astronomy and mathematics degree programmes, and among recent graduates with no more than two years of teaching experience. The recruitment occurred through mailing lists of students who had attended courses on physics education in the two years before the experimentation, and direct contact with local schools. N=8 participants were recruited (6 females and 2 males) this way, four of which were early-career teachers, while the other 4 were students in Mathematics, Physics or Astronomy.

All participants were involved in an initial ("pre") semi-structured individual interview aimed at collecting a baseline response for the RQ. The protocol, described in further detail in the "Data collection" section, was constructed from the model used by Monash University and adapted to the Italian context.

The participants were then involved in a VCoP involving two UniPD researchers (the authors of this paper), one in Pedagogy (O.T.) and one in Physics Education (M.C.), and two in-service teachers with a background in PER. These teachers acted as tutors in the design of the lesson cycle. The researchers facilitated common meetings, conducted the interviews, set up the VCoP online platform on Moodle. Both the researchers and the tutors observed the lessons and provided feedback. Moreover, Monash University tutor R.G. was welcomed as a visiting fellow for two weeks during the VS activities. She collaborated with the researchers, tutors and participants in the final design phase of the virtual lessons and in their observation.

The Virtual School took the form of a summer course consisting of 8 online lessons, each lasting 1 hour. Given the pilot nature of the project, it was restricted to the two schools (a "Liceo Scientifico" and a "Technical Institute") where the tutors were respectively teaching. The participants were divided into two groups of four and each group was assigned to a school/tutor. The disciplinary areas covered in the lessons were defined by each tutor in consideration of the specificities of the school and the major difficulties observed in the students. Specific topics were kinematics + forces (Technical Institute) and thermal effects (Liceo Scientifico). The lessons were delivered through the Zoom platform, at a pace of 2 or 3 per week, soon after the end of the school year (June-July 2022). Each participant was a co-teacher in two lessons. In parallel with the synchronous lessons, each school/group activated a Google Classroom course for asynchronous interaction with students. After each lesson, the coaches provided feedback and discussed the lesson with the preservice teachers, highlighting their different perspectives (practitioner, pedagogy expert, online teaching expert, physics/physics education expert).

At the end of the lecture cycles, a second individual online interview ("post") was conducted. The protocol went through the same areas covered in the initial interviews, additionally asking for narratives about the participant's role and activities during the VS experience.

4.2 Data collection

This paper reports on the data from a subset (N = 4) of the preservice teachers who participated in the VCoP. All participants in the study were informed about the protocol and agreed to the methods of data collection, analysis, and dissemination. Participants were interviewed twice – before and after the digitally-based Virtual School program –, in Italian, for 30-45 minutes each. Preservice teachers were asked about their perceptions of effective physics teachers' roles and competencies. The protocol was constructed around five main epistemic elements:

1. Epistemology (e.g., What subject areas are you focusing on as part of your teacher training?).
1. Identity (e.g., If a colleague was asked about something you do really well as a virtual teacher, what would they say?).
2. Knowledge (e.g., Do you look for different types of software applications to change the way you represent content or to have students work with content in different ways?).
3. Skills (e.g., Have you had any professional development to enhance your virtual teaching skills?).
4. Values (e.g., How critical is it for you to have flexibility in structuring your lessons?).

This interview protocol allowed the researchers to collect data relevant to the nine teacher roles and competencies described in 2.3, as pertaining to teaching online (Phillips et al., 2023).

The interviews were conducted via Zoom conferencing system, with both audio and video recorded using Zoom's inbuilt recording tools. Once transcribed, the interviewees were notified for approval. Two members of the research team coded deductively the transcripts autonomously for the nine roles and competencies in 2.3 (i.e., teacher as content deliverer; relationship manager; technology user; workload manager; designer; critical thinker; innovator; leader; and student expert). Cohen's kappa coefficient, k = 0.55, provided significant results in calculating interrater reliability (McHugh, 2012). Disagreements between the researchers' coding were discussed until a consensus was reached.

An Epistemic Network Analysis (ENA) tool was used to visualize the data (Shaffer et al., 2016). ENA assumes that (1) a set of meaningful features ("codes") can be identified systematically in the data; (2) the data have local structure (segments or conversations); and (3) the codes are connected within conversations in an important way (Oshima & Shaffer, 2021; Shaffer et al., 2016). ENA models the connections between codes by quantifying their co-occurrence within conversations and associated visualizations for each unit of analysis in the form of weighted networks. This allows ENA to compare all networks at once both visually and statistically. Data structure is considered to be the most important aspect of the analysis.

We applied the ENA1.7.0 Web Tool. The units of analysis were all lines of data associated with a single value of time (“pre” and “post”) subset by the speaker (the individual participants). By using a moving window, ENA constructs a network model for every line of data, showing how codes occur within recent temporal contexts (Phillips et al., 2019), defined as 4 lines within a conversation. The resulting weighted networks are aggregated for all lines for each unit of analysis.

Prior to dimensional reduction, the ENA model normalizes the networks for all units of analysis, accounting for the fact that different units of analysis may have different numbers of coded lines. Singular value decomposition was used for dimensional reduction, producing orthogonal dimensions that maximize the variance explained by each dimension (Oshima & Shaffer, 2021; Shaffer et al., 2016). In the weighted network graphs, nodes correspond to codes, and edges reflect the relative frequency of co-occurrence between codes, or “connections”. Each unit of analysis – i.e., pre- or post-interviews – is shown in two coordinated representations: (1) a plotted point that represents the location of its network in low-dimensional projected space – Figure 1 later, and (2) a weighted network graph – Figure 2 later. An optimization routine determines the locations of the network graph nodes by minimizing the difference between the plotted points and their corresponding network centroids. Due to their co-registration, network graph nodes and their connections can be used to interpret the dimensions of projected space and explain plotted points' positions in the space. In our model, co-registration correlations were 0.69 (Pearson) and 0.66 (Spearman) for the first dimension, and 0.81 (Pearson and Spearman) for the second dimension.

5. Findings

ENA was used to visualize participants’ epistemic frames and to model similarities and differences between them. The figure illustrates three elements: 1. Participants’ centroids (red circles represent each preservice teacher during the pre-test; blue circles represent participants’ conversations at post-test); 2. Group centroids, i.e., network centres (red square for pre-test conversation, blue square for post-test); 3. Each group’s confidence intervals.

As per Figure 1, pre- and post- conversations shifted significantly. Group centroids – i.e., aggregated means that function as gravitational core of the group’s weighted epistemic network – are significantly different on the x-axis (Mann-Whitney test $p = .003$, r = 1.00). To better understand similarities and differences between participants’ pre- and post-test perceptions of physics teachers' roles and competencies, we need to zoom into the weighted networks.

Figure 1- Epistemic Network Pre- and Post- Group visualization

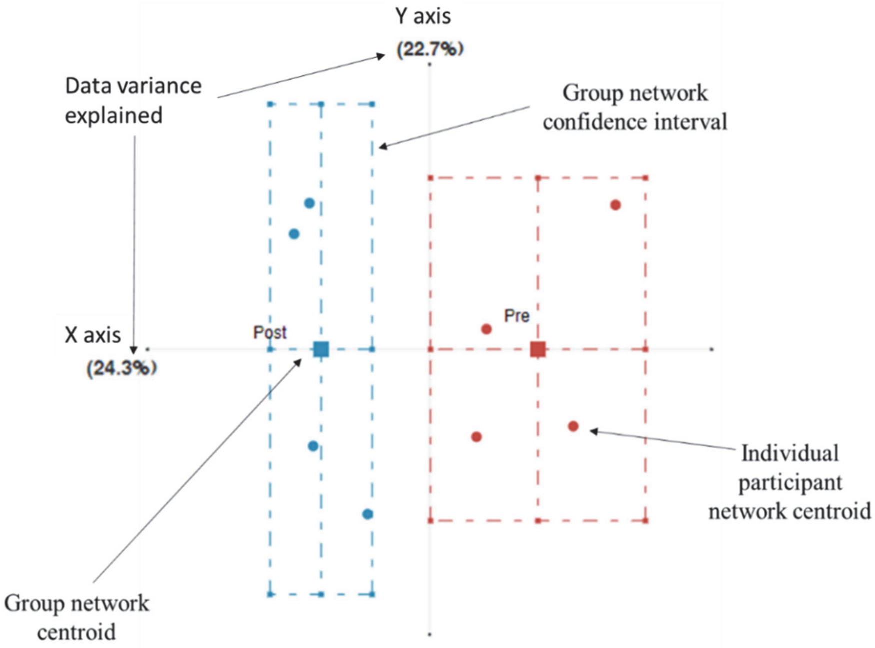


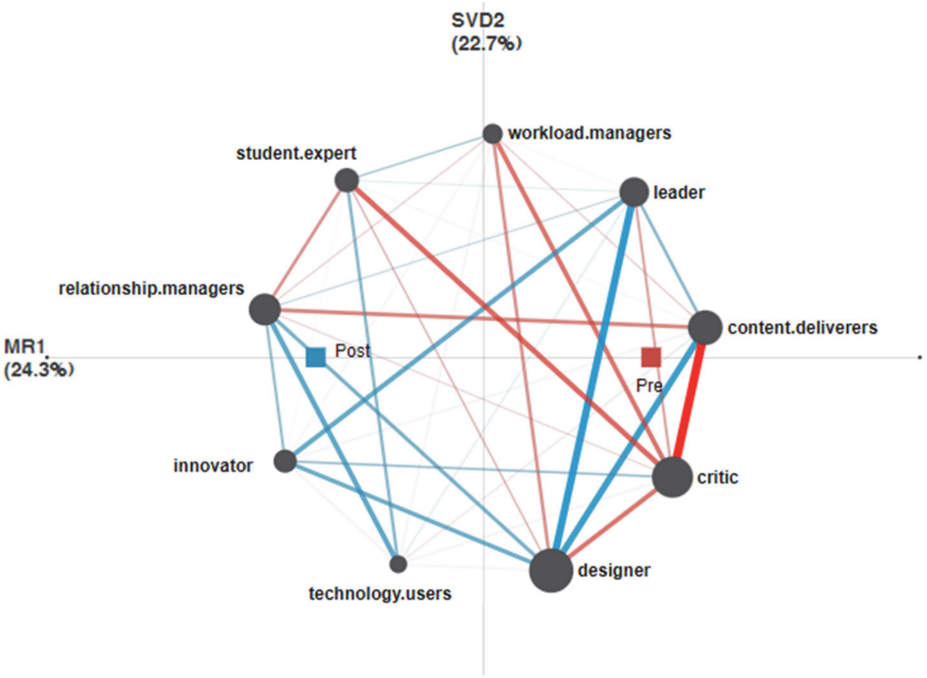
Figure 2 zooms into each of the two groups' networks (i.e., pre- and post-group) from Figure 1. Specifically, Figure 2 shows a subtraction visualization between pre- and post-test weighted networks. The size of the nodes represents the frequency of those codes in the post-test, once subtracted the ones in the pre-test. The thickness of the lines represents the co-occurrence of the couples of connected nodes in the post-conversations, once subtracted the pre-test. Finally, the colour of the lines represents whether the pre-test (in red) or post-test (in blue) presented higher frequency of co-occurrences, hence being still visible after the subtraction.

Figure 2 indicates that perceptions of physics teachers being *designers, critical thinkers, content deliverers, relationship managers, and leaders* held true through the VCoP: their frequency is still high at post-test even subtracting the pre-test mentioning, as is shown by the node size. For example, in the words of a participant (P):

> P6-post: We developed [our lesson plan] from the point of view of much more than the concepts that we transfer. We moved forward step by step but not doing three steps at a time. We walked [the pupils] along adding little

by little, building blocks and then reaching, getting to the last exercise that contained everything.

Figure 2 - Subtraction Epistemic Network visualization between pre-test and post-test



However, the participants connected those keywords differently before and after the VCoP experience. In the pre-test conversation, the stronger connections are between beliefs of *content* and *critical thinking* competencies for a physics teacher (see thickness of red lines), for example:

> P2-pre: Sometimes if an exercise doesn't come out right to me, I say very honestly "guys, I don't know how to do it. I'll look at it at home. In the solution book." As a mathematician, I lean on those too if I don't know things.

Closely follow connections between *critic* and *student expert*, *critic* and *workload manager* or *designer*, and between *content deliverer* and *relationship manager.* Examples of such connections are:

> P4-pre: I guess I get lost in the dispersion sometimes. Because if the [pupils show] some interest, I try to follow it, because, I mean, if they miss a piece

of physics, I don't think it's going to be a drama in their future, whereas if they find something in physics that they like…then it seems to me that they are more attentive, attracted [even to the following topics]

P5-pre: I see that it destroys you… I mean to prepare for the lessons, I have to plan, I have to write down A, then B, then C, then D, because otherwise I would be someone who gets an idea and then goes that way or skips a step.

The strength of the aforementioned connections is such that the entire group's centroid results positioned between physics teachers as *content deliverers* and *critical thinkers.*

At post-test, however, participants connect more strongly a wider variety of perceptions of physics teachers: as *designers, leaders, content deliverers, innovators,* and *relationship managers* and *technology users* (see thickness and number of blue lines). Particularly the connections involving teachers as *relationship managers* and *innovators* hold such a weight that the entire group's centroid is pulled close to them.

P6-post: We got very good at organizing the [learning] path, connecting the various things. About pupils' participation, maybe when we started calling them by name, when we started to push them a little bit, even just sending a message [in the chat] ... the first time we got a private message, the second time we got a chat message with everyone, at the third time [the pupil probably thought] "whatever, at this point [it's] quicker to talk". It was gradual, they realized that no one was judging them. […] the interactions between us – along with them – we also grew. we started to know each other more, we started to see the dynamics what we could do...

P3-post: I feel like we worked on [making sure learning would happen]. even designing things together helped, breaking down the problem into little pieces, doing a problem with incredible slowness, emphasizing every single step, every little thing to pay attention to so it helped [them].

6. Discussion and conclusions

The Virtual School has significantly impacted the epistemic frameworks of preservice and early-career physics teachers about their professional identity. Following their participation in the VCoP, they tend to place greater emphasis on relational competences and student learning rather than focusing solely on content delivery. Moreover, they are more focused on the design on lessons and are open to (technological) innovation and collaborative work (leading the learning experience along with the class colleagues).

A tendency to place emphasis on content delivery while disregarding classroom relationships has been reported in literature about preservice physics teachers (Salazar López & Nardi, 2021; Frågåt et al., 2021). These results suggest that the VCoP has been effective in tackling this issue.

Preservice and early-career teachers' post-VCoP perspective on the teaching profession also highlights a higher level of interconnectedness among the different dimensions, suggesting an evolution in their teacher identity marked by a more nuanced mindset. That there were individual variations in this evolution, reflecting the diverse starting points and attitudes of participants, supporting the idea that teachers' development may follow different pathways (Clarke & Hollingsworth, 2002). This perspective has been taken in recent studies about in-service physics teacher education (Levy et al., 2021); our study supports applying it also in the realm of preservice physics teacher education.

In 2023, the Virtual School concept was further developed and refined. Activities are ongoing and will be analysed to highlight the evolution from the pilot version. The results so far suggest that the Virtual School community is a promising framework for initial and early-career teacher training and suggests areas for its improvement, as also advocated by recent literature (Murtagh & Rushton, 2023).

The Virtual School experience integrates several insights from research in both general education and physics education, supporting a more research-based approach in the design of initial and early-career teacher training programs. We expect that it could serve as a model for designing teacher training programs in the future, and in particular we think that it can provide insights for the ongoing reform of initial teacher training in Italy. At the time of writing this paper, Italian universities are working to define new secondary school teacher training curricula as a response to the new law requiring prospective teachers to gain 60 ECTS as qualification for the profession. These must include 16 discipline-specific-course credits managed by the different Departments. In the context of physics, several stakeholders such as the Italian Physical Society (SIF) and the National Coordination of the academic field "physics teaching and history of physics" (CooFIS08) have released recommendations for the development of research-based curricula grounded in the findings of physics education research. We believe that the Virtual School experience is a relevant example of a training opportunity informed by findings in both general pedagogy and discipline-specific research, of a productive collaboration between researchers of different departments, and of a pragmatic application of the CoP paradigm in the context of teacher training in the Italian context.

The Virtual School experience gains relevance also in light of the pandemic experience, which has expedited the integration of digital technologies into educational practices and the adoption of online or blended learning modalities within school environments.

The approach described in this paper also reflects a more personalized approach to the design and evaluation of teachers' professional development, adopting a twofold – individual and collective – stance. Analyzing interactions withing the VCoP and comparing different "versions" of it will shade light on the processes leading to the results discussed in this paper. Finally, from a methodological perspective, the analysis presented in this study supports the use of Epistemic Frame Theory and Epistemic Network Analysis as a powerful tool to study and interpret (physics) teachers' identity and professional growth.

Limitations

The data reported here refer to a subset of the group who participated in the VCoP and may not reflect a general trend. Different backgrounds of the participants may also influence both the pre- and post-results. Further research is ongoing to extend the analysis to a larger sample and to compare between different educational contexts.

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