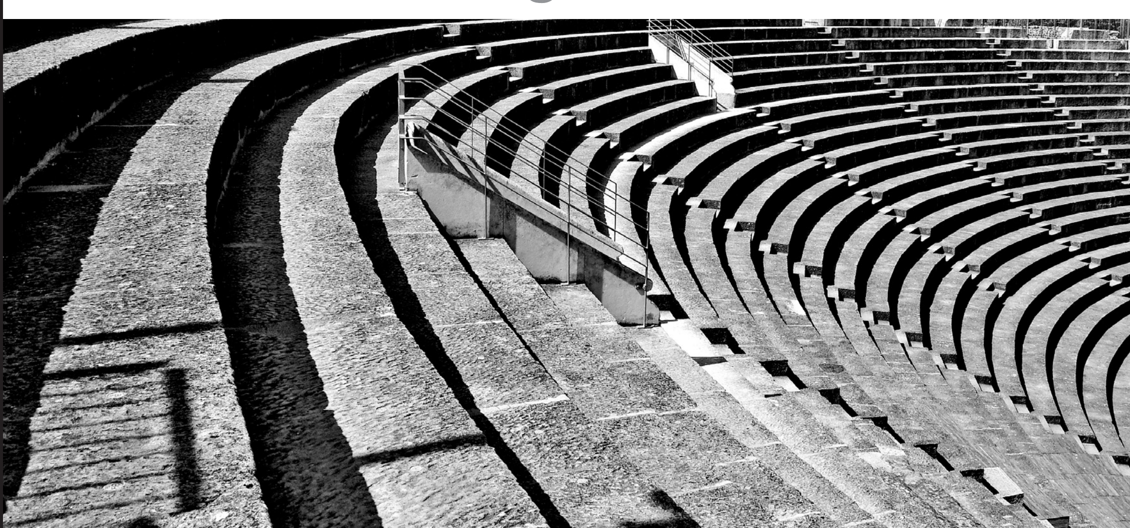
Anno 8, 2/2023

Excellence and Innovation in Learning and Teaching
Research and Practices

INNOVAZIONE E PROCESSI TRASFORMATIVI PER LE DIDATTICHE STEAM

INSTRUCTIONAL INNOVATION AND TRANSFORMATIVE PROCESSES IN STEAM

FrancoAngeli
OPEN ACCESS



Anno 8, 2/2023

Excellence and Innovation in Learning and Teaching
Research and Practices

INNOVAZIONE E PROCESSI TRASFORMATIVI PER LE DIDATTICHE STEAM

INSTRUCTIONAL INNOVATION AND TRANSFORMATIVE PROCESSES IN STEAM

FrancoAngeli
OPEN ACCESS

Per contattare la redazione: Centro Interdipartimentale di Studi per i Servizi alla Persona (CISSPE), Università degli Studi di Padova, Piazza Capitaniato 3, 35139 Padova; e-mail: eilt.journal.cisspe@unipd.it

Ricerche empiriche e studi teorici saranno sottoposti a doppio referaggio cieco; esperienze sul campo saranno sottoposte a singolo referaggio cieco.
Empirical researches and theoretical studies will be double-blind refereed.

La rivista è in Fascia A Anvur, area 11 SCIENZE STORICHE, FILOSOFICHE, PEDAGOGICHE, PSICOLOGICHE: 11/D1 (Pedagogia e storia della pedagogia), 11/D2 (Didattica, Pedagogia speciale e Ricerca educativa).
Progetto grafico di copertina: Alessandro Petrini.

Sommario

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

Ottavia Trevisan[*], Marta Carli[^]

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.

Article submitted: 20/09/2023; accepted 08/11/2023
Available online: 13/12/2023

[*] Philosophy, Sociology, Pedagogy and Applied Psychology Department, University of Padova, e-mail: ottavia.trevisan@unipd.it.
[^] Physics Department, University of Padova, e-mail: marta.carli.1@unipd.it.
Le autrici confermano di aver equamente contribuito alla presente pubblicazione. Per doveri di attribuzione puramente formale, si consideri M. Carli come primaria autrice dei paragrafi 2, 4.1, 6, 7; e O. Trevisan come primaria autrice di 1, 3, 4, 4.2, 5.

Excellence and Innovation in Learning and Teaching (ISSNe 2499-507X), 2023, 2

Doi: 10.3280/exioa2-2023oa16807

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

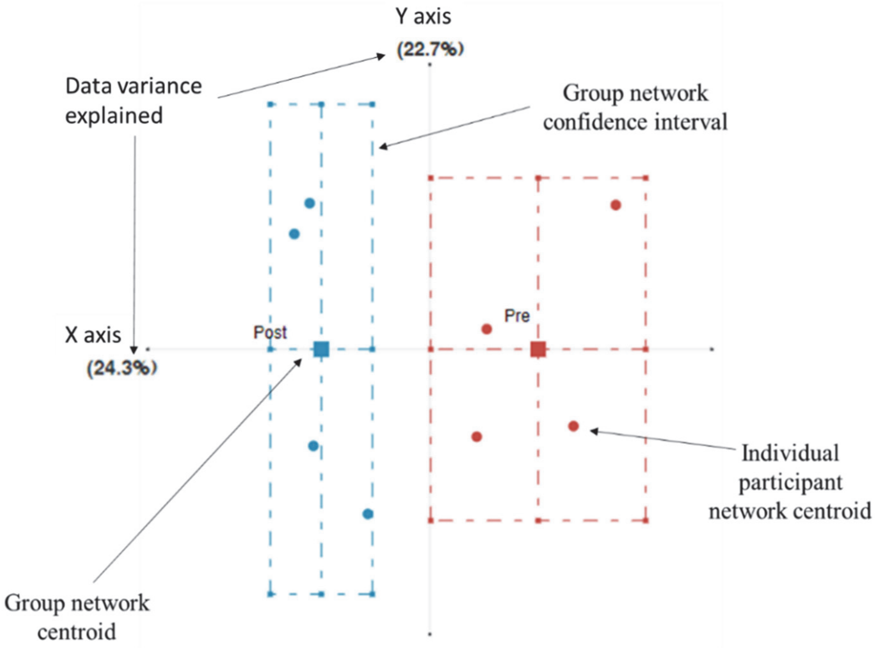


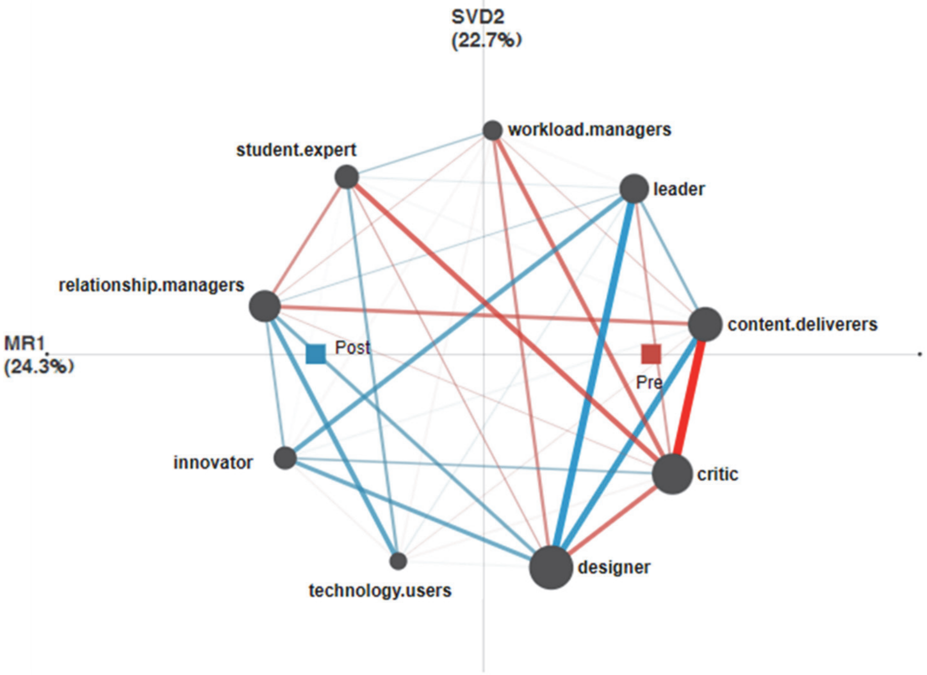
Figure 2 zooms into each of the two groups' networks (i.e., pre- and post-group) from Figure 1. Specifically, Figure 2 shows a subtraction visualization between pre- and post-test weighted networks. The size of the nodes represents the frequency of those codes in the post-test, once subtracted the ones 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.

References

Avraamidou, L. (2014). Studying science teacher identity: current insights and future research directions. *Studies in Science Education* 50(2), 145-179. Doi: 10.1080/03057267.2014.937171.

Bjurholt, N., & Bøe, M. V. (2023). Remote physics teaching during the Covid-19 pandemic: losses and potential gains. *Physics Education, 58*, 015004. Doi: 10.1088/1361-6552/ac96be.

Boettcher, J. V., & Conrad, R.-M. (2021). *The online teaching survival guide: Simple and practical pedagogical tips*. John Wiley & Sons.

Burkholder, E., Salehi, S., Sackeyfio, S., Mohamed-Hinds, N., & Wieman, C. (2022). Equitable approach to introductory calculus-based physics courses focused on problem solving. *Physical Review Physics Education Research 18*, 020124. Doi: 10.1103/PhysRevPhysEducRes.18.020124.

Clarke, D., & Hollingsworth, H. (2002). Elaborating a model of teacher professional growth. *Teaching and Teacher Education,* 18(8), 947-967.

Cleveland-Innes, M. (2019). The community of inquiry theoretical framework: Designing collaborative online and blended learning. In *Rethinking pedagogy for a digital age* (pp. 85-102). Routledge.

Criswell, B. A., Rushton, G. T., Nachtigall, D., Staggs, S., Alemdar, M., Cappelli, C. J. (2018). Strengthening the vision: Examining the understanding of a framework for

teacher leadership development by experienced science teachers. *Science Education* 102, 1265-1287. Doi: 10.1002/sce.21472.
Etkina, E. (2010). Pedagogical content knowledge and preparation of high school physics teachers. *Physical Review Special Topics - Physics Education Research 6*, 020110. Doi: 10.1103/PhysRevSTPER.6.020110.
Etkina, E., Gregorcic, B., & Vokos, S. (2017). Organizing physics teacher professional education around productive habit development: A way to meet reform challenges. *Physical Review Physics Education Research 13*, 010107. Doi. 10.1103/PhysRevPhysEducRes.13.010107.
Farmer, H., & Ramsdale, J. (2016). Teaching competencies for the online environment. *Canadian Journal of Learning and Technology*, *42*(3), 1-17.
Fischer, H.E., & Kauertz, A. (2021). Professional competencies for teaching physics. In H.E. Fischer & R. Girwidz (Ed.). *Physics Education. Challenges in Physics Education* (pp. 25-53). Springer. Doi: 10.1007/978-3-030-87391-2_2.
Frågåt, T., Henriksen, E. K., & Tellefsen, C. W. (2021). Pre-service science teachers' and in-service physics teachers' views on the knowledge and skills of a good teacher. *Nordic Studies in Science Education (NorDiNa) 17*(3), 277-292. Doi: 10.5617/nordina.7644.
Fullan, M. (2020). Learning and the pandemic: What's next?. *Prospects, 49*(1-2), 25-28. Doi: 10.1007/s11125-020-09502-0.
Ghamrawi, N. (2021). Teachers' virtual communities of practice: A strong response in times of crisis or just another Fad?. *Education and Information Technology 27*, 5889-5915. Doi: 10.1007/s10639-021-10857-w.
Goffman, E. (1974). *Frame analysis: An essay on the organization of experience*. Harvard University Press.
Goodyear, P., Salmon, G., Spector, J. M., Steeples, C., & Tickner, S. (2001). Competences for online teaching: A special report. *Educational Technology Research and Development, 49*(1), 65-72
Grossman, P. L., & Stodolsky, S. S. (1995). Content as Context: The Role of School Subjects in Secondary School Teaching. *Educational Researcher 24*(8), 5-23. Doi: 10.3102/0013189X024008005.
Hadar, L. L., O., Ergas, Alpert, B., & Ariav, T. (2020). Rethinking teacher education in a VUCA world: preservice teachers' social-emotional competencies during the Covid-19 crisis. *European Journal of Teacher Education* 43(4), 573-586. Doi: 10.1080/02619768.2020.1807513.
Kavanagh, S. S., Conrad, J., & Dagogo-Jack, S. (2020). From rote to reasoned: Examining the role of pedagogical reasoning in practice-based teacher education. *Teaching and Teacher Education, 89,* 69-84. Doi: 10.1016/j.tate.2019.102991.
Kirkby, J., Walsh, L., & Keary, A. (2018). A case study of the generation and benefits of a community of practice and its impact on the professional identity of early childhood teachers. *Professional Development in Education 45(*2), 264-275. Doi: 10.1080/19415257.2018.1449003.
Lave, J., & Wenger, E. (1991). *Situated Learning: Legitimate Peripheral Participation*. Cambridge, MA: Cambridge University Press. Doi: 10.1017/CBO9780511815355.

Levy, S., Bagno, E., Berger, H., & Eylon, B.-S. (2022). Professional growth of physics teacher-leaders in a Professional Learning Communities program: the context of inquiry-based laboratories. *International Journal of Science and Mathematics Education 20*, 1813-1839.

McHugh, M. L. (2012). Interrater reliability: The kappa statistic. *Biochemia medica 22*(3), 276-282.

McLaughlan, T. (2021) Facilitating factors in cultivating diverse online communities of practice: A case of international teaching assistants during the COVID-19 crisis. *International Journal of Information and Learning Technology 38*(2), 177-195. Doi: 10.1108/IJILT-05-2020-0074.

Milner-Bolotin, M. (2018). Evidence-Based Research in STEM Teacher Education: From Theory to Practice. *Frontiers in Education* 3(92). Doi: 10.3389/feduc.2018.00092.

Murtagh, L., & Rushton, E. A. C. (2023). The role of teacher educator virtual communities of practice (VCoPs) in mobilising policy engagement: A case study of the initial teacher training market review from England. *Asia-Pacific Journal of Teacher Education.* Doi: 10.1080/1359866X.2023.2191306.

Nadeau, M., Modir, B., Lock, R. M., & Newton, W. G. (2020). Participation in an online community of high school physics teachers. In Wolf, S., Bennett, M. B., & Frank, B. W. (Eds.). *2020 Physics Education Research Conference Proceedings* (pp. 370-375). Doi: 10.1119/perc.2020.pr.Nadeau.

O’Brien, D. J. (2021). A guide for incorporating e-teaching of physics in a post-COVID world. *American Journal of Physics 89*, 403. Doi: 10.1119/10.0002437.

O'Brien, A., & Fuller, R. (2018). Synchronous teaching techniques from the perspective and observation of virtual high school teachers: An investigative study. *International Journal of Information and Communication Technology Education (IJICTE), 14*(3), 55-67.

Oshima, J., & Shaffer, D. W. (2021). Learning analytics for a new epistemological perspective of learning. *Information and Technology in Education and Learning*, *1*(1), 1-11. Doi: 10.12937/itel.1.1.Inv.p003.

Perkins, D. (1992). *Smart schools*. Free Press.

Phillips, M., Kovanović, V., Mitchell, I., & Gašević, D. (2019). The Influence of Discipline on Teachers’ Knowledge and Decision Making. In B. Eagan, M. Misfeldt, & A. Siebert-Evenstone (Eds.), *Advances in Quantitative Ethnography* (pp. 177-188). Springer International Publishing. Doi: 10.1007/978-3-030-33232-7_15.

Phillips, M., Trevisan, O., Carli, M., Mannix, T., Gargiso, R., Gabelli, L. & Lippiello, S. (2023). Uncovering patterns and (dis)similarities of preservice teachers through Epistemic Network Analysis. In E. Langran, P. Christensen & J. Sanson (Eds.), *Proceedings of Society for Information Technology & Teacher Education International Conference* (pp. 1021-1030). New Orleans, LA, United States: Association for the Advancement of Computing in Education (AACE). -- Retrieved September 11, 2023 from https://www.learntechlib.org/p/221960.

Redecker, C. (2017). *European framework for the digital competence of educators* (Y. Punie, Ed.). Publications Office of the European Union.

Salazar López, T. I., & Nardi, R. (2020). Imaginários de futuros professores de física sobre os saberes docentes: sentidos produzidos na interface universidade-escola no estágio curricular supervisionado. *Investigações Em Ensino De Ciências, 25*(3), 454-470. Doi: 10.22600/1518-8795.ienci2020v25n3p454.

Shaffer, D. W. (2006a). Epistemic frames for epistemic games. *Computers & Education 46*(3), 223-234. Doi: 10.1016/j.compedu.2005.11.003.

Shaffer, D. W. (2006b). *How computer games help children learn*. Palgrave Macmillan.

Shaffer, D. W., Collier, W., & Ruis, A. R. (2016). A tutorial on Epistemic Network Analysis: Analyzing the structure of connections in cognitive, social, and interaction data. *Journal of Learning Analytics*, *3*(3), 9-45. Doi: 10.18608/jla.2016.33.3.

Ulla, M. B. & Perales, W. F. (2021). Emergency remote teaching during COVID19: The role of teachers' online Community of Practice (CoP) in times of crisis. *Journal of Interactive Media in Education 1*(9), 1-11. Doi: 10.5334/jime.617.

Vangrieken, K., Meredith, C., Packer, T., & Kyndt, E., (2017). Teacher communities as a context for professional development: A systematic review. *Teaching and Teacher Education 61*, 47-59. Doi: 10.1016/j.tate.2016.10.001.

Wei, B., Avraamidou, L. & Chen, N. (2021). How a beginning science teacher deals with practical work: an explorative study through the lens of identity. *Research in Science Education 51*, 1-19. Doi: 10.1007/s11165-019-9826-z.

Wenger, E., McDermott, R. A., & Snyder, W. (2002). *Cultivating Communities of Practice: A guide to Managing Knowledge*. Harvard Business School.

Hybrid blended learning solutions in a STEM teaching of the degree course in Computer Engineering

Marina De Rossi*; Carlo Mariconda^

Abstract

The case study reports the implementation of Hybrid Blended Learning solutions in the teaching of Fundamentals of Analysis and Probability in the Computer Engineering Degree Course at the University of Padua. The teaching organization and methodology have been revised in a transformative perspective, using innovative STEM and digitally integrated approaches in blended learning mode (Ministerial Decree 289/2021). The context of the study is a cohort of 200 students, divided into two groups for organizational issues. The study analyzed data collected with different instruments: a survey administered by the lecturer and the course evaluation questionnaire required by university quality assurance standards, focusing on overall satisfaction, organizational and teaching aspects and perceived workload. In addition, data on final examination assessment were taken into account.

Keywords*:* Higher education, Blended Learning, Teaching methods, Educational technology, STEM.

Article submitted: 26/09/2023; accepted: 08/11/2023
Available online: 13/12/2023

Hybrid Blended Learning Solutions

With the development of information and communication technologies, the way of teaching, especially in higher education, has gradually shifted from the

---

* Marina De Rossi, Università di Padova, e-mail: marina.derossi@unipd.it.
^ Carlo Mariconda, Università di Padova, e-mail: carlo.mariconda@unipd.it.
The article was written by Marina De Rossi and the data provided by Carlo Mariconda.

Excellence and Innovation in Learning and Teaching (ISSNe 2499-507X), 2023, 2

Doi: 10.3280/exioa2-2023oa16821

traditional face-to-face learning experience to the more efficient blended learning approach. Many researchers and institutions have begun to thoroughly investigate the principles and models of this unconventional learning method, given its flexibility (Bernard et al., 2014; Gaebel et al., 2021). According to data from the European University Education (Gaebel & Morrisroe, 2023), over the past decade, blended learning mode is much more accepted and used throughout the European Higher Education Area (EHEA).

Currently, blended learning is an increasingly popular innovative mode of educational delivery: on average, it is used in 75 % of EHEA institutions, whether in some courses or University-wide (Gaebel & Morrisroe, 2023). Especially following the response to the Covid-19 emergency, some institutions have begun to provide hybrid learning and teaching, that is, courses that can be taken both physically and virtually (Megahed & Ghoneim, 2022). However, a paradigm shift in instructional design is needed to achieve effectiveness in teaching-learning processes.

For example, McGee and Reis (2012) identified common errors that occur in the design of blended courses, including a lack of consistency between online and face-to-face modes and attempted direct conversion from one mode to the other. Other studies have identified guidelines for blended design and teaching to ensure that this approach achieves maximum effectiveness (Reeves & Reeves, 2012; Sancassani et al., 2023). These include the importance of addressing content-related methodological issues ahead of technology; constructive alignment of course content; building cognitive, social, and instructional presences; selective adoption of new social media tools; and commitment to systematic formative assessment. They suggested that a well-planned online and blended learning environment should be geared toward pedagogical-technology integration, beginning by reviewing the core components of the discipline before considering which technologies can be used; aligning the instructional context constructively with the expected learning outcomes; using constructive and collaborative learning theory within the framework of the community of inquiry to maintain effective levels of cognitive, social and instructional presence; taking into consideration different age groups and potential pedagogical effectiveness in selecting the adoption of new technologies; engaging in formative assessment for the continuous improvement of existing blended subjects.

All this requires solid design skills on the part of teachers, specifically in the ability to integrate different types of knowledge: disciplinary content expertise, knowledge of appropriate methodological approaches and the pedagogical possibilities of digital tools. This unique amalgam of expertise has been framed in research as the Technological Pedagogical Content Knowledge (TPCK) (De Rossi & Trevisan, 2018; Mishra & Koehler, 2006; Angeli & Valanides, 2009) framework. Hybrid blended learning modes have been extensively studied over the past two decades, highlighting a paradigm shift in education geared toward promoting innovative teaching-learning processes (Graham & Dziuban, 2008; Torrisi-Steele & Drew, 2013). The literature has shown that the reasoned use of ICT promotes flexibility of space and time through learner-centered approaches (Philipsen et al., 2019).

Moreover, with the advent and consolidation of ICT use in the synergy between formal, non formal, and informal learning contexts, new models of integrated teaching, known as hybrid instructional solutions, have become widespread and continue to be refined. The term "hybrid solution" encompasses a variety of instructional formats, including blended learning (Kaleta et al., 2007). The literature interprets the hybrid education approach basically as a combination of face-to-face and distance learning activities that are technologically integrated (Graham, 2006). Indeed, the implementation of hybrid educational solutions can take many forms: among others, the integration of technology into face-to-face teaching in a fluid dynamic (Trentin, 2015), the use of multiple methodological approaches, tools, and instructional formats between presence and distance (Bruggeman et al., 2021; Philipsen et al., 2019). The educational quality of hybrid solutions is based on their ability to foster active learning, support collaborative and student-centered instruction, and enable sustainability processes from a work-life balance perspective (De Rossi & Trevisan, 2023; Bruggeman et al., 2021).

Education supported by hybrid blended learning solutions (HBLS) can be developed with different approaches in organizing learning processes. For example, adding online activities to traditional in-person classes, designing blended learning paths with flexible spatial/temporal distribution of activities between presence and distance, setting up specific platforms as integrated learning environments (Alammary, 2014).

However, the preparation of teaching staff and institutions for the integration of digital tools in teaching has not always produced quality results, and this critical issue became particularly clear when the Covid-19 pandemic forced the online transition (De Rossi & Trevisan, 2022; Trevisan et al., 2021; Trevisan & De Rossi, 2022; Zhang et al., 2022).

The challenge has been taken up in 2021-22 by the University of Padua as part of the *Teaching4Learning@Unipd®* (T4L) Project, which has as its main objective the improvement and innovation of university teaching through faculty professional development (De Rossi & Trevisan, 2022). An extensive program has been initiated to disseminate blended learning mode (upon faculty adherence, with the coordination of course chairs) to implement online lesson delivery for up to 10% of lecture hours (Ministerial Decree 289/21).

Research Questions and Instruments

The research was realized as a case study (Yin, 2009), guided by the following research question:

- how do students perceive the efficacy of a HBLS course in the STEM area?
- how do they perceive the teaching modalities?
- how do they perceive the different assessment methods?

Its context was the course of Fundamentals of Analysis and Probability (Computer Engineering curriculum) at the university of Padova, in the academic year 2022-2023. This context was deemed relevant to the research question because this was the first time the course implemented HBLS consistently.

A total of 200 students enrolled in the course were selected as participants for the case study, through a conventional sampling technique. The students were adequately informed of the means and scope of the research.

Further, the cohort of students was divided in two groups, namely A (n = 100) and B (n = 100). This was due to the classroom capacity, not research design. The two groups were divided according to their matriculation number but no differences whatsoever occurred in their education. The same face-to-face and online activities were realized in both groups, with the same percentage (1/3 online and 2/3 face-to-face), the same organization of the space on the Moodle platform and support materials.

The two groups had the following demographic characteristics: students in their first year of higher education, mostly male (85%) and with an average age of 20.

The course

The HBLS design of the course aimed to integrate the contents of the Mathematics discipline with those of Technology through the use of digital resources, while activating collaborative and reflective processes in students between presence and distance, using the MOODLE platform. The teaching approach was that of the STEM disciplines, which is based on an interdisciplinary design and methodological orientation that stimulates the integrated development of disciplinary and transversal skills required by the labor market (Kennedy & Odell, 2014). The STEM teaching method encompasses an innovative teaching method aimed at enhancing the connections between the disciplines (i.e., mathematics and technology as a transversal skill), enabling the student to have a critical reading of everyday events, to improve their cognitive reasoning and problem solving processes, and to have a greater capacity for communication (Ortiz-Revilla, 2022).

Several conditions can favor the effectiveness of STEM teaching, such as the use of technologies as a support to teaching (not as a substitute for the teacher); the integration of approaches typical of direct instruction and of collaborative instruction (especially if based on structured meta-cognitive strategies and based on pair-work or small group work); the valorization of teacher-student and peer feedback with a formative function (Allan et al., 2019). However, Evidence Based Education research data show that it is not technologies that are the main factor affecting the quality of teaching, but rather teaching strategies and methods (Hattie, 2009, 2012; Calvani, 2014).

For this reason, special attention was paid in this course to the instructional design for both groups A and B. Maximum consistency was sought between in-presence (2/3 of tot hours) and distance activities (1/3 of tot hours); the diversification of teaching formats suited to the different training objectives (frontal lessons and workshops for group work), of teaching resources and strategies (Mariconda, 2023), MOOCs for flipped classroom experiences (Mariconda, 2020); Perusall for the creation of peer review strategies; ChatGPT and in general Artificial Intelligence to generate tasks to be carried out autonomously.

Two assessment strategies were used:

- for attending students: formative assessment through weekly quizzes, shared comments (using Perusall), peer review and summative test at the end of the course;
- for non-attending students: a summative assessment in the institutionally mandated exams sessions.

It should be noted that attendance to class (either face-to-face or online) was not mandatory, and students attending the HBLS activities were 128.

The course quality was monitored through two instruments: a Wooclap survey on the MOODLE platform, administered by the lecturer at the end of the course to the attending students, to record: participation in the distance activities; students' perceptions of teaching methodologies and assessment strategies proposed in HBLS modality; students' perceived effectiveness of the course on their learning. The second instrument was the institutionally-mandated questionnaire, to be filled in before enrolling for the final exam, of which we will consider the items relating to overall satisfaction, HBLS organization, perceptions of the lecturer's action, contents and program offered, and the perceived workload.

In addition, the pass rate of the final examination at the end of the course was considered, distinguishing between the results of the attending students (i.e. who benefitted from formative assessment) and those not attending. Such final examinations consisted in solving mathematical and engineering exercises, applying the theoretical knowledge addressed during the course.

The passing rate was considered relevant to the research question because it indicates the effectiveness of the course in fostering learning in the students.

Results

The first analyzed data come from the lecturer's survey administered to both groups at the end of the course lessons but before the final examination (January 2023). A total of 128 students took part in the survey, answering the 4 questions on:

1. attendance to peer review activities during the course;
2. preference for HBLS also in other courses – as an index of satisfaction with the teaching modalities implemented;
3. perceived effectiveness of HBLS and formative assessment for their own learning;
4. perceived effectiveness of HBLS in fostering content learning.

Table 1 synthesizes the results.

	Yes	No	Indifferent/ I don't know
1. I participated in the peer review and in at least half of the weekly quizzes.	124 96,88%	4 3,13%	0
2. I would like to attend other courses in the future with the HBLS mode used in this course.	70 54,69%	31 24,22%	27 21,09%
3. I would like in the future to attend other courses offering the type of in-progress assessment used in this course.	87 67,97%	25 19,53%	16 12,50%
4. I feel that the mode used in this teaching (HBLS + formative assessments) enabled me to learn the content better than a traditional course.	75 58,59%	25 19,53%	28 21,88%

Overall, attendance to at least half of the blended learning and peer assessment activities was at a positive level (62% out of the total of 128 students taking the survey), taking into account that attendance at lectures was not compulsory.

The answers to the next three questions (2,3,4) are affirmative for more than 50% of the respondents. In particular, with regard to the possible opportunity to be able to apply the formative assessment with diversified tests realized during the learning pathway to other subjects (67.97%).

The institutional survey was mandatory for the entire cohort (N = 200) and anonymously filled out. From the data extracted from the institutional survey (N = 200), some differences can be seen between the assessments (score 0-10) of participants.

Below we will present a summary of the results of the different sections of the questionnaire comparing the responses of the group A and B. indeed, data was gathered divided by group.

Overall satisfaction: group A recorded an average score of 6.96 out of 10 (20.2% answers with a rating lower than 6; 60.6% answers with a rating between 6-8 and 19.9 answers with a rating between 8-10). Group B, instead had an average score of 8.08 (3.9% answers with a rating lower than 6; 53.25% answers with a rating between 6-8 and 42.85% answers with a rating between 8-10).

Organization of the course: this section groups together a set of questions relating to the teacher's clarity in presenting the training objectives, the mode of assessment, the appropriateness of teaching-learning time and the teaching material. In both groups the evaluations were positive. Students in group A evaluated course organization quality with an average score of 8.56 (8.05% answers with an evaluation below 6; 26.66% of answers between 6-8; 55.56% answers with an evaluation between 8-10). Group B gave an average score of 8.74 (3.9% answers with an evaluation below 6; 53.25% answers with an evaluation between 6-8 and 42.85% answers with an evaluation between 8-10).

Teaching activity (teacher's action): this section includes questions relating to students' assessment of the teacher's actions: motivating and arousing interest in the discipline taught; clarity of presentation; willingness to provide clarifications and explanations; perceived usefulness of the workshops and other learning activities on offer. As can be seen in the table (the complete data on all questions in the section of the questionnaire on teaching activity), there are differences between the evaluations of the two groups of students. In particular, the evaluations of group B in all questions are > 8 (%) (Table 2).

Table 2 - Teaching activities data

Teaching activities	Avg (dev. St.)		< 6 (%)		6-8 (%)		>8 (%)	
	A	B	A	B	A	B	A	B
Teacher action to stimulate motivation and interest in the discipline.	6.93	8.22	19.19	5,19	51,52	42,86	29,29	51.95
Clear definition of assessment methods.	6.84	8.00	21.21	3,9	52,53	55,84	26,26	40.26
Availability of the teacher to give clarifications and explanations.	8.52	8.93	6.19	0	34,02	33,33	59,79	66.67
Perceived usefulness for learning the discipline, derived from workshops and other proposed teaching activities	7.34	8.30	14	4,92	53,52	44,26	32,04	50.82

Content and program: the section includes two questions; one on the coherence between the course syllabus and the activities carried out, and the other about student interest in the content. In group A, the average score of the two answers was 7.85 (10.13% average of answers with a rating lower than 6 in the various aspects investigated; 46.38% answers with a rating between 6-8; 43.48% answers with a rating between 8-10). In group B the average score was 8.36 (4.6% answers with a rating lower than 6; 42.72% answers with a rating between 6-8 and 52.76% answers with a rating between 8-10).

Perceived workload: this section includes one question about whether students believe they had adequate prior knowledge to understand the course topics. It also has another question regarding the perception of the appropriateness of the assigned workload, considering the amount of course credits (Table 3).

Table 3 - Perceived workload data

Perceived workload	Avg (dev. St.)		< 6 (%)		6-8 (%)		>8 (%)	
	A	B	A	B	A	B	A	B
Adequacy of prior knowledge	7.67	8.06	10.02	3,09	57,14	55,84	32,36	40.26
Adequacy of the required study load	5.22	6.84	49.49	23,38	40,04	42,86	10,11	33.76

A final reflection was conducted on the data collected through final examination results from the 2013/2014 academic year considering the methodological and evaluative transformations made to teaching over the past decade by the same lecturer.

Until 2013/14, this course was carried out exclusively in the classroom, with face-to-face lectures and traditional assessment methods (summative, with a final exam). The average pass rate was 35% in the first session after the course and 55% in the following exam sessions.

From 2014/15 to 2021/22, the course continued to be taught in the traditional mode (face-to-face only), but changing the mode of assessment. For attending students, various types of activities and assessments with feedback (formative assessment) were instituted, as well as a final examination at the end of the course. For non-attending students, only the final exam was maintained for each exam session (summative assessment). The average pass rate of the examinations for students who carried out the formative assessment activities during the course, in the years taken into consideration was: 50% pass rate in the first session after the course and 60% in the other subsequent sessions. Grades were between 18 and 26 for 57%, between 27 and 30 and Honors for 43%.

For the academic year 2022/23, the teaching was carried out using the HBLS approach and considered in this study included a formative and summative assessment. 69% of the students passed the final examination (21% with a grade between 18 and 26, 79% with a grade between 27 and 30 and Honors). 76% of the students passed the exam in the subsequent winter and summer sessions.

Conclusion

Overall, the feedback provided by students through the teacher survey showed a high percentage of participation in blended learning and formative assessment activities, out of the total number of students enrolled. The idea of extending this way of organizing the course to other disciplines was well received by most of the students involved, although for around 20% the response was negative. This can be explained by the subsequent analysis of the data from the institutional evaluation questionnaire. As can be seen from the workload perceptions, in general the lowest ratings were recorded on the adequacy of the workload required (Table 3). In fact, despite success in terms of passing exams and grades obtained, satisfaction on this dimension was lower in academic year 2022-23 than in previous years when teaching was delivered in the traditional mode. Despite adherence to the institutional load of 25 working hours per credit and the reduction of the number of lectures by a third in favor of online teaching, the amount of autonomous and group work, to be carried out at times other than lectures, was perceived as excessive. One explanation could be related to the busy academic calendar, with a few weeks of intensive coursework close to exam sessions, as opposed to more diluted periods for subsequent exam sessions. The concentration of the course in a few weeks may not be entirely adequate to support continuous formative assessment activities. A less demanding formative assessment might be more effective. The help provided by ChatGPT and generative Artificial Intelligence in homework could be more adequate if a part of the formative assessment was carried out in the classroom (Liu & Gibson, 2023).

These considerations align with the University's guidelines on blended teaching, which encourage lecturers, together with course chairs, to consider spatio-temporal organization as a crucial element of teaching quality, especially in HBLS environments.

A final interesting element is the figure that emerged in the section of the institutional questionnaire devoted to Teaching Activities. As mentioned above, the teacher, activities, time, digital resources and assessment methods were the same for both groups of students considered, however the evaluations of the various questions, although overall above sufficient, returned by the students in group A are on average 1 point lower than those of the students in group B. This set of data aligns with the statements of Evidence Based research (Hattie, 2012) that highlight the relevance of the teacher's methodological action, rather than just the technological equipment, and the students' awareness of the changes they will have to face when faced with innovative HBLS teaching. Indeed, again according to Evidence Based literature, technological implementation in education is most effective when it is guided by active learning strategies; when multiple learning possibilities are implemented; when the student is facilitated in the autonomous use of digital resources and when peer learning and feedback are optimized (Marzano & Calvani, 2020). This requires the competence not only of the teacher, through specific training, but also of the students, so that they are effectively prepared to learn in an innovative way (Coggi & Ricchiardi, 2018).

The case considered has some limitations when considering the application of the intended STEM teaching approach, which did not span the entire curriculum with more than one course in the STEM area disciplines but was only applied to one course in which the learning objectives of mathematics and technology were integrated. However, the relevance of the study lies in the context of the bachelor's degree in Computer Engineering, which is fully within the STEM area, and in the didactic design developed that addresses the learning objectives in an interdisciplinary manner and with an active learning approach (student-centred participatory and collaborative learning) (Kennedy & Odell, 2014). This activity is part of the policies undertaken by the University of Padua to promote the STEM area. Starting from the academic year 2022-23, the university has implemented a dedicated platform that also offers postgraduate master courses in this area (e.g. Omics Data Analysis; Biostatistics for Research and Scientific Publication; Advanced Biostatistics for Clinical Research; Pharmaco-epidemiology and Evaluation of Integrated Care; Geostatistics for Human, Animal and Environmental Health; Machine Learning and Big Data in Precision Medicine and Biomedical Research; Synthesis of Empirical Evidence and Reproducibility of Research).

References

Alammary, A., Sheard, J., & Carbone, A. (2014). Blended learning in higher education: Three different design approaches. *Australasian Journal of Educational Technology*, 30(4), 67-74. Doi: 10.14742/ajet.693.

Allan, C. N., Campbell, C., & Crough, J. (2019). Blended learning designs in STEM higher education. *Blended learning designs in STEM Higher Education*, 339-362. Springer.

Angeli, C., & Valanides, N. (2009). Epistemological and Methodological Issues for the Conceptualization, Development, and Assessment of ICT-TP-CK: Advances in Technological Pedagogical Content Knowledge (TPCK). *Computers & Education, 52*(1), 154-168. Doi: 10.1016/j.compedu.2008.07.006.
Bernard, R., M., Borokhovski, E., Schmid, R. F., Tamim, R. M., & Abrami, P. C. (2014). A meta-analysis of blended learning and technology use in higher education: From the general to the applied. *Journal of Computing in Higher Education,* 26(1), 87-122.
Bruggeman, B., Tondeur, J., Struyven, K., Pynoo, B., Garone, A., & Vanslambrouck, S. (2021). Experts speaking: Crucial teacher attributes for implementing blended learning in higher education. *The Internet and Higher Education*, 48-57. Doi: 10.1016/j.iheduc.2020.100772.
Calvani, A. (2014). *Come fare una lezione efficace*. Carocci.
Coggi, C., & Ricchiardi, P. (2018). Sviluppare un insegnamento efficace in Università-Developing effective teaching in Higher Education. *Form@ re*, *18*(1), 23-38. Doi: 10.13128/formare-22452.
De Rossi, M., & Trevisan, O. (2018). Technological Pedagogical Content Knowledge in the literature: how TPCK is defined and implemented in initial teacher education. *Italian Journal of Educational Technology*, 26(1), 7-23
De Rossi, M., & Trevisan, O. (2022a). Innovare la didattica universitaria con Hybrid Blended Learning Solution: Una ricerca design-based project per la formazione iniziale degli insegnanti. *Formazione & Insegnamento, 20*(3), 475-490. Doi: 10.7346/-fei-XX-03-22_33.
De Rossi, M., & Trevisan, O. (2023). Hybrid Blended Learning Solution for Teacher Education Innovation. *Excellence and Innovation in Learning and Teaching, 8*(1), 26-37. https://doi.org/10.3280/exioa1-2023oa16039
Gaebel, M. & Morrisroe, A. (2023). *The future of digitally enhanced learning and teaching in European higher education institutions*. European University Association absl.
Gaebel, M., Zhang, T., Stoeber, H., & Morrisroe, A. (2021). *Digitally enhanced learning and teaching in European higher education institutions*. European University Association absl.
Graham, C. R. (2006). Blended learning systems. In C. J. Bonk & C.R. Graham (Eds.), *The handbook of blended learning: Global perspectives, local designs*, *1*, 3-21. Pfeiffer Publishing.
Graham, C. R., & Dziuban, C. (2008). Blended learning environments. In *Handbook of research on educational communications and technology* (pp. 269-276). Routledge.
Hattie, J. (2009). *Visible learning: A synthesis of over 800 meta-analysis relating to achievement.* Routledge.
Hattie, J. (2012). *Visible learning for teachers: Maximizing impact on learning*. Routledge.
Kaleta, R., Skibba, K., & Joosten, T. (2007). Discovering, designing, and delivering hybrid courses. In Picciano, A. G., Dziuban, C. D. (Eds), *Blended Learning: Research perspectives*, pp. 111-144. Sloan Consortium.

Kennedy, T. J., & Odell, M. R. (2014). Engaging students in STEM education. *Science education international*, *25*(3), 246-258.

Liu, L., & Gibson, D. (2023, March). Exploring the Use of ChatGPT for Learning and Research: Content Data Analysis and Concerns. In *Society for Information Technology & Teacher Education International Conference* (pp. 893-895). Association for the Advancement of Computing in Education (AACE).

Mariconda, C. (2020). *MOOC Analisi matematica: calcolo in più variabili ed equazioni differenziali.* -- https://lms.federica.eu/course/view.php?id=137.

Mariconda, C. (2023). *Introduzione al calcolo in più variabili ed equazioni differenziali.* Springer.

Marzano, A. & Calvani, A. (2020). Evidence Based Education e didattica efficace: come integrare conoscenze metodologiche e tecnologiche nella formazione degli insegnanti. *ECPS Journal*, 22, 125-143. Doi: 10.7358/ecps-2020-022-maca.

McGee, P., & Reis, A. (2012). Blended course design: A synthesis of best practices. *Journal of Asynchronous Learning Networks*, *16*(4), 7-22.

Megahed, N. & Ghoneim, E. (2022). Blended Learning: The New Normal for Post-COVID-19 Pedagogy. *International Journal of Mobile and Blended Learning (IJMBL), 14*(1), 1-15. Doi: 10.4018/IJMBL.291980.

Ministero dell'Università e della Ricerca (2021). *Linee generali di indirizzo della programmazione delle università 2021-23 e indicatori per la valutazione periodica dei risultati.* -- https://www.mur.gov.it/sites/default/files/2021-04/Decreto%20Ministeriale%20n.289%20del%2025-03-2021.pdf.

Mishra, P., & Koehler M. J. (2006). Technological Pedagogical Content Knowledge: a Framework for Integrating Technology in Teacher Knowledge. *Teachers College Record, 108*(6), 1017-1054. Doi: 10.1111/j.1467-9620.2006.00684.x

Ortiz-Revilla, J., Greca, I. M., & Arriassecq, I. (2022). A theoretical framework for integrated STEM education. *Science & Education*, *31*(2), 383-404. Doi: 10.1007/s11191-021-00242-x.

Philipsen, B., Tondeur, J., Pareja Roblin, N., Vanslambrouck, S., & Zhu, C. (2019). Improving teacher professional development for online and blended learning: A systematic meta-aggregative review. *Education Tech Research & Development*, 67, 1145-1174. Doi: 10.1007/s11423-019-09645-8.

Reeves, T.C., & Reeves, P.M. (2012). *Designing online and blended learning in University Teaching in Focus: A Learning-Centred Approach*. Routledge.

Sancassani, S., Baldoni, V., & Brambilla, F. (2023). *La ricerca del giusto mezzo. Strategie di equilibrio tra aula e digitale.* Pearson.

Torrisi-Steele, G., & Drew, S. (2013). The literature landscape of blended learning in higher education: The need for better understanding of academic blended practice. *International journal for academic development*, *18*(4), 371-383.

Trentin, G. (2015). Orientating pedagogy towards Hybrid spaces. In Nata, R. V. (Ed.). *Progress in education*, 35, pp. 105-124. Nova Science Publisher Inc.

Trevisan, O., & De Rossi, M. (2022b). Accessibility in Blended Learning and Hybrid Solutions at Higher Education Level: A Word from the Students. In Studium (Ed). *Helmeto 2022 – Book of abstract*, pp. 107-110.

Trevisan, O., De Rossi, M., Grion, V. (2021). The positive in the tragic: Covid pandemic as an impetus for change in teaching and assessment in higher education. *Research on Education and Media*, 12(1), 69-76. Doi: 10.2478/rem-2020-0008.
Yin, R. K. (2009). *Case Study research. Design and Methods*. Sage.
Zhang, L., Carter Jr., R. A., Qian, X., Yang, S., Rujimora, J., Wen, S. (2022). Academia's responses to crisis: A bibliometric analysis of literature on online learning in higher education during COVID-19. *British Journal of Educational Technology*, 53(3), 620-646. Doi: 10.1111/bjet.13191.

Il Service Learning come via italiana alle Cliniche Legali: limiti e prospettive

Service Learning as the Italian Way to Legal Clinics: Strengths and weaknesses

Stefano Bonometti*, Giacomo Felloni*, Letizia Ferri^

Riassunto
Il presente contributo approfondisce l'istituto delle Cliniche Legali, alla luce del modello del Service Learning sotto il profilo metodologico e disciplinare, in relazione all'ambito accademico giuridico italiano.
Vi è oggi la necessità di riflettere sul tema di un'innovazione didattica nel contesto universitario, in particolare nel settore delle Scienze giuridiche, dove emerge la necessità di promuovere una circolarità tra modelli ed esperienze. Le Cliniche Legali costituiscono un esempio innovativo di come le metodologie didattiche classiche di insegnamento e apprendimento possano essere applicate in ogni contesto di studi, assumendo prospettive e connotazioni adeguate all'ambito disciplinare ed al contesto culturale in cui vengono trasposte, come previsto dal costrutto dell'interdisciplinarietà.
Dopo aver presentato le potenzialità di un approccio interdisciplinare all'insegnamento, si approfondirà la metodologia del Service Learning e le sue potenzialità di integrazione tra apprendimenti e servizi al territorio (terza missione).
In seguito, le Cliniche Legali saranno approfondite nei loro risvolti formativi in ambito nazionale ed internazionale, con una particolare sottolineatura delle peculiarità che devono assumere per essere introdotte efficacemente nell'attuale realtà accademica italiana.
Parole chiave: Didattica, Service Learning; Cliniche Legali, interdisciplinarità, apprendimento esperienziale.

---

* TLC dell'Università degli Studi dell'Insubria di Varese e Como.
^ TLC dell'Università degli Studi dell'Insubria di Varese e Como. E-mail: letizia.ferri@uninsubria.it.
L'articolo è frutto del lavoro congiunto di tutti gli Autori. Tuttavia, è possibile attribuire la supervisione del lavoro e il par. 1.1 e 6 a S. Bonometti, il par. 1 e 2 a L. Ferri; i par. 3, 4, 5 a G. Felloni.

Excellence and Innovation in Learning and Teaching (ISSNe 2499-507X), 2023, 2

Doi: 10.3280/exioa2-2023oa16822

Abstract
This paper provides a comprehensive exploration of the institution of Legal Clinics in the context of the Service Learning model, with a particular focus on methodological and disciplinary considerations, within the framework of Italian legal academia.
In response to the evolving landscape of higher education, particularly in the field of Legal Sciences, there is a growing imperative to contemplate educational innovation. This paper addresses the pressing need to foster a symbiotic relationship between pedagogical models and practical experiences. Legal Clinics serve as a pioneering example of how traditional teaching and learning methodologies can be adapted to various academic contexts, imbued with perspectives and nuances tailored to the specific disciplinary and cultural milieu they inhabit, all in accordance with the principles of interdisciplinarity.
Following an exploration of the potential benefits associated with adopting an interdisciplinary approach to education, this paper delves into the methodology of Service Learning and its capacity to seamlessly integrate learning with community service (the "third mission"). Subsequently, Legal Clinics are scrutinized in terms of their educational implications at both the national and international levels, with a particular focus on the unique adaptations required for their effective implementation within the current framework of Italian higher education.
Keywords: Didactics; Service Learning; Legal Clinics; interdisciplinarity; experiential learning.

Articolo sottomesso: 13/09/2023; accettato: 10/11/2023
Disponibile online: 13/12/2023

1. Il ruolo delle metodologie didattiche nell'ambito accademico attuale

Vi è oggi la necessità di riflettere sul tema dell'innovazione didattica nell'ambito accademico, in particolare nel settore giuridico, dove emerge la necessità di promuovere una circolarità tra modelli ed esperienze attraverso didattiche legate ad un apprendimento esperienziale che valorizzi il fare autentico e la relazione con un mentore; all'interno di questa riflessione nasce l'interesse per le Cliniche Legali, metodologia che si andrà a dettagliare dopo averla situata nell'ambito della riflessione accademica e metodologica attuale.

Nel mondo universitario, come nel mondo lavorativo, in tutti i loro ambiti e sfaccettature, una delle parole che risuona maggiormente, in particolare a seguito della pandemia di Covid-19, è "Relazione", nelle sue diverse declinazioni. Spesso ci si accorge del valore di qualcosa solo nel momento stesso in cui se ne viene privati, per questo motivo probabilmente l'accento sull'importanza del tessuto relazionale e delle competenze ad esso connesse, a tre anni dall'inizio della pandemia, è così presente, come afferma Benasayang (2019):

> per spingere verso una riconquista della esistenza e mettere le persone in condizione di ridare senso alle proprie azioni è necessario metterle in condizione di ritrovare il valore delle relazioni, ridando valore al corpo umano e cioè al contatto fisico tra le persone (oltre che a quello virtuale) e riorientare le esperienze individuali e relazionali agite e vissute corporalmente e affettivamente entro una configurazione concreta di spazi, tempi, corpi e oggetti investiti simbolicamente e culturalmente (p.56).

Le relazioni costituiscono dunque un ambito di studio e riflessione che, anche in termini di collaborazione tra diverse professionalità e competenze, può trovare nuovi ambiti di sperimentazione, a partire dal contesto pedagogico-educativo, seguendo le sollecitazioni che provengono anche dal contesto legislativo nazionale ed internazionale. Le più recenti indicazioni provenienti dall'Unione Europea e dal Piano Nazionale di Ripresa e Resilienza (2021), ci restituiscono che il compito principale dell'Università sia costruire conoscenza utile allo sviluppo del paese e formare futuri professionisti capaci di interagire con nuovi costrutti professionali. Con i fondi stanziati nel PNRR, vi sono molte attività che mettono al centro l'importanza della collaborazione tra professionalità diverse, sia in ambito di ricerca che di didattica.

In una società sempre più complessa ed in rapido mutamento, come quella in cui ci si trova attualmente a vivere, sembra che solo la cooperazione, l'aiuto reciproco, l'unione di saperi e competenze diverse potrà permettere di non soccombere alla velocità con cui, anche gli stessi dispositivi tecnologici, come l'intelligenza artificiale, si adeguano in maniera apparentemente molto più immediata e rapida di quanto le persone siano in grado di fare (Fabbri et al., 2022).

1.1 L'interdisciplinarietà

Ai docenti universitari è richiesto uno sviluppo di molteplici abilità e competenze che trascendano la specificità delle proprie discipline e siano in grado, attraverso una conoscenza delle più innovative metodologie didattiche, di migliorare la qualità del loro insegnamento, della valutazione e delle proprie competenze. Questa richiesta di ampliare i propri ambiti e ambienti di azione, che viene fatta oggi con insistenza in ambito accademico e da molti anni è stata proposta agli insegnanti di ogni ordine e grado, è un invito ad aprirsi ad uno sguardo inter e transdisciplinare. Per quanto concerne l'interdisciplinarietà Fundarò (2020) a definisce come:

una realtà totale alla quale si può fare riferimento come oggetto possibile di tutti i vari punti di vista parziali o settoriali dell'educazione disciplinare e delle educazioni. D'altronde esiste una unità soggettiva del sapere, essendo tutte le varie scienze nient'altro che il prodotto di un'unica attività dell'intelletto umano. La scienza è una creazione dell'intelletto umano, con le sue libere invenzioni di idee e di concetti (p. 1).

Ci si chiede come riuscire a trovare un linguaggio, delle metodologie e un'applicazione che permetta alle diverse discipline di mettersi in dialogo tra loro senza perdere le proprie peculiarità, ma anzi potenziandosi. Per rispondere a questa esigenza le teorie del Boundary Crossing (Akkerman, 2011; Engeström 1995) offrono strategie per superare la rigidità disciplinare, ciò che Engeström definisce incapsulamento, per individuare due possibili livelli di integrazione. Il primo è ciò che abbiamo anticipato con il costrutto dell'interdisciplinarietà, uno sguardo che crea collegamenti tra le diverse discipline, ricercando nuclei tematici posti come dei ponti che aprono spazi di dialogo e confronto tra le discipline e con il contesto di realtà. La stessa definizione di competenza di Pellerey (2004) e Castoldi (2017) rappresenta uno sguardo interdisciplinare, ovvero un agire consapevole che orchestra le differenti risorse (discipline e contesto) al fine di affrontare in modo efficace il compito/problema assegnato.

Un secondo livello di integrazione è dato dal concetto di transdisciplinarietà, un andare oltre al riconoscere l'interazione, la reciprocità, i punti in comune tra le discipline, riconoscendo uno spazio oltre le discipline inteso come un sovrasistema senza confini stabili. Marzocca (2014) nel suo saggio indica che

la risposta transdisciplinare a questo problema è data dal riconoscere che esistono differenti vie della scienza e non esiste gerarchia fra esse. Al contrario, le diverse modalità sono complementari e – questo è il primo principio chiave della transdisciplinarità – afferiscono a diversi livelli di realtà (p.11).

Questo livello di integrazione si esprime in possibili tessiture tra differenti tematiche, sguardi plurali per cogliere diversi livelli della realtà; da qui una didattica che incrocia linguaggi e soggetti, tempi e problemi in un territorio "terzo" e aperto per rispondere ai nuovi problemi posti dalla complessità.

2. L'apprendimento "a servizio" della comunità

Uno strumento didattico-pedagogico che si è diffuso per implementare le competenze relazionali e interdisciplinari in ambito educativo negli ultimi anni è il Service Learning. L'istruzione di qualità equa ed inclusiva per un apprendimento permanente per tutti, così come previsto dal Goal 4 dell'Agenda 2030, necessita il ricorso ad un modello pedagogico che valorizzi l'impegno, la responsabilità, il senso di cittadinanza globale (sul tema, con precipuo riferimento alle cliniche legali v. Lombardi, 2020). Anche all'interno della Costituzione Italiana vi sono innumerevoli sottolineature dell'importanza del "(...) pieno sviluppo della persona umana e l'effettiva partecipazione di tutti i lavoratori all'organizzazione politica, economica e sociale del Paese" (art. 3, 2° comma, Cost.). Alla base dell'importanza di nuove metodologie come il Service Learning non vi sono motivazioni esclusivamente di natura didattica, benchè ogni modalità che metta al centro l'apprendimento e lo studente sia ormai dimostrato che porti gli alunni ad essere più propensi allo sviluppo di competenze significative per l'attuale contesto sociale, ma anche di natura sociale e di cittadinanza attiva. La Raccomandazione del Consiglio europeo del 22 maggio 2018 ribadisce, infatti, che "Le competenze richieste oggi sono cambiate: [...] e le competenze, sociali e civiche diventano più importanti per assicurare resilienza e capacità di adattarsi ai cambiamenti".

Infine, altra fonte particolarmente rilevante, specie per quanto riguarda le cliniche legali, è il c.d. Processo di Bologna (un accordo intergovernativo di collaborazione nel settore dell'Istruzione superiore, siglato nel 1999 a Bologna, cui sono seguite ulteriori riunioni). Nel comunicato redatto nel 2001 a seguito dell'incontro di Praga, nell'ambito del Processo di Bologna, si è riconosciuto che:

> in the future Europe, built upon a knowledge-based society and economy, lifelong learning strategies are necessary to face the challenges of competitiveness and the use of new technologies and to improve social cohesion, equal opportunities and the quality of life (Communiqué of the meeting of European Ministers in charge of Higher Education in Prague on May 19th, 2001).

Da un lato, dunque, occorre perseguire la competitività e, dall'altra, la giustizia sociale.

Riprendendo l'importanza per la società odierna delle relazioni e della collaborazione tra discipline, il Service Learning è proprio quell'approccio pedagogico che

> porta a ripensare i contenuti ed i metodi secondo la logica della trasformazione migliorativa della realtà, unendo il Learning, l'apprendimento, al Service, l'impegno costruttivo per la comunità. (...) Tramite il Service Learning la scuola diventa soggetto partecipe alla vita della comunità di cui fa parte, prendendo in carico una responsabilità sociale volta al miglioramento (MIUR, 2018).

Tra le centinaia di definizioni[1] che ormai appartengono alla letteratura sul Service-Learning scegliamo quella di Furco, uno dei pionieri internazionali di questa proposta:

> Il Service Learning è un approccio pedagogico che unisce in un unico progetto ben articolato i processi di insegnamento/apprendimento e l'intervento nella realtà, allo scopo di dare risposta a bisogni o problemi presenti nella comunità. In questo modo gli studenti imparano con lo scopo di poter offrire un loro personale contributo al miglioramento sociale e ambientale (Furco & Billig, 2001, p. 25).

Si è scelto di mettere in evidenza questa definizione perché qui emerge con immediatezza come l'elemento pedagogico e quello sociale debbano essere coerenti e bilanciati tra loro perché l'attività si conformi correttamente e non tradisca la sua epistemologia originale. Un Service Learning non si può improvvisare e non può essere occasionalmente applicato; come tutte le metodologie didattiche necessita una progettazione coerente[2] ed una visione che integri coerentemente tutte le competenze che si vogliono sviluppare nei discenti con i bisogni effettivi di un territorio e di un contesto sociale. Infine, la proposta di apprendimento tramite Service Learning deve coniugarsi opportunamente con il curricolo di studi in cui va ad inserirsi, per non correre il rischio di diventare un'attività a latere o aggiuntiva ad un percorso che si costituirebbe anche in maniera indipendente da esso.

2.1 Il Service Learning e l'Università

Per la sua stessa natura, il Service Learning è una metodologia che dà ampie possibilità di applicazione in ambito universitario e non solo per la formazione dei docenti, ma anche e soprattutto per quella degli studenti, nelle aree disciplinari più diverse.

Nell'introduzione al numero dedicato al Service Learning universitario di Sapere pedagogico e Pratiche educative, ne viene sottolineata l'importanza all'interno dell'ambito della terza missione:

> si potrebbe aggiungere che attraverso il Service Learning si prospetta un ripensamento radicale del curricolo in atto nelle Scuole e, per l'Università, un inveramento

[1] Una varietà di studi nel contesto internazionale si esplicita anche nella presenza di diverse denominazioni e sfaccettature per questa metodologia, quali: Civic Engagement education (UK), Aprendizaje y Servicio Solidario – (America Latina e Spagna), Lerner durch Engagement Education (Germania), Service-Learning (USA), ed altro ancora. Nel contesto italiano si riporta la breve sintesi degli studi stilata da Taub (2022)

[2] Il modello di progettazione diffuso in Italia è quello di CLAYSS, in Fiorin 2016.

della terza missione, non come adempimento di ulteriori indicatori, ma come prospettiva di interdipendenza reale e propulsiva con il territorio (Colazzo & Ellerani 2018, p. 32).

Il Service Learning non è una proposta di arricchimento del curricolo, ma di ripensamento, è un nuovo metodo di insegnamento, è un approccio pedagogico che porta a ripensare i contenuti e i metodi secondo la logica della trasformazione migliorativa della realtà, è un cambio di paradigma. Porta dunque una risignificazione dei fini, non modifica l'impianto scientifico, ma lo trasforma, restituendo una prospettiva educativa e formativa più propriamente radicata nello sviluppo umano (Colazzo & Ellerani 2018).

Più recentemente, nel numero 1/2023 dedicato al Faculty Development e alla didattica innovativa di Excellence and innovation in learning and teaching, si trova la presentazione di un interessante progetto in ambito di Service Learning universitario. Qui l'attenzione alla pratica didattica del Service Learning accademico viene proposta non solo per il suo ruolo nella terza missione, ma anche come un valido aiuto alla costruzione di una comunità educante, interna ed esterna all'ateneo e come un dispositivo fondamentale per l'apprendimento e la formazione dei docenti stessi (Culcasi & Cinque, 2023).

Queste potenzialità del Service Learning lo rendono dunque una metodologia particolarmente adeguata allo sviluppo delle relazioni e dell'interdisciplinarietà, così rilevanti ed attuali in questo momento storico.

Tra i Service Learning si può classificate la metodologia delle cliniche legali poiché la letteratura afferma che esse hanno tra i loro principi:

1. un atteggiamento esplorativo e competenze di analisi critica rispetto al sapere disciplinare,
2. competenze riflessive
3. competenze collaborative e di team working (Mortari et al., 2022).

3. Le tipologie di Cliniche Legali

Con l'espressione "clinica legale" ci si riferisce ad una metodologia didattica – riconducibile, secondo gli autori, al Service Learning – sviluppatasi nei primi decenni del XX secolo, specialmente negli Stati Uniti d'America, con l'obiettivo di fornire agli studenti delle materie giuridiche un approccio più concreto all'oggetto dei loro studi. Si tratta, in particolare, di un'attività didattica contraddistinta da metodologie molto differenti, tutte, però, caratterizzate dall'utilizzo di "metodi interattivi per l'insegnamento di specifiche abilità professionali" (Roccaro, 2015, p. 14).

In particolare, le cliniche legali hanno, come obiettivo, quello di formare, sin dall'ambito universitario, gli studenti delle materie giuridiche anche nelle competenze pratiche connesse alla materia che studiano (il "saper fare"), in modo non diverso da quanto accade, con le cliniche mediche, per gli studenti di medicina: da questa analogia discende, pertanto, l'espressione "clinica legale" (Carnelutti, 1935; Frank, 1932-1933; Wigmore, 1926).

In questa prospettiva, un ruolo preponderante viene svolto dal Service Learning, con il quale lo studente viene chiamato a svolgere attività non solo affini al suo corso di studio, ma altresì funzionali al miglioramento della comunità (Casadei, 2019).

In particolare, si possono individuare diverse forme di clinica legale[3] , in cui la funzione di Service Learning è più o meno marcata.

Anzitutto, rientrano in tale definizione le c.d. "in-house clinic": in questi casi, lo studente entra direttamente in contatto con gli utenti, svolgendo, all'interno dell'università, un'attività di consulenza non dissimile da quella che svolgerebbe, nel proprio studio, un avvocato. Un'altra forma di clinica legale, che prende il nome di "externship", comporta, invece, che lo studente svolga la suddetta attività non più nelle mura universitarie, ma al di fuori di esse (in uno studio legale, in un'impresa, in tribunale), sempre sotto la supervisione di un tutor. In questo caso, lo scarto tra l'università e il mondo del lavoro viene ulteriormente ridotto. A questa categoria si possono ricondurre anche i programmi di street law, molto utilizzati nell'ordinamento italiano, nel quale gli studenti sono chiamati a educare una specifica comunità su questioni giuridiche di particolare interesse per quel territorio: in tal modo si offre ai membri di quella comunità la conoscenza dei diritti essenziali. Al riguardo, le ipotesi più note sono le assistenze nelle case circondariali oppure nelle associazioni a tutela degli immigrati.

In queste ipotesi, la funzione di Service Learning emerge in modo preponderante, essendo lo studente chiamato a svolgere un'attività in prima persona finalizzata a fornire risposte alle esigenze manifestate da determinate categorie appartenenti al territorio in cui l'Università si trova.

Diverso è, invece, il caso della clinica legale esclusivamente simulativa: in questi casi, lo studente si limita a studiare dei casi (fittizi o reali) selezionati dal professore (una sorta di moot court). Se tale tipologia di clinica legale ha l'indubbio vantaggio di ridurre lo stress dello studente, non essendo chiamato ad assumersi alcuna reale responsabilità, essa, dall'altro, comporta anche un minor coinvolgimento emotivo dello studente stesso.

Proprio questo minore coinvolgimento dello studente ha comportato un acceso dibattito tra quanti ritengono che anche la modalità simulativa rientri a

[3] Per un'ampia rassegna v. Roccaro, 2015; Grossman, 1974.

pieno titolo tra le cliniche legali (Roccaro, 2015) e quanti, invece, escludono questa soluzione estensiva (Serafinelli, 2022; Chiaromonte, 2021).

4. Il Service Learning nelle Cliniche Legali

La funzione di Service Learning – nel significato sopra chiarito – è, in realtà, una caratteristica delle cliniche legali che non si è sviluppata immediatamente, ma ha richiesto molto tempo. D'altra parte, come si vedrà, il ruolo di Service Learning della clinica legale può declinarsi in modalità anche molto diverse a seconda dei contesti socioeconomici in cui il servizio di clinica opera.

In effetti, nella sua versione originaria, quale era stata concepita nel sistema statunitense da J. Frank e in quello italiano da F. Carnelutti, la funzione di Service Learning della clinica del diritto era pressoché assente: il beneficiario della clinica legale era considerato poco più che uno strumento per l'apprendimento dello studente; affermava, infatti, Carnelutti (1935) che "il povero dà qualcosa in corrispettivo all'assistenza che riceve; fornisce, appunto, alla scuola il corpus necessario all'insegnamento" (p. 174).

La spiegazione di questo approccio didattico, molto lontano dal Service Learning, trova le sue basi dogmatiche nella concezione di teoria generale all'epoca imperante (realismo giuridico), di cui J. Frank era uno dei massimi esponenti. In questa concezione, fonte del diritto non sono tanto le norme di legge, ma soprattutto l'applicazione giurisprudenziale che di queste norme viene operata dalla giurisprudenza. In questa prospettiva, dunque, particolarmente feconda in un sistema di common law[4] quale è quello nordamenticano, allo studente non possono essere insegnate solo le norme di legge o gli orientamenti giurisprudenziali, ma è necessario che egli apprenda anche i percorsi logico-giuridici e financo emotivi, che guidano il giudice ad adottare una certa decisione:

> where the langdell system [i.e. il metodo casistico, di stampo meramente teorico, elaborato dal prof. Langdell presso la Harvard Law School, n.d.r.] is most seriously at fault is in its naive assumption of the inviolability of the stare decisis doctrine and its corollaries, in its implied belief that in a study of the precedents and nowhere else is to be found the answer to the question, "How does a court arrive at its decisions?" (Frank, 1932-1933, p. 912).

[4] In tale ordinamento i precedenti giurisprudenziali hanno un'efficacia vincolante che non esiste nei sistemi di civil law (come è quello italiano), in cui i giudici sono sottoposti solo alla legge.

Questa visione è progressivamente mutata, nel sistema nordamericano, nel corso del tempo, dapprima con le Legal aid societies (finalizzate ad offrire assistenza legale agli indigenti) e, poi, nell'ambito della rivoluzione sociale degli anni '60, sino ad un ribaltamento di prospettiva (Grossmann, 1974). Nel sistema nordamericano il Service Learning delle cliniche legali ha assunto un'importanza tale che senza giustizia sociale non è neppure più ipotizzabile una clinica legale.

Questo retroterra socioeconomico era meno presente nell'Europa continentale, in cui, in effetti, le cliniche legali non hanno, sino a tempi recenti, avuto particolare successo.

Al riguardo, è stato correttamente osservato nella dottrina d'oltralpe come tanto il sistema socioeconomico, quanto, quello universitario siano profondamente diversi tra i paesi di common law (specialmente gli Stati Uniti) e quelli di civil law (Poillot, 2017).

Sotto il primo profilo, le esigenze di giustizia sociale, sottese al successo delle cliniche legali negli Stati Uniti, sono in larga parte sconosciute nel sistema nordamericano.

In effetti, la questione è solo apparentemente ovvia, poiché, ferma restando la funzione centrale riconosciuta alla didattica, la clinica legale ha progressivamente assunto un ruolo sociale sempre più marcato (Grossmann, 1974). Anzi, secondo una teoria alquanto accreditata, è stato proprio il ruolo di service a determinare il successo della clinica legale nel sistema statunitense. Infatti, a seguito della pronuncia della Corte Suprema (Caso Gideon vs. Wainright) che ha sancito il diritto per ogni imputato non abbiente alla difesa tecnica a spese dello Stato, nel contesto della c.d. war on poverty negli anni '60 e '70 furono istituite molteplici associazioni con lo scopo di permettere un accesso universale alla giustizia. In un tale contesto la clinica legale poteva, così, rappresentare un efficace strumento per garantire un'attività legale gratuita ai non abbienti, in concorso con i legal aids.

Si tratta, però, di problematiche in larga parte estranee all'Europa occidentale, in cui lo Stato sociale è, complessivamente, più forte che negli Stati Uniti (Poillot, 2017).

Pertanto, se una qualche funzione sociale deve riconoscersi a questo istituto, esso deve essere ricercato non già nell'assistenza legale ai soggetti economicamente più fragili, ma, semmai, in favore di soggetti socialmente più deboli. Non sorprende, dunque, che le principali direttrici in cui si sono mosse le cliniche legali in Europa concernono la protezione internazionale, le richieste di asilo politico e la tutela dei consumatori (Bartoli, 2016). Si tratta, infatti, di settori in cui può riconoscersi un ruolo di Service Learning della clinica legale, ma diversi da quelli in cui solitamente operano le cliniche legali nordamericane. Del resto, questa diversità di ambiti non deve stupire: è, infatti, inevitabile che ciascuna Università modelli la propria offerta, anche in termini di cliniche legali, in base alle esigenze del tessuto sociale in cui è inserita.

In particolare, nel sistema italiano il focus è incentrato non tanto sulla tutela dei non abbienti, quanto, piuttosto, di minoranze o, comunque, di categorie di persone più fragili: in tutti questi casi, all'esigenza statunitense di assicurare al non abbiente un'assistenza legale minima, nell'ordinamento italiano si sostituisce, con maggior forza, l'esigenza di informare gli utenti delle cliniche legali circa i loro diritti.

Questa differenza con il sistema nordamericano si spiega agilmente con le ragioni già esaminate in precedenza: da un lato, un tessuto sociale mediamente più compatto; dall'altro, una maggiore facilità, anche per i non abbienti, ad ottenere una sufficiente tutela legale. Ne risulta, quindi, fortemente rafforzato il ruolo di terza missione dell'Università (Casadei, 2019): l'istruzione superiore non viene più "relegata" a lezioni meramente frontali, avulse dal contesto socioeconomico in cui sono inserite, ma ne diventa parte. In questo contesto, dunque, si giustifica una maggiore attenzione a colmare le asimmetrie informative del cittadino rispetto alle istituzioni.

Sotto il secondo profilo, poi, anche il sistema universitario italiano (e, più in generale, europeo) si presenta assai diverso da quello americano.

Infatti, mentre nel sistema nordamericano la figura del professore e quella del clinico sono nettamente separate, questa distinzione manca nel sistema europeo, in cui i clinici sono gli stessi professori incardinati nell'università; consegue una maggiore importanza, oltre che dell'attività didattica, anche della ricerca, quale elemento distintivo dei docenti universitari (Poillot, 2017, pp. 133 e seg.).

5. La via italiana alle Cliniche Legali

La proposta di una via italiana alle cliniche legali non sarebbe completa senza aver esaminato anche i limiti che i modelli sopra proposti assumono nel nostro ordinamento. Ciò vale, in particolare, proprio per quei casi in cui il ruolo di Service Learning è maggiore (in particolare, i già esaminati modelli di in-house clinic).

Infatti, molte attività svolte, nel sistema americano, dagli studenti sono, nel nostro ordinamento (ma, più in generale, in molti Paesi europei), vietate, stante la riserva riconosciuta dalla legge alla professione di avvocato.

Ciò vale, anzitutto, per quanto riguarda l'attività giudiziaria (da intendersi, ai sensi dell'art. 2, 5° comma, l. n. 247/2012, "l'assistenza, la rappresentanza e la difesa nei giudizi davanti a tutti gli organi giurisdizionali e nelle procedure arbitrali rituali”). Questa attività, se svolta a sostegno dei destinatari delle cliniche legali, richiede l’iscrizione nell’albo degli avvocati, ai sensi della citata normativa. Al riguardo, non vi può essere dubbio che gli studenti che svolgessero tali attività violerebbero la riserva di attività in favore degli avvocati e potrebbero trovarsi a rispondere financo del reato di esercizio abusivo di una professione[5]. Peraltro, è appena il caso di aggiungere come sia assai improbabile che nel nostro ordinamento una qualunque clinica legale richieda lo svolgimento di attività giudiziarie, le quali sono notoriamente riservate agli avvocati.

Più complessi sono, invece, i limiti entro cui possono muoversi gli studenti al di fuori delle aule di giustizia, nell’ambito di attività di consulenza prestata in favore degli utenti delle cliniche. Si tratta, del resto, del caso di gran lunga più frequente nell’organizzazione delle cliniche legali. Ciò vale, senz’altro per le in-house clinics, ma anche per la maggior parte delle cliniche redatte secondo il modello della externship. In tali modelli, infatti, come visto, gli studenti sono chiamati a svolgere una diretta attività di consulenza nei confronti degli utenti direttamente in università (in-house clinic) oppure al di fuori di esse (externship).

Ebbene, in questi casi risulta quantomai opportuno delimitare l’ambito di attività, al fine di evitare di incorrere in sanzioni. In effetti, ai sensi dell’art. 2, 6° comma, I, pt., l. n. 247/2012, è di competenza esclusiva degli avvocati “l'attività professionale di consulenza legale e di assistenza legale stragiudiziale, ove connessa all'attività giurisdizionale, se svolta in modo continuativo, sistematico e organizzato”. Fattispecie in cui la clinica legale, in quanto tale, sembrerebbe rientrare, stante la continuità, sistematicità e organizzazione dell’istituto in esame.

Queste preoccupazioni hanno, dunque, mosso, a livello operativo, molte università a concludere accordi con gli Ordini degli Avvocati dei rispettivi circondari, con l’obiettivo di delimitare e rispettare le rispettive sfere di attribuzioni riconosciute dalla legge agli avvocati.

Si tratta di soluzione senz’altro da condividere, che prevedendo, seppur a vario titolo, il coinvolgimento diretto di avvocati, permette un coordinamento da parte di un professionista legittimato a svolgere l’attività riservata. Al contempo, questa soluzione permette altresì agli studenti di beneficiare della professionalità degli avvocati all’interno della clinica, con beneficio anche in termini di apprendimento.

[5] Previsto dall’art. 348 del Codice Penale.

6. Conclusioni

In conclusione, possiamo osservare come il Service Learning sia la base della metodologia didattica delle Cliniche Legali, qualora queste, come solitamente accade, siano inserite nei corsi di laurea in Giurisprudenza. È, dunque, in questa direzione che occorre muovere nel progettare una clinica legale. Infatti, sono strumenti che permettono ai futuri giuristi una formazione più completa e consapevole della complessità dei contesti di esercizio della professionalità.

Basti, al riguardo, osservare che l'insegnamento universitario italiano, specialmente nei dipartimenti di giurisprudenza, ha sempre peccato di una eccessiva "cattedraticità". Scriveva, infatti, Piero Calamandrei, già negli anni '20 dello scorso secolo:

> credo che il difetto fondamentale dell'insegnamento giuridico universitario sia il tradizionale metodo cattedratico (altresì detto metodo "chiacchieratorio") secondo il quale la lezione consiste in una predica che l'insegnante dal suo pulpito gesticolando infligge a una turba di penitenti immobili e silenziosi (Calamandrei, 1921, p. 134).

E ancora,

> in un ordinamento, come il nostro, che mantiene gli insegnamenti obbligatori e considera la esercitazione non come forma unica o principale di insegnamento, ma come integrazione di un corso di lezioni cattedratiche, manca agli studenti il tempo materiale per seguire le esercitazioni, e soprattutto, per seguirle con frutto (…) Finché lo studente sa che il vero scopo pratico dei suoi studî è l'esame, che interesse ha a imparare meno superficialmente di quanto la lezione cattedratica gli consenta? (Pasquali & Calamandrei, 1923, pp. 230-231).

Ebbene, se tale staticità nell'insegnamento rappresenta, ab immemorabili, il tratto distintivo, ma anche il punto debole dell'università italiana, la clinica legale, nella rivisitazione europea sopra proposta, rappresenta, a parere di chi scrive, un'eccellente occasione di sviluppo. Infatti, questa metodologia garantisce un miglior apprendimento degli studenti non solo, tramite il Service Learning, delle nozioni teoriche insegnate, ma anche di competenze pratiche solitamente estranee al mondo accademico. Inoltre, nel perseguimento di questo obiettivo, anche il ruolo di terza missione dell'università verrebbe notevolmente irrobustito, con beneficio per l'intera comunità in cui l'università opera. Del resto, con le precauzioni operative che si è cercato di illustrare nelle pagine che precedono, non paiono esservi seri ostacoli, né giuridici né pratici, all'inserimento di questi istituti nelle università.

Riferimenti bibliografici

Akkerman, S. F., & Bakker, A. (2011). Boundary crossing and boundary objects, in *Review of Educational Research*, 81, 132-169. DOI: 10.3102/0034654311404435.

Bartoli, C. (2016). Legal clinics in Europe: for a commitment of higher education in social justice, *Diritto & Questioni Pubbliche*, 1.

Benasayag, M. (2019). *Funzionare o esistere?*. Milano: Vita e Pensiero.

Calamandrei, P. (1921). *Troppi avvocati!* (Vol. 46). La Voce.

Carnelutti, F. (1935). Clinica del diritto, in *Proc. Civ.*, (Vol. 2, No. 1).

Casadei, T. (2019). L'approccio clinico-legale e le sue (utili) implicazioni, *Rivista di filosofia del diritto*, *8*(2), 277-296.

Castoldi, M. (2017). *Costruire unità di apprendimento. Guida alla progettazione a ritroso*. Carocci.

Chiaromonte, W. (2021). *La formazione del giurista attraverso l'insegnamento clinico del diritto: qualche spunto ricostruttivo "per principianti"*. LLC.

Colazzo, S., & Ellerani, P. (2018). *Service learning: tra didattica e terza missione. Ripensare e riprogettare l'organizzazione nelle scuole e nelle università*. Università del Salento. DOI. 10.1285/i26108968n2.

Culcasi, I., & Cinque, M. (2021) L'impatto del Service-Learning universitario: il progetto Hope. *Excellence and Innovation in Learning and Teaching, (1).* DOI: 10.32801-2021oa12076.

Dewey, J. (2014) (1938). *Esperienza e educazione*. Raffello Cortina.

D.M. n.35 del 22/06/2020: Linee Guida per l'insegnamento dell'educazione civica, ai sensi dell'articolo 3 della legge 20 agosto 2019, n. 92.

Engeström, Y., Engeström, R., & Kärkkäinen, M. (1995). Polycontextuality and boundary crossing in expert cognition: Learning and problem solving in complex work activities. *Learning and Instruction, 5*(4), 319-336. Doi: 10.1016/0959-4752(95)00021-6.

Fabbri, L., Romano, A., Carmignani, S. (2022). Sviluppare i processi di innovazione attraverso i meccanismi di apprendimento all'interno delle comunità professionali. Un modo di pensare e fare i Teaching & Learning Center. In Fabbri, L., Romano, A. (a cura di). *Transformative teaching in higher education.* Pensa Multimedia. pp. 19-50.

Fiorin, I. (2016). *Oltre l'aula. La proposta pedagogica del Service Learning.* Mondadori Università.

Frank, J. (1933). Why not a clinical lawyer-school?. *University of Pennsylvania Law Review and American Law Register*, *81*(8), 907-923.

Freire, P. (1970). *La pedagogia degli oppressi*. Gruppo Abele.

Fundarò, A. (26 giugno 2020), Interdisciplinarietà: cos'è, metodologia e pratica, in *Orizzonte Scuola*, in: https://www.orizzontescuola.it/interdisciplinarieta-cose-metodologia-e-pratica (8/9/2023).

Furco, A. & Billing, S.H. (2001). S*ervice-Learning: the Essence of the Pedagogy*. Information Age Publishing.

Furco, A. (2009). La reflexión sobre la práctica, una componente vital de las experiencias de aprendizaje-servicio. In *Actas del XII Seminario Internacional de Aprendizaje-Servicio Solidario*, pp. 27-36.

Grossman, G. S. (1974). Clinical Legal Education: History And Diagnosis. *Journal of Legal Education*, *26*(2), 162-193. http://www.jstor.org/stable/42892228.

LEGGE 31 dicembre 2012, n. 247: Nuova disciplina dell'ordinamento della professione forense.

LEGGE 20 agosto 2019, n. 92: Introduzione dell'insegnamento scolastico dell'educazione civica.

Lombardi, P. (2020). L'accesso alla giustizia nel quadro dell'Agenda ONU 2030 sullo sviluppo sostenibile. *Federalismi.it*, (16/2020), 184-205.

Marzocca F. (2014). Il nuovo approccio scientifico Verso la transdisciplinarità. *Atopon Rivista di Psicoantropologia Simbolica, 10*, 1-40.

Milani, L. (1967). *Lettera a una professoressa, a cura di Scuola di Barbiana*. Mondadori.

MIUR (2018a). *Una via italiana per il Service Learning*, Roma. https://www.miur.gov.it/web/guest/-/una-via-italiana-per-il-service-learning (10/10/2023).

MIUR (2018b). *Percorsi per le competenze trasversali e per l'orientamento. Linee guida* https://www.miur.gov.it/documents/20182/1306025/Linee+guida+PCTO+con+allegati.pdf.

Mortari, L., Silva, R., & Bevilacqua A.M.A. (2022). L'analisi delle pratiche discorsive come strumento per la valutazione d'efficacia dell'innovazione didattica: Il caso delle cliniche legali. In Fabbri, L., Romano, A. (a cura di). *Transformative teaching in higher education.* Pensa Multimedia. pp. 157-178.

Orlandini, L., Chipa, S., & C. Giunti, (a cura di) (2020). *Il Service Learning per l'innovazione scolastica: le proposte del Movimento delle Avanguardie educative.* Carocci.

Pasquali, G. & Calamandrei, P. (1923). *L'università di domani*. Foligno

Pellerey, M. (2004). *Le competenze individuali e il portfolio*. La Nuova Italia.

Poillot, E. (2017). Comparing Legal Clinics: Is There a Way to a European Clinical Culture?: The Luxembourg Experience. *European Journal of Comparative Law and Governance*, *4*(2), 111-139. DOI: 10.1163/22134514-00402003.

Roccaro, D. (2015). Caratteri e tipologie delle cliniche legali. In Smorto, G.(a cura di). *Un manuale operativo*. Edizioni NEXT, pp. 13-32.

Santoro, E. (2019). Guai privati e immaginazione giuridica: le cliniche legali e il ruolo dell'università. *Rivista di filosofia del diritto*, *8*(2), 231-256.

Serafinelli, L. (2022). Alle origini delle cliniche legali nella formazione del giurista statunitense: tra nativismo e New Deal. *DPCE Online*, *49*(4).

Taub, M.K. (2022). L'impatto del Service-Learning su docenti e educatori. In Boffo, V., & Togni, F. (edited by). *Esercizi di ricerca. Dottorato e politiche della formazione*. Firenze University Press, pp. 231-234.

Wigmore, J. H. (1926). The Legal Clinic: What It Does for the Law Student. *The ANNALS of the American Academy of Political and Social Science*, *124*(1), 130-135.

Orientare con le discipline STEAM

Orientation with the STEAM education disciplines

Rossana Sicurello*

Riassunto
L'importanza di avere solide conoscenze in ambito tecnologico e scientifico senza dubbio negli ultimi anni è diventata una necessità che tende ad amplificarsi ogni giorno sempre di più. Rispetto a ciò, a livello europeo, è stato promosso l'approccio alle discipline STEM, acronimo di Science, Technology, Engineering, Mathematics. Negli ultimi anni si sono affermate anche le discipline STEAM, acronimo di Science, Technology, Engineering, Art, Mathematics che rappresentano un ampliamento rispetto alle STEM e, al tempo stesso, un completamento. Le discipline STEAM si trovano oggi al centro di un grande dibattito che coinvolge scuole, università e aziende sia per il loro ruolo da protagoniste nell'attuale mercato del lavoro, sia per la capacità di essere motore di cambiamento in un mondo in rapido mutamento. In tal senso, il ruolo dell'orientamento alle discipline STEAM risulta fondamentale.
Parole chiave: orientamento, STEAM, tecnologia, didattica, complessità.

Abstract
The importance of a solid knowledge in the technological and scientific field has undoubtedly become a necessity in recent years that tends to amplify more and more every day. In relation to this, at a European level, the approach to STEM disciplines, an acronym for Science, Technology, Engineering, Mathematics, has been promoted. In recent years, the STEAM disciplines have also established themselves, an acronym for Science, Technology, Engineering, Art, Mathematics which represent an expansion compared to STEM and, at the same time, a completion. STEAM disciplines today find themselves at the center of a great debate involving schools, universities and companies both for their leading role in the current job market and for their ability to be a driver of

* Università degli Studi di Palermo, e-mail: rossana.sicurello@unikore.it.

Excellence and Innovation in Learning and Teaching (ISSNe 2499-507X), 2023, 2

Doi: 10.3280/exioa2-2023oa16824

change in a rapidly changing world. In this sense, the role of orientation towards STEAM disciplines is fundamental.
Keywords: orientation, STEAM, technology, teaching, complexity.

Articolo sottomesso: 27/09/2023; accettato: 15/11/2023
Disponibile online: 13/12/2023

Premessa

Nella società odierna, in cui la tecnologia gioca un ruolo fondamentale in quasi tutti gli ambiti professionali, risulta indispensabile ripensare l'educazione, la formazione e la didattica in un'ottica di preparazione al lavoro; non basta, infatti, conoscere i fondamenti in storia, geografia, scienze, matematica, geometria e algebra, così come non basta conoscere una o più lingue. È di fondamentale importanza allenare al pensiero trasversale, studiare non a compartimenti stagni, bensì fondendo, arricchendo a vicenda costrutti via via sempre più complessi per fare in modo che essi non siano visti da un solo punto di vista. Questo è il principio alla base della STEAM Education, fortemente ancorata alle sfide promosse dall'innovazione didattica learner-centered, riuscendo a stimolare la curiosità, a far emergere i talenti, a promuovere la ricerca in modo da formare e preparare le studentesse e gli studenti al futuro mondo del lavoro, basato non più su una sola competenza ma sulle cosiddette soft skills.

Il contributo intende affrontare l'impatto trasformativo che potrebbe avere l'integrazione offerta dall'applicazione dell'approccio della STEAM Education attraverso un'azione di tipo orientativo che può acquistare un significato nuovo e più completo se a scuola si lavora nell'ottica dello sviluppo dell'identità personale, della conoscenza di se stessi, del proprio modo di operare, dei punti di forza e della proprie debolezze, dell'individuazione degli scopi personali e del modo migliore per raggiungerli, delle capacità di mettere a frutto i successi, della capacità di imparare dalle proprie reazioni agli eventi, qualunque sia il loro esito, in breve, nell'ottica della costruzione di un'immagine di sé come esseri umani, capaci di relazionarsi con se stessi e con gli altri, nonché della capacità di modificarla tramite una riflessione critica sul presente che viene dall'esercizio che si fa della scelta, dalla possibilità che si ha di scegliere e di prendere delle decisioni e di farsi carico anche delle conseguenze. Dunque, è affidato alle istituzioni educative il compito di orientare alle STEAM a cominciare però da un lavoro di decostruzione della percezione che si ha di se stessi. Non si tratta, infatti, di introdurre semplicemente le discipline scientifiche e tecnologiche nella vita delle studentesse e degli studenti ma di fare in modo che essi si pensino in grado di poter contribuire con il loro talento allo sviluppo della scienza e della tecnica e dunque alla società auto-orientando se stessi.

L'orientamento in Italia

Negli ultimi decenni l'orientamento scolastico e professionale ha assunto un ruolo strategico rispetto ad alcune criticità dei sistemi formativi quali la dispersione scolastica, i bassi livelli d'istruzione, il disorientamento educativo, il disallineamento della formazione con il mondo del lavoro (Margottini, 2015), l'incertezza esistenziale generata dalla precarietà del futuro (Toffler, 1971; Bauman, 2000).

L'innovazione profonda che sta interessando il sistema di istruzione e formazione italiano ha coinvolto anche l'orientamento[1] identificato come un vero

[1] Nel panorama delle discipline umanistiche, in particolare, l'antropologia pedagogica entra in campo nell'analisi etimologica del termine "orientamento" offrendo alcuni spunti per identificare anche a livello formativo e professionale tutti quegli elementi che rendono l'orientamento stesso un processo volto a favorire tutte quelle condizioni che mettono la persona, in ogni fase della propria vita, nelle condizioni di identificare le proprie capacità, le proprie competenze e i propri interessi, prendere decisioni in materia di istruzione, formazione e occupazione, nonché di gestire i propri percorsi personali di vita nelle attività formative, professionali e in qualsiasi altro ambiente in cui si acquisiscono e/o sfruttano tali capacità e competenze, ossia di districarsi nelle trame della propria vita verso la direzione più vantaggiosa per sé. In tale direzione, l'azione dell'orientare rappresenta una sfida complessa che racchiude elementi culturali di cambiamento nonché elementi legati alle caratteristiche del territorio e della realtà economica e produttiva, caratterizzandosi come processo prevalentemente formativo, informativo e di counseling e riorientamento. Nello specifico, in riferimento soprattutto a quest'ultima prospettiva, il costrutto di orientamento, in quanto centrale per la costruzione di un welfare inclusivo, è assunto come processo imprescindibile dell'azione educativa rappresentando, nell'attuale società complessa, una categoria fondante del processo educativo stesso (Loiodice, 2012). Si ricordano, in tal direzione, tra le altre, le posizioni di: Pombeni (2007) che definisce l'orientamento come un mezzo per contrastare la dispersione e l'insuccesso formativo; Biagioli (2014) per la quale l'orientamento rappresenta un importante momento di conoscenza del sé e della realtà esterna; Batini (2011; 2015) che considera l'orientamento formativo come un mezzo tramite cui sviluppare le competenze che servono ad auto-orientarsi e ad assumere il controllo della propria vita e delle proprie scelte nelle diverse fasi della vita; Ulivieri e Martini (2015) secondo i quali l'atto dell'orientare può essere identificato con l'atto di educare, richiedendo un fortissimo impegno pedagogico diretto alla realizzazione di un'armonizzazione, per tutti e per ciascuno, tra istruzione ed educazione, tra formazione culturale e formazione professionale, tra potenzialità individuali e funzione sociale; Sibilio (2015)

e proprio processo strutturale, sia nell'ambito di istruzione e formazione (in riferimento alla didattica, alla dimensione orientativa delle singole discipline e al curricolo scolastico), sia nell'ambito lavorativo (in riferimento ai momenti di accompagnamento verso il lavoro e durante il periodo di svolgimento di un lavoro). Dunque sebbene l'orientamento si radichi nei processi formativi, mirando a sostenerli, non si esaurisce in essi, qualificandosi per l'apertura verso il mondo del lavoro, nel quale anzi trova una sua dimensione costitutiva specie a fronte della crescente flessibilizzazione che lo caratterizza. L'orientamento viene cioè considerato come un dispositivo di accompagnamento non solo di percorsi formativi individuali che presentano i caratteri di complessità lungo l'intero arco della vita attiva ma anche di carriere lavorative che si fanno più incerte e discontinue, che contemplano l'alternanza tra lavoro, non lavoro e formazione, nonché delle situazioni di marginalizzazione o disagio che si possono manifestare tanto tra i banchi di scuola quanto nell'accesso al lavoro.

Dal punto di vista formativo e metodologico-didattico, il dibattito sull'orientamento, anche se in forme circoscritte, si sviluppa a partire dagli anni '50 e '60 del secolo scorso, periodo nel quale il nuovo processo di industrializzazione in Italia ha richiesto un ampliamento della scolarità soprattutto di base per rispondere alle emergenti esigenze produttive. L'orientamento si è poi affermato come centrale nell'epoca contemporanea alla luce dei dati (Istat, 2019) sulla percentuale di laureati in età tra i 30 e 34 anni e sull'incidenza dei NEET[2] che dimostrano la difficoltà evidente di raggiungimento degli obiettivi stabiliti per i paesi OCSE, ma ancora di più per l'Italia, nonostante i miglioramenti registrati negli ultimi anni. Oggi sono numerosi i Rapporti, le ricerche e le indagini nazionali e internazionali (Istat, 2019; OECD, 2016, 2018, 2017) che rilevano l'influenza esercitata da alcuni fattori, quali i contesti territoriali, dalle condizioni sociali e culturali di appartenenza, dalle differenze di genere, etc., sulle scelte dei percorsi scolastici al termine della scuola secondaria di primo grado che condizionano, di riflesso, le capacità decisionali degli studenti e delle studentesse riguardo la scelta dei percorsi universitari da intraprendere al termine della scuola secondaria di secondo grado e/o la scelta e l'accesso alle professioni e al mondo del lavoro.

---

per il quale l'orientamento viene visto come sviluppo di capacità decisionali da parte dei giovani all'interno di un contesto in mutamento, quindi, quale processo educativo permanente e trasversale che investe la persona nella sua globalità e che percorre tutti gli ordini e i gradi di scuola e tutte le discipline.

[2] NEET (Not (engaged) in Education, Employment or Training). Indicatore atto ad individuare la quota di popolazione di età compresa tra i 15 e i 29 anni che non è né occupata né inserita in un percorso di istruzione o di formazione.

In un contesto economico attraversato da un cambiamento rapido e persistente dovuto essenzialmente all'introduzione delle nuove tecnologie dell'informazione e della comunicazione e alla globalizzazione dei mercati ed in cui le persone sono chiamate a cambiare con più frequenza tipologie e modalità di lavoro, luoghi e tempi di lavoro ed il mercato del lavoro è diventato altamente competitivo, la scuola ha via via assunto il compito di rispondere alla complessità sociale ed educativa con la messa in atto di processi di orientamento specifici di tipo informativo, formativo e di consulenza personale. Superata la fase storica che ha portato a confinare l'orientamento ad azione prevalentemente psicologica o informativa, nel corso degli anni si è, dunque, consolidata la necessità di sviluppo di un'azione orientativa di tipo multifattoriale, multidimensionale, multi-componenziale (Domenici, 2015; Marone, 2002).

Da quando si è passati, in particolare con il Congresso Internazionale dell'Unesco che si è tenuto a Bratislava nel 1970 sui temi dell'orientamento e dell'educazione permanente, da una concezione dell'orientamento quale intervento sporadico e a richiesta ad una visione dello stesso quale insieme di azioni da portare direttamente nei luoghi deputati alla formazione dei soggetti in età evolutiva, l'orientamento viene abitualmente inserito tra le attività cui gli studenti partecipano all'interno di una programmazione scolastica sempre più attenta non solo a trasferire conoscenze (Trovesi, 2007) e a far sviluppare abilità e competenze (Soresi et al., 2004; Rubie-Davies, 2006) ma anche a fornire gli strumenti necessari a far fronte alle fasi di transizione scuola-scuola e a prendere decisioni in campo scolastico, formativo e professionale (Sartori, 2010; Sartori & Rappagliosi, 2012; Sartori & Ceschi, 2013). Tale visione, influenzata dall'affermarsi sulla scena internazionale dell'idea di "educazione permanente" (Lengrand, 1970), privilegia, tra gli anni '60 e gli anni '70, la piena realizzazione di un individuo capace di prendere coscienza di sé e consapevolezza del contesto a cui appartiene, nonché delle concrete possibilità e dei vincoli provenienti dall'esterno, dei limiti e delle risorse individuali valutati con senso critico e costruttivo. Si sviluppa, quindi, un'idea attiva, dinamica e permanente di orientamento, secondo cui quest'ultimo non costituisce un atto episodico, bensì un continuum che, attraverso interventi di tipo "diacronico-formativo" (Domenici, 2015), si prolunga in tutto l'arco della vita, tenendo conto, come si legge già negli scritti del promotore dell'orientamento in Italia, "da un lato delle mutevoli esigenze sociali, dall'altro dell'adattabilità della vita umana alle varie condizioni di ambiente" (Gemelli, 1947, p. 10) con il duplice scopo di contribuire al progresso della società e di conseguire il pieno sviluppo della persona umana.

Non è un caso che l'orientamento rappresenti ormai una delle questioni tematiche al centro delle politiche educative dell'UE e della quasi totalità dei paesi tecnologicamente avanzati (Domenici, 2015). Molteplici e diverse sono le tipologie, le metodologie e le organizzazioni che concorrono alla realizzazione delle azioni di orientamento secondo delle strategie di sistema: avendo al centro dell'attenzione la persona che, in più e in diversi momenti della vita, è chiamata a compiere scelte importanti per il proprio futuro formativo e professionale, i differenti enti e le differenti istituzioni coinvolte nel processo di orientamento sono chiamati alla unitarietà e all'integrazione degli interventi, se pur utilizzando materiali e strumenti specializzati. Le azioni di orientamento hanno lo scopo di: a) fornire una corretta ed esaustiva informazione riguardo ai possibili percorsi scolastici e professionali (orientamento in entrata e in uscita; b) favorire nei giovani la scoperta delle proprie attitudini, dei propri talenti e dei propri interessi personali, creando, nello stesso tempo, le condizioni affinché il giovane possa individuare quei riferimenti che gli consentiranno una scelta consapevole e responsabile sia per la prosecuzione degli studi, che per l'inserimento nel mondo del lavoro (orientamento in itinere); c) predisporre adeguati strumenti informativi/formativi per le famiglie; d) organizzare interventi ad hoc per le categorie sociali più deboli quali disabili, giovani con background migratorio, giovani che vivono situazioni familiari e sociali a rischio, etc.); e) attuare azioni di sostegno per giovani che hanno abbandonato la scuola o che manifestano fragilità in tale direzione.

Così definite, le azioni di orientamento assumono una rilevanza fondamentale sia nelle discipline di insegnamento delle quali viene sottolineato soprattutto il valore orientativo laddove risultano finalizzate a rilevare le propensioni e le aspettative degli alunni, verificarne anche i risultati, monitorare in corso d'opera quali sono i settori del sapere in cui le prestazioni degli studenti raggiungono un livello soddisfacente e dove invece incontrano delle difficoltà, sia in alcuni dispositivi didattici come i PCTO (ex Alternanza Scuola-Lavoro) che le istituzioni scolastiche promuovono per sviluppare le competenze trasversali, esaltando nello stesso tempo la valenza formativa dell'orientamento in itinere, laddove pongono gli studenti e le studentesse nella condizione di maturare un atteggiamento di graduale e sempre maggiore consapevolezza delle proprie vocazioni, in funzione del contesto di riferimento e della realizzazione del proprio progetto personale e sociale, in una logica centrata sull'auto-orientamento. A questo punto della trattazione, l'interrogativo che ci si pone è il seguente: quali sono stati i passi compiuti in tale direzione dai decisori politici, dai sistemi formativi, dalle parti sociali e dal mondo del lavoro per affrontare congiuntamente e in modo integrato la questione relativa all'orientamento?

L'urgenza di riflettere sul valore educativo dell'orientamento, derivata dalla consapevolezza delle difficoltà di progettazione esistenziale nella società postmoderna, caratterizzata dal rischio e dall'incertezza del futuro, dalla maggiore imprevedibilità dei percorsi individuali e della instabilità di punti di riferimento quali valori, tradizioni, istituzioni che un tempo orientavano la vita delle persone, ha spinto la scuola ad elaborare strumenti e dispositivi finalizzati all'acquisizione della consapevolezza relativamente alle proprie risorse e alla propria progettualità al fine di aiutare la persona a realizzarsi in campo lavorativo e sociale. In tale direzione, l'emanazione del Decreto Ministeriale n. 328 del 2022 da parte del Ministero dell'Istruzione e del Merito contenente le nuove Linee Guida per l'orientamento in accordo con la "Riforma del sistema di orientamento", nell'ambito della Missione 4 – Componente 1 – del Piano Nazionale di Ripresa e Resilienza, finanziato dall'Unione Europea – Next Generation EU, rappresenta un atto normativo rilevante cui prestare necessariamente attenzione.

In primo luogo, le suddette Linee Guida sottolineano la necessità di superare un approccio frammentario all'orientamento, definito come

> un processo volto a facilitare la conoscenza di sé, del contesto formativo, occupazionale, sociale culturale ed economico di riferimento, delle strategie messe in atto per relazionarsi ed interagire in tali realtà, al fine di favorire la maturazione e lo sviluppo delle competenze necessarie per poter definire o ridefinire autonomamente obiettivi personali e professionali aderenti al contesto, elaborare o rielaborare un progetto di vita e sostenere le scelte relative.

Ne deriva un ruolo educativo, formativo e pedagogico preciso svolto dall'orientamento, in quanto attiene alla dimensione della crescita, nonché dell'accompagnamento dei processi di formazione e apprendimento nei contesti nei quali essi avvengono, necessario per sostenere la fiducia, l'autostima, l'impegno, le motivazioni, e per riconoscere talenti e attitudini, il potenziale personale esercitando la capacità di scegliere in autonomia senza trascurare la possibilità di coltivare direzioni di crescita inedite o non convenzionali da parte di alunni e alunne, studenti e studentesse. Nel contesto educativo attuale, quindi, il processo orientativo assume una intenzionalità pedagogica più esplicita poiché basato sul contributo che l'educazione può dare nello sviluppo della consapevolezza di sé, dei propri limiti e delle proprie risorse.

Le discipline STEAM

Gli ultimi decenni sono stati caratterizzati da grandi mutamenti nelle economie dei maggiori paesi industrializzati, con ripercussioni anche nell'economia di paesi meno sviluppati. Il XXI secolo è stato testimone di innovazioni tecnologiche e scientifiche che hanno avuto un impatto su quasi tutti i settori delle istituzioni sociali, contribuendo a caratterizzare lo stile di vita dei cittadini del mondo[3]. Per competere nell'economia globale presente e futura è essenziale, per qualsiasi nazione, sviluppare una forza lavoro istruita ed esperta nelle aree scientifico-tecnologiche. Con le tecnologie che permeano quasi ogni aspetto della quotidianità, dal tempo libero, all'istruzione, al mondo del lavoro, essere in possesso degli strumenti cognitivi per padroneggiarle è fondamentale. L'acronimo STEM, dall'inglese Science, Technology, Engineering, Mathematics, viene introdotto per la prima volta negli Stati Uniti, agli inizi degli anni Duemila, per identificare un gruppo di discipline scientifiche ritenute necessarie per incrementare l'innovazione e la prosperità dei Paesi. L'acronimo STEM si diffonde poi a partire da una conferenza della National Science Foundation (NSF)[4] sia in ambito scolastico che universitario, con la finalità di preparare le studentesse e gli studenti, adeguandone la formazione ad un mercato del lavoro in forte cambiamento già a partire dall'anno Duemila in un mondo ormai globalizzato e interconnesso. Risulta fondamentale, quindi, che tutte le studentesse e tutti gli studenti siano alfabetizzati nelle discipline STEM per avere l'opportunità di apprendere le conoscenze e le abilità di cui avranno bisogno in un futuro già tecnologicamente orientato.

Negli ultimi anni si sono affermate anche le discipline STEAM, acronimo anglosassone di Science, Technology, Engineering, Art, Mathematics che rappresentano un ampliamento rispetto alle STEM e, al tempo stesso, un completamento perché tengono in considerazioni le inserzioni delle scienze con le altre discipline umanistiche e artistiche. Si possono, infatti, sfruttare delle competenze che, sebbene essenziali in realtà in ogni singola disciplina, – si pensi ad esempio a creatività, collaborazione, comunicazione – vengono più facilmente ed estesamente apprese e potenziate in discipline umanistiche e artistiche.

In Italia il Ministero dell'istruzione con il Decreto Ministeriale 30 aprile 2021, n. 147, ha offerto, nell'ambito del Piano Nazionale Scuola Digitale, la possibilità per le istituzioni scolastiche di accedere ai fondi utili per l'acquisto di materiali finalizzati all'educazione alle discipline STEM, a partire dalla scuola dell'infanzia e fino alla scuola secondaria di secondo grado, rimarcando un'attenzione particolareggiata verso l'alfabetizzazione nelle discipline STEM per la loro spiccata valenza educativa. In attuazione dell'articolo 3 del Decreto del Ministro dell'Istruzione 30 aprile 2021, n. 147, l'Avviso MI del 19 maggio 2021 intende promuovere l'adozione delle metodologie didattiche innovative

[3] Si pensi all'influenza nella vita quotidiana da parte degli strumenti informatici (dal telefonino, al tablet, al computer) e della comunicazione mediata attraverso i social network. Si veda in proposito Cantelmi (2013), Carletti &Varani (2007), Rivoltella (2006).

[4] Agenzia governativa degli Stati Uniti d'America che si occupa di ricerca e formazione di base in tutti i campi scientifici non medici.

da parte delle scuole, con particolare riferimento alla didattica digitale e alle discipline STEAM (Scienze, Tecnologia, Ingegneria, Arti e Matematica), ispirate al protagonismo degli studenti, all'apprendimento attivo e cooperativo, al benessere relazionale, in coerenza con l'ambito "Competenze e Contenuti" del Piano Nazionale per la Scuola Digitale.

Nell'ambito dei processi di apprendimento connessi con l'educazione alle discipline STEM/STEAM vengono sviluppate competenze trasversali o soft skills oggi fondamentali come il pensiero analitico, il problem solving, il team working, il critical thinking[5] o pensiero critico, communication o comunicazione[6], collaboration o collaborare con gli altri[7], creativity o creatività[8], alfabetizzazione informatica, mediatica e tecnologica, leadership, senso di responsabilità individuale e di gruppo, che possono garantire un pieno sviluppo della personalità nella vita sociale e lavorativa in senso ampio.

Si tratta di competenze per la vita, molte delle quali sono riconducibili alle competenze chiave europee aggiornate il 22 maggio 2018 contenute nelle Raccomandazioni del Parlamento e del Consiglio europeo in cui si parla di competenza matematica, competenza in scienze, tecnologie e ingegneria e competenza digitale, trasformando lo spirito di iniziativa in una più articolata competenza imprenditoriale e le competenze sociali e civiche nella competenza di cittadinanza.

---

[5] Per critical thinking si intende l'analisi di un problema (o di una situazione) e dei fatti, delle prove e delle evidenze a esso collegato: un'analisi oggettiva e obiettiva, scevra da opinioni e distorsioni emozionali. In questo senso, le discipline STEM permettono agli studenti di sviluppare numerose skills funzionali all'esercizio del pensiero critico, come la capacità di osservazione e di analisi, il problem solving e l'abilità di praticare inferenze corrette.

[6] Per communication si intende non solo la predisposizione al dialogo e all'ascolto dell'altro, ma anche la capacità di adattare il proprio linguaggio ai diversi media utilizzati e all'abilità di trasmettere le proprie idee e i propri processi decisionali quando si comunica con i membri di un team. A questo proposito, un approccio STEM incentrato sull'applicazione e sulla pratica può aiutare gli studenti a cimentarsi in project work di gruppo sfidante in cui mettere alla prova le proprie abilità comunicative.

[7] Per collaboration si intende il lavorare con gli altri in modo armonico, aiutandosi l'un l'altro, dividendo i compiti e le scadenze in maniera equa e in base alle proprie attitudini e capacità. Anche in questo caso, le discipline STEM possono aiutare i più piccoli, fin dalla scuola primaria, a impegnarsi in un obiettivo che sia collaborativo e non competitivo, in cui lo sforzo di ciascuno può portare al raggiungimento di un traguardo comune.

[8] Il pensiero creativo è la capacità di pensare fuori dagli schemi, trovando soluzioni innovative ai problemi.

È possibile individuare moltissime ragioni per cui le competenze promosse dalle discipline STEM/STEAM sono considerate un elemento chiave dello sviluppo delle società in Europa, come è stato sancito dal rapporto della Commissione europea Science Education for Responsible Citizenship, pubblicato nel 2015. Secondo tale rapporto è fondamentale per la crescita delle società:

- promuovere una cultura del pensiero scientifico e ispirare i cittadini a usare un ragionamento basato su prove per prendere decisioni;
- assicurare che i cittadini abbiano la fiducia, le conoscenze e le abilità per partecipare attivamente in un mondo scientifico e tecnologico sempre più complesso;
- sviluppare le competenze necessarie per accogliere l'innovazione nei diversi settori, sviluppando un pensiero critico e analitico, per consentire ai cittadini di condurre una vita soddisfacente, socialmente responsabile e professionalmente impegnata;
- ispirare i bambini e gli studenti di ogni età e talento ad aspirare a carriere scientifiche, in ambiti professionali ed economie ad alta intensità di innovazione che sono alla base delle nostre società, in cui possano essere creativi e realizzati;
- permettere alle organizzazioni pubbliche, private e del Terzo settore, con sede in Europa, di trovare persone adeguatamente qualificate e competenti e di promuovere e alimentare un ambiente innovativo in tutta Europa, dove le aziende e gli altri stakeholder di tutto il mondo vogliono investire, lavorare e vivere.

Partendo da queste considerazioni, si può comprendere quanto sia importante fare sviluppare precocemente competenze che permettono di affrontare la vita nella società complessa attuale (Baumann, 2011; Appadurai, 2014). Per avere successo nell'economia mondiale in evoluzione e garantire un'occupazione significativa, l'alfabetizzazione e l'educazione STEAM sono considerate dunque una priorità educativa. Per questi motivi si ritiene che l'educazione alle discipline STEAM dovrebbe rivestire una parte importante nell'ambito dello sviluppo olistico della personalità fin dalla prima infanzia (Rosati, 2021).

Quale orientamento per le discipline STEAM?

Le esperienze formative in ambito scolastico risultano centrali per l'acquisizione delle competenze intrapersonali ed interpersonali necessarie a orientare le scelte nei percorsi di vita e ad affrontare incertezze e difficoltà del presente. In tale direzione, tra le più importanti novità introdotte dalle Linee Guida per l'orientamento nella scuola secondaria di cui sopra rientra l'introduzione a partire dall'anno scolastico 2023-2024 dei moduli di 30 ore annuali specifici sull'orientamento nella scuola secondaria di primo e di secondo grado come di seguito specificato: moduli di orientamento formativo, di almeno 30 ore, anche extra curricolari, per anno scolastico, nelle classi prime e seconde e moduli curriculari di orientamento formativo, di almeno 30 ore per anno scolastico, nelle classi terze, quarte e quinte. I suddetti moduli annuali curricolari o extracurricolari per l'orientamento non vanno intesi come il contenitore di una nuova disciplina ma costituiscono uno strumento per aiutare le studentesse e gli studenti a riflettere criticamente in modo inter/intradisciplinare sulla propria esperienza scolastica e formativa in vista della costruzione in itinere del proprio personale progetto di vita culturale e professionale, sottolineando in questo modo il ruolo attivo che le stesse e gli stessi dovrebbero avere quando riflettono sulle proprie attitudini, capacità limiti ed esperienze tramite prospettive di piena personalizzazione del percorso formativo. I moduli di 30 ore annuali potranno essere realizzati tenendo conto degli spazi di flessibilità garantiti alle istituzioni scolastiche nell'ambito dell'autonomia; nello specifico, le scuole potranno prevedere nei rispettivi PTOF lo svolgimento di moduli in parte o del tutto come curricolari o extracurricolari non necessariamente ripartite in ore settimanali prestabilite da articolare al fine di realizzare attività per gruppi proporzionati nel numero di studenti, distribuite nel corso dell'anno, secondo un calendario progettato e condiviso tra studenti e docenti coinvolti nel complessivo quadro organizzativo di scuola.

In questa articolazione si possono anche collocare, a titolo esemplificativo, tutti quei laboratori che nascono dall'incontro tra studenti di un ciclo inferiore e superiore per esperienze di peer tutoring, tra docenti del ciclo superiore e studenti del ciclo inferiore, per sperimentare attività di vario tipo, riconducibili alla didattica orientativa e laboratoriale, comprese le iniziative di orientamento nella transizione tra istruzione e formazione secondaria e terziaria e lavoro, laboratori di prodotto e di processo, presentazione di dati sul mercato del lavoro. La progettazione didattica dei moduli di orientamento e la loro erogazione si realizzano anche attraverso collaborazioni che valorizzino l'orientamento come processo condiviso, reticolare, co-progettato con il territorio, con le scuole e le agenzie formative dei successivi gradi di istruzione e formazione, con gli ITS Academy, le università, le istituzioni dell'alta formazione artistica, musicale e coreutica, il mercato del lavoro e le imprese, i servizi di orientamento promossi dagli enti locali e dalle regioni, i centri per l'impiego e tutti i servizi attivi sul territorio per accompagnare la transizione verso l'età adulta. I moduli di orientamento saranno oggetto di apposito monitoraggio tramite il sistema informativo del Ministero dell'Istruzione e del Merito, nonché documentati nell'e-portfolio che rappresenta in assoluto uno strumento per sviluppare competenze trasversali che rimandano alla concezione di un "soggetto in situazione", chiamato a riflettere su di sé e nel contempo a confrontarsi con la realtà esterna, con i vincoli e le opportunità che essa pone, autodeterminandosi.

Nelle Linee Guida viene precisato che l'orientamento riveste un ruolo fondamentale anche nell'ambito delle riforme del PNRR, con la promozione dell'integrazione, all'interno dei curricula di tutti i cicli scolastici, di attività, metodologie e contenuti volti a sviluppare le competenze STEM, digitali e di innovazione. La misura si rivolge in particolare alle studentesse e prevede un approccio interdisciplinare. L'intervento mira, inoltre, a garantire pari opportunità e la parità di genere in termini di approccio metodologico e di attività di orientamento STEM.

Nella riforma dell'orientamento sono direttamente coinvolti non solo il Ministero dell'Istruzione e del Merito ma anche il Ministero dell'Università e della Ricerca, in particolare per ciò che concerne l'attivazione, nell'ambito del PNRR, della specifica linea di investimento 1.6 "Orientamento attivo nella transizione scuola-università", che consente a tutte le scuole secondarie di secondo grado di poter realizzare percorsi di orientamento di 15 ore ciascuno nelle classi terze, quarte e quinte, promossi dalle università e dagli AFAM, tramite sottoscrizione di specifici accordi.

Nello specifico, la nota del 3 marzo 2023, n. 937, Interventi per l'orientamento nell'ambito del PNRR, riepiloga le misure e fornisce indicazioni sulla gestione delle attività, evidenziando come le due misure (moduli di 30 ore e moduli di 15 ore) possano essere organizzate in sinergia. Viene precisato che i corsi di 15 ore organizzati dalle Università "possono costituire una utile occasione per realizzare qualificate attività formative da integrare nelle suddette 30 ore di orientamento curriculare previste dalla Linee guida". Viene ribadito, altresì, che

> La possibilità, da parte delle istituzioni scolastiche autonome, di gestire i percorsi di 15 ore in forma flessibile (ovverosia inserendoli nelle attività curriculari o extracurriculari) consentirà di realizzare una proficua sinergia tra le iniziative proposte dalle Università e le Istituzioni AFAM con le altre iniziative da realizzare nelle ore residue, valorizzando l'orientamento come processo condiviso, reticolare e co-progettato con una pluralità di attori, permettendo di articolare le attività per gruppi proporzionati nel numero di studenti, individualizzando ed ottimizzando gli interventi, al fine di accompagnare la transizione verso il proseguimento degli studi nella formazione superiore.

L'autonomia didattica ed organizzativa potrà consentire di regolare i tempi dell'insegnamento e dello svolgimento delle attività secondo una programmazione oraria che possa adeguarsi nel modo maggiormente rispondente alle diverse circostanze. Infine, la nota evidenzia come

Ulteriore elemento di raccordo e convergenza tra le misure previste nel PNRR di competenza dei due Dicasteri, che le Linee guida per l'orientamento, con l'intento di migliorare l'efficacia dei percorsi orientativi negli ultimi tre anni della scuola secondaria di secondo grado, prevedono l'integrazione dei moduli curriculari di orientamento formativo con i percorsi per le competenze trasversali e l'orientamento (PCTO), i quali, frequentemente, sono realizzati anche in collaborazione con le Università e le Istituzioni AFAM.

Tali percorsi da erogare con modalità curricolare o extracurricolare, sono organizzati dalle Istituzioni universitarie, sulla base di specifici accordi da sottoscrivere con gli Istituti scolastici con l'obiettivo di consentire agli studenti di:

a) conoscere il contesto della formazione superiore e del suo valore in una società della conoscenza, informarsi sulle diverse proposte formative quali opportunità per la crescita personale e la realizzazione di società sostenibili e inclusive; b) fare esperienza di didattica disciplinare attiva, partecipativa e laboratoriale, orientata dalla metodologia di apprendimento del metodo scientifico; c) autovalutare, verificare e consolidare le proprie conoscenze per ridurre il divario tra quelle possedute e quelle richieste per il percorso di studio di interesse; d) consolidare competenze riflessive e trasversali per la costruzione del progetto di sviluppo formativo e professionale; e) conoscere i settori del lavoro, gli sbocchi occupazionali possibili nonché i lavori futuri sostenibili e inclusivi e il collegamento fra questi e le conoscenze e competenze acquisite (D.M. n. 934/2022).

Risulta evidente, dunque, la necessità da parte della scuola e delle Università di rispondere adeguatamente alle sfide imposte dalla veloce evoluzione della tecnologia, dagli obiettivi delle aziende collegate ad un mercato che richiede professionalità con competenze scientifiche, tecnologiche, ingegneristiche e matematiche, che al momento scarseggiano anche con azioni di orientamento mirate a tali direzioni.

Quali interventi per orientare alle discipline STEAM?

Lo studio delle discipline STEAM offre opportunità senza precedenti per lo sviluppo personale e professionale. Promuovere e sostenere le discipline STEAM è fondamentale per il progresso della società, l'innovazione tecnologica e la crescita economica. Inoltre, incoraggiare le studentesse e gli studenti a perseguire carriere nei settori delle STEAM, anche attraverso specifici percorsi di orientamento, può contribuire a creare una società più equa, inclusiva e avanzata. Investire sulle STEAM non significa, quindi, solo valorizzare l'importanza di queste discipline in senso tradizionale; piuttosto, vuol dire soprattutto avvalersi di un metodo di insegnamento nuovo, in grado di affiancarsi alle classiche lezioni frontali, con un approccio laboratoriale e cooperativo, integrando sempre di più il contributo offerto dalle discipline scientifiche con quello delle discipline umanistiche, adottando interventi basati su:

- educazione inclusiva, basata su un accesso equo a programmi educativi STEAM per tutte le studentesse e tutti gli studenti, indipendentemente dal genere, dall'etnia o dal background socio-economico di provenienza;
- attività extracurricolari, con opportunità di partecipazione a club o programmi extracurricolari che coinvolgano le studentesse e gli studenti in attività STEAM coinvolgenti e motivanti a carattere laboratoriale e con l'uso di metodologie appositamente pensate per l'insegnamento delle STEAM – tra cui l'IBL (Inquiry-Based Learning)[9], basato sulle 5E[10];
- mentoring e modelli di ruolo, con professionisti e mentori STEAM impiegati nell'ambito dei percorsi di orientamento curriculare ed extracurricolare per ispirare e guidare le studentesse e gli studenti nelle suddette discipline, mostrando loro le applicazioni reali e le sfide affrontate nel mondo reale.

Riflessioni conclusive

Di fronte agli evidenti cambiamenti che hanno interessato il mondo del lavoro è fondamentale porre attenzione alle competenze che la persona deve sviluppare al fine di adattarsi alle rapide e continue trasformazioni del lavoro e

[9] L'IBL è un apprendimento basato sull'indagine: durante le loro "inquiry", ossia ricerche, le studentesse e gli studenti possono scegliere e delimitare il loro campo d'indagine e la loro domanda di ricerca, a seconda della situazione. Si distinguono quattro tipi di indagine che possono essere condotte in classe: 1. inquiry confermativa: l'oggetto dell'indagine è già stato esplorato in ogni sua caratteristica e quindi si cerca una conferma su un aspetto indagato ulteriormente; 2. inquiry strutturata: indagine su un problema conosciuto parzialmente dagli studenti; in questo caso l'insegnante dovrà dunque suggerire un procedimento adatto per arrivare alle conclusioni corrette; 3. inquiry aperta: gli studenti scelgono sia il problema che il metodo di indagine, a prescindere dai dettami della tradizione; 4. inquiry guidata e/o esplorativa: indagine su un problema totalmente nuovo per gli studenti che sono accompagnati da un docente che svolga il ruolo di tutor.

[10] L'insegnante che adotta il metodo IBL può avvalersi anche del "Learning cycle delle 5E". Le 5E sono le fasi in cui si scandisce l'indagine, vale a dire: engage; explore; explain; elaborate; evaluate. Ogni fase corrisponde allo sviluppo di una competenza necessaria per andare avanti.

delle professioni ed adeguarsi ai mutamenti sociali e ai cambiamenti dei contesti relazionali. La complessità, la fluidità e la rapidità che caratterizzano la società post-moderna, hanno ridefinito la finalità della scuola che ora diviene quella di educare/formare gli studenti a risolvere problemi, trovare soluzioni meditate e responsabili, autonome e flessibili attraverso la ricerca di strumenti e metodi specifici di ogni disciplina sempre più realistici e resilienti in relazione al loro futuro e alle richieste del mondo lavorativo. Ciò implica la revisione di nuovi percorsi di istruzione-formazione per tutto l'arco della vita e la promozione di competenze trasversali, un livello di istruzione più elevato e competitivo, una formazione responsabile e globale del cittadino. In tal senso, qualsiasi percorso formativo, pur modellandosi durante l'intero corso della vita dell'individuo, acquista la giusta rilevanza solo in rapporto alle personali capacità di evolversi ed allinearsi ai mutamenti repentini e imprevedibili dell'intero pianeta ed in grado di progettare e dirigere lo sviluppo socio-economico, di prendere decisioni secondo principi quali l'inclusività, l'auto-orientamento e l'auto-apprendimento. In tale ottica, l'orientamento si inserisce nel processo formativo con la funzione di guidare ed accompagnare la persona alla "scelta", rappresentando un mezzo per conoscere opportunità, l'ambiente in cui si vive e le prospettive di lavoro che questo offre.

L'attività di orientamento, quale parte integrante del curriculo di studio, contempla sia l'osservazione di realtà disparate e interpretate da diversi punti di vista, sia una incessante e sistematica sinergia di azioni tra istituzioni scolastiche e territorio per assicurare un tipo di intervento non solo a carattere puramente informativo ma indirizzato ad un processo di crescita integrale, permanente e globale della persona come sottolineato dalle Linee Guida per l'orientamento ove si sottolinea che il sistema dell'istruzione e della formazione è impegnato a dare risposte soddisfacenti a bisogni orientativi specifici della fase di vita in cui l'esperienza dominante per la persona è quella legata all'apprendimento. L'orientamento infatti deve aiutare le persone a sviluppare la propria identità, a prendere decisioni sulla propria vita personale e professionale e, successivamente, a facilitare l'incontro tra la domanda e l'offerta di lavoro. Orientare con le discipline STEAM significa aiutare le studentesse e gli studenti a costruire un "nuovo" progetto di vita – prima ancora che scolastico e professionale – basato sui bisogni delle studentesse e degli studenti che sono sì individuali, ma anche correlati ai reali contesti sociali ed economici in continuo mutamento e che potrà arricchirsi nel tempo attingendo a situazioni e lavori non ancora immaginati. Un approccio didattico-orientativo basato sulle STEAM, pertanto, costituisce un valido anello di congiunzione tra i saperi scientifici e quelli umanistici, aperto all'extra-scuola e al territorio nella sua complessità e nei suoi molteplici aspetti che potrebbe potenziare le diverse abilità dell'allievo e la sua resilienza individuale per saper affrontare e collocare temi e problemi nei contesti di quotidianità.

Riferimenti normativi

DECRETO DEL MINISTRO DELL'ISTRUZIONE E DEL MERITO 22 dicembre 2022, n. 328, concernente l'adozione delle Linee guida per l'orientamento, relative alla riforma 1.4 "Riforma del sistema di orientamento", nell'ambito della Missione 4 - Componente 1- del Piano nazionale di ripresa e resilienza.

DECRETO MINISTERIALE 3 agosto 2022, n. 934, Criteri di riparto delle risorse e modalità di attuazione dei progetti relativi al "Orientamento attivo nella transizione scuola-università" nell'ambito del PNRR (M4.C1-24)

DECRETO MINISTERIALE 30 aprile 2021, n. 147, Decreto di riparto delle risorse per il Piano nazionale per la scuola digitale per l'anno 2021.

NOTA MINISTERIALE 3 marzo 2023, n. 937Interventi per l'orientamento nell'ambito del PNRR.

AVVISO MINISTERIALE 19 maggio 2021, AOODGEFID 12181, Avviso pubblico per la raccolta di manifestazioni di interesse per progetti di sperimentazione di metodologie didattiche innovative nell'ambito delle STEAM con l'utilizzo delle tecnologie digitali.

Riferimenti bibliografici

Appadurai, A. (2014). *Il futuro come fatto culturale. Saggi sulla condizione globale.* Raffaello Cortina.

Batini, F. (2011). *Storie, futuro e controllo. Le narrazioni come strumento di costruzione del futuro.* Liguori.

Batini, F. (2015). Costruire futuro a scuola. Che cos'è, come e perché fare orientamento nel sistema di istruzione. *I Quaderni della Ricerca, 24*, Loescher.

Bauman, Z. (2011). *Culture in a Liquid Modern World.* Malden-MA, Polity.

Bauman, Z. (2000). *Modernità liquida.* Laterza

Biagioli, R. (2014). La formazione orientativa. *Studium Educationis*, *2*, pp. 39-50.

Cantelmi, T. (2013). *Tecnoliquidità. La psicologia ai tempi di internet.* San Paolo.

Carletti, A., Varani, A. (a cura di) (2007). *Ambienti di apprendimento e nuove tecnologie.* Erickson.

Rivoltella, P. C. (2006). *Screen generation. Gli adolescenti e le prospettive dell'educazione nell'età dei media digitali.* Vita e pensiero.

Domenici, G. (2015). *Manuale dell'orientamento e della didattica modulare.* Laterza.

Gemelli, A. (1947). *L'orientamento professionale dei giovani nelle scuole.* Vita e Pensiero.

Istat (2019). *Livelli di istruzione e ritorni occupazionali.* Estratto da: https://www.istat.it/it/files//2019/07/Report-Livelli-di-istruzione-e-ritorni-occupazionali_2018.pdf.

Lengrand, P. (1970). *Introduction à l'éducation permanente.* Paris: UNESCO.

Loiodice, I. (2012). Orientamento come educazione alla transizione. Per non farsi "schiacciare" dal cambiamento. *MeTis. Mondi educativi. Temi, indagini, suggestioni*, 2(*1)*. Estratto da: http://www.metisjournal.it/metis/anno-ii-numero-1-giugno-2012-orientamenti-temi/37-saggi/224-orientamento-come-educazione-alla-transizione-per-non-farsi-schiacciare-dal-cambiamento.html.

Margottini M. (2015). L'orientamento a livello universitario. *Orientamenti pedagogici*, 62(3), pp. 531-545.

Marone, F. (2002). Orientamento come narrazione. In E. Frauenfelder & V. Sarracino (a cura di), *L'orientamento. Questioni pedagogiche* (pp. 75-95). Liguori.

OECD (2018), Equity in Education: Breaking Down Barriers to Social Mobility, PISA, OECD Publishing, Paris. Estratto da: https://doi.org/10.1787/9789264073234-en.

OECD (2017). Youth Aspirations and the Reality of Jobs in Developing Countries: Mind the Gap, Development Centre Studies, OECD Publishing, Paris. Estratto da: https://doi.org/10.1787/9789264285668-en.

OECD (2016). Education at a Glance 2016: OECD Indicators, OECD Publishing, Paris. Estratto da: http://dx.doi.org/10.187/eag-2016-en.

Pombeni, M.L. (2007). *Metodologie per lo sviluppo delle competenze orientative. Il contributo della scuola nel processo di orientamento.* Intervento al convegno Tavolo per l'orientamento, Tione (Trento).

Rosati, N. (2021). L'educazione STEM al nido: una sfida possibile. *IUL Research, Open Journal of IUL University*, *2*(4), pp. 188-207.

Rubie-Davies, C.M. (2006), Teacher expectations and student self-perceptions: Exploring relationships. *Psychology in the Schools, 43*(5), pp. 537-552.

Sartori, R. (2010), Stage e tirocinio tra orientamento e formazione: il caso di alcune laureate in discipline umanistiche di Verona e Provincia. *Giornale Italiano di Psicologia dell'Orientamento*, *11*, pp. 23-33.

Sartori, R., Rappagliosi, C.M. (2012). *Orientamento, formazione e lavoro: dalla psicologia alle organizzazioni*. LED.

Sibilio, M. (2015). La funzione orientativa della didattica semplessa. *Pedagogia Oggi*, *1*, pp. 327-334.

Soresi, S., Nota, L. & Ferrari, L. (2004), Autodeterminazione e scelte scolastiche professionali: uno strumento per l'assesment, *Giornale Italiano di Psicologia dell'Orientamento*, 5, pp. 26-42.

Toffler, A. (1971). *Lo choc del futuro*. Rizzoli.

Trovesi, G. C. (2007). *Leggere, scrivere, far di conto. Superare i problemi di apprendimento con la musica*. Armando Editore.

Ulivieri, S., & Martini, B. (2015). Orientare è educare. *Pedagogia Oggi*, *1*, pp. 7-9.

Inquiry Based Learning in practice to enhance an Immunological Biotechnologies laboratory experience

Regina Tavano[*], Federica Picasso[°], Antonella Lotti[^]

Abstract
This paper aims to describe a teaching redesign experience that took place through the introduction of the Inquiry Based Learning methodology within the course of Immunological Biotechnology included in the program of the Master's Degree in Industrial Biotechnologies at the University of Padua. The decision to introduce this approach starts from the need to maximise and support students during the learning experience, to sustain the development of specific skills related to real-world laboratory research environments, making them more aware of the design and practical steps of the laboratory itself. The new design (and its implementation) has both enhanced student learning and improved satisfaction with the teaching. The feedback from the students also allowed us to acquire important information to work further on teaching and create more authentic and effective experiences, through a teaching and learning approach based on investigation.
Key words: Inquiry Based Learning, teaching-learning design, laboratory experience, research competences, technologies for education.

Article submitted: 19/09/2023; accepted: 08/11/2023
Available online: 13/12/2023

[*] Dipartimento di Scienze Biomediche, Università degli Studi di Padova, e-mail: regina.tavano@unipd.it.
[°] Dipartimento di Psicologia e Scienze Cognitive, Università degli Studi di Trento.
[^] Dipartimento di Studi Umanistici, Lettere, Beni Culturali, Scienze della Formazione, Università degli Studi di Foggia.

Excellence and Innovation in Learning and Teaching (ISSNe 2499-507X), 2023, 2

Doi: 10.3280/exioa2-2023oa16825

1. Introduction and reasons for the experience

1.1 The Inquiry Based Learning methodology and implementation

The Inquiry Based Learning (IBL) approach envisages a design based on the inquiry-based teaching approach, intended as "a technique that encourages students to discover or construct information by themselves instead of having teachers directly reveal the information" (Uno, 1999; Duran & Duran, 2004, p.49)", so "an educational strategy in which students follow methods and practices similar to those of professional scientists to construct knowledge" (Keselman, 2003; Pedaste et al., 2015, p.48).

One of the most popular approaches for designing IBL experience is the 5E Instructional Model (Bybee & Landes, 1990) based upon cognitive psychology, constructivist-learning theory (Bruner, 1990), and best practices in science teaching.

The design and the implementation process are composed by the following steps:

- Engagement: assessment of student's prior knowledge and/or identification of possible misconceptions. Motivational phase that supports the desire to actively explore the topic further, through a concrete learning experience.
- Exploration: students are encouraged to actively apply skills such as observing, questioning, investigating, testing predictions, hypothesising and communicating with other peers, supported by the teacher as facilitator.
- Explanation: students describe their understanding and ask questions about the concepts explored. Subsequently, the teacher introduces scientific and technical information in a direct manner, including the use of interactive resources, clarifying doubts raised during the previous phases.
- Elaboration: students are encouraged to apply their new understanding, reinforcing new skills and to compare themselves with their peers, design new experiments or models and carry out further investigations.
- Evaluation: assessment as a continuous process in which teachers observe students as they apply new concepts and skills. Observation may be accompanied by self- or peer-assessment experiences and may also include a summative experience (quiz, exam or writing assignment) (Duran & Duran, 2006).

This methodology is characterised by a process of students discovering new causal relations, through the formulation of hypotheses, the relative testing process by conducting experiments and/or making observations (Pedaste et al., 2012; National Research Council (NRC) Standards, 1996) and it is sustained by the 'learning by doing' perspective (Dewey, 1933; Spronken-Smith, 2012).

IBL is comprehended in the student-centred approaches (Kember, 1997; Archer-Kuhn et al., 2020) so an active learning methodology that sustains the development of self-directed learning skills: the strategy promotes the vision of students as direct creators and builders of their own knowledge, also with the implications of collaborative way of learning through work group activities (Kember, 1997; Gibbs, 1988, Healey & Roberts, 2004).

The methodology could be useful to stimulate the development of specific skills like problem solving and critical thinking (Pedaste & Sarapuu, 2006; Thaiposri & Wannapiroon, 2015): its implementation can in fact "emphasises active participation and learner's responsibility for discovering knowledge that is new to the learner" (de Jong & van Joolingen, 1998, Pedaste et al., 2015, p.48). The teachers' role is to guide the inquiry process as facilitator of learning for students: in fact, as the literature points out, empirical research on inquiry learning sustains that delivering specific assistance during the inquiry activity - such as feedback, worked examples, elicitation of explanations - benefits learners and improves learning outcomes achievement (Alfieri et al. 2011; Lehtinen & Viiri, 2017).

In order to structure the IBL experience Banchi & Bell (2008) theorised different levels of complexity: in fact, they found a four-level continuum useful to classify the levels of inquiry in a specific teaching and learning activity.

- Confirmation Inquiry: students acquire the research questions and the process and results are made available a priori. Then the whole process is made available to the students who must then confirm it through an investigation process.
- Structured Inquiry: teachers offer to students the research questions and process, but the data collection and the results analysis are connected to the specific action of students themselves.
- Guided Inquiry: determination of the research problem/question, leaving freedom of investigation and analysis to the learners who, through their own knowledge and research, will extrapolate from the problem the process of performing the method and establish the results.
- Open Inquiry or Project Work: it is defined as pure inquiry. When the students are high-skilled, in fact everything is designed by them and the teacher plays the role of facilitator of learning during the investigation and design process.

1.2 The course of Immunological Biotechnologies

Demaria, Barry & Murphy (2019) show the complexity in teaching immunology in the undergraduate laboratory: in fact, "it requires background knowledge, data analysis skills, critical thinking, and design capacities to include relevant controls and applications of particular techniques to answer a research question. It also requires strong technical skills" (p.1). Teaching process in courses with practical laboratory could be structured combining traditional teaching strategies to scaffold students learning on basic fundamental disciplinary techniques, but to support the development of the specific technical skills, it is important to move from the recipe-based approach to a more interactive modality of teaching (Demaria et al., 2019).

In connection with our formative design context, the IBL activity was implemented in a course named Immunological Biotechnologies, a second-year course of the Master Degree in Industrial Biotechnologies (University of Padova). Immunological Biotechnologies course includes frontal lectures (32 hours) and a practical activity held in the didactical laboratories (32 hours). The main topic of the course is how a vaccine, both preventive and therapeutic, is developed; the practical activity simulates how a therapeutic vaccine could be produced in laboratory; students work in pairs and they learn how to handle primary human immune cells in sterility conditions, how to evaluate their responses in vitro, how to perform complex immunology experimental protocols (ELISA, western blot, flow cytometry), and how to analyse data and draw proper conclusions from them. The practical experience requires ten days, during which the students are in the laboratory about 4 hours a day. During the final exam, students must answer a 30-question quiz about the practical activity, which includes different types of questions about the methodologies and the protocols used during the laboratory.

1.3 Research aim

The main aim of the research is to understand if:

1. The introduction of a specific teaching methodology, like in this case the IBL approach, could be useful to sustain students' engagement during the learning process.
2. The IBL can scaffold the students' major awareness about laboratory processes.
3. It helps the improvement of the final exam performance. Furthermore, the IBL methodology will be adopted to stimulate the acquisition of specific competencies, like critical thinking and problem solving.

In fact, the results of the final quiz in previous years were not satisfactory. Moreover, although the students were able to follow very detailed protocols, the workflow, which is intended to mimic what happens in a real research laboratory, was not clear to the majority of students. For these reasons, we decided to introduce this kind of activity, just before the beginning of the laboratory, to help students to become more aware of the practical steps of the laboratory and also to help them to better understand how to plan a research experience. In the literature, there are many examples where the IBL has been introduced in preparation for a laboratory activity, not only in the field of immunology (Demaria et al., 2019) but also in other study programs where laboratories are fundamental (Parappilly et al., 2013; Lents, Cifuentes & Carpi, 2010; Wiseman et al., 2020). All of them highlight how the transition from a laboratory activity based on standardised protocols – which students follow without any involvement – to an IBL-activity allows students to use their prior knowledge and critical reasoning. In fact, IBL-activity design can be crucial to sustain an engaging teaching and learning process and to stimulate the development of specific disciplinary competences in an interactive way.

To structure the experience, the IBL-activity was designed based on the guided level, to prompt the reflection on how to construct a research activity starting from a scientific question. Additionally, through the IBL-activity, students were guided in the use of laboratory protocols by reasoning through the steps of the laboratory techniques before implementing them.

The IBL-activity aimed therefore to enhance the following specific skills:

1. Proactive review of concepts learned in other courses, interconnected with the new topics;
2. Reflecting on the process of planning a research activity;
3. Reflecting on the correct order of the various phases of a laboratory assay;
4. How and where to search for information on laboratory protocols relevant to a specific task;
5. Reflecting on the importance of choosing positive and negative controls in a scientific experiment.

2. Description of the Methodology

The IBL-activity lasted for 5 hours and was conducted one week before the beginning of the practical activity. Through open-ended questions, short bibliographic research, multiple-choice questions, word clouds, label an image, and the “sorting” activity, students, working in groups, were guided to:

- Understand the connection between theoretical lectures and the practical laboratory activity Reflect about choosing experimental techniques, based on the research goal.
- Reflect on the different phases involved in the laboratory work.
- Conduct bibliographic research on methods used in laboratory for a specific purpose.
- Consider the concepts of negative and positive controls, essential when performing experiments in laboratory.

- Reflect on the appropriate methodology to analyse experiments.
- Reflect about the correct sequence of steps of a particular technique.
- Bring out knowledge acquired from previous courses that had not been put into practice.

During the IBL-activity the following activities were included:
- Engagement activities to present the various laboratory assays and the "experimental problem".
- Exploration activities by means of bibliographic research and consolidation of prior knowledge.
- Explanation and Debriefing phases to discuss the answers from different groups and to provide further details on the experimental activity.

After the actual IBL session, these activities were also implemented:
- Elaboration activities during which students generated experimental data, analysed and discussed the results, and recorded them in their laboratory notebooks.
- Evaluation phases by means of feedback modules, a midway evaluative quiz with Wooclap and a Moodle quiz one week after the end of the laboratory activity.

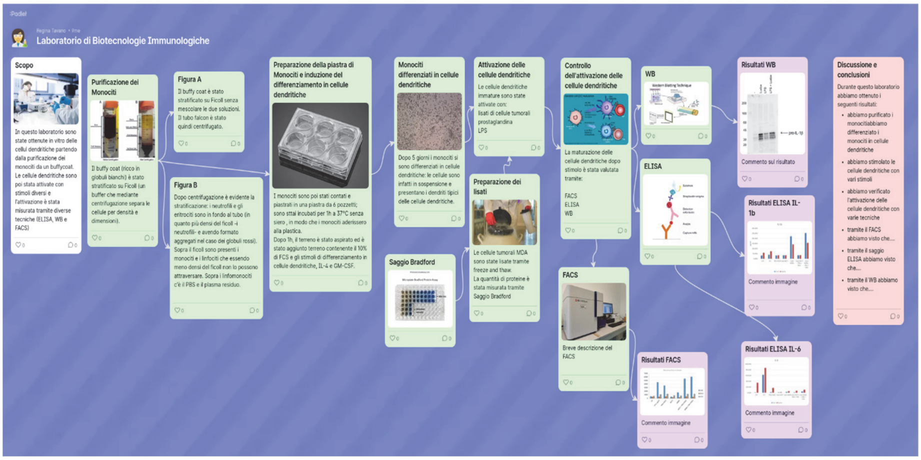
The IBL-activity was entirely conducted using the student response system Wooclap, integrating slides with explanations, debriefing moments and different kinds of questions. Wooclap was also used to collect final feedback on the level of student engagement during IBL, and to gather ideas and suggestions for further implementation. This aimed to assess the students' perception of satisfaction and usefulness of the activity.

To help students in the learning process of the numerous concepts and techniques, they were asked to complete a predefined form at the end of each laboratory day, mimicking a true laboratory notebook. The form was created in the Moodle "database" activity and students were required to include the following information:
- Experiment date;
- Objective of the laboratory session;
- Materials/methods/tools used;
- Descriptive list of the steps performed;
- Results obtained;
- Self-evaluation (description of difficulties encountered with the protocol and particularly successful steps).

At the midpoint of the laboratory experience, a short group challenge was introduced using Wooclap, to give the students the opportunity to assess how much they had learned and understood about the practical activity. At the end, a ranking was created, and bonus points were awarded to the top three groups, which were included in the final evaluation.

With the purpose of guiding students in the learning process and making them reflect on the flow of the practical experience (scientific question, methodologies, and assays used to answer the scientific question, data analysis, and interpretation), each group was assigned to create a summary with Padlet, a software useful to the creation of multimedia boards, similar to the one shown in Figure 1.

Figure 1 – Example of Padlet application for visualising the workflow during the practical laboratory



Eventually, at the end of the practical laboratory, students were asked to fill out a feedback form, aimed to evaluate the satisfaction and usefulness of the laboratory experience. The same module had been used in the previous academic year (a.y.), allowing for an assessment of the effectiveness of the inclusion of the IBL-activity.

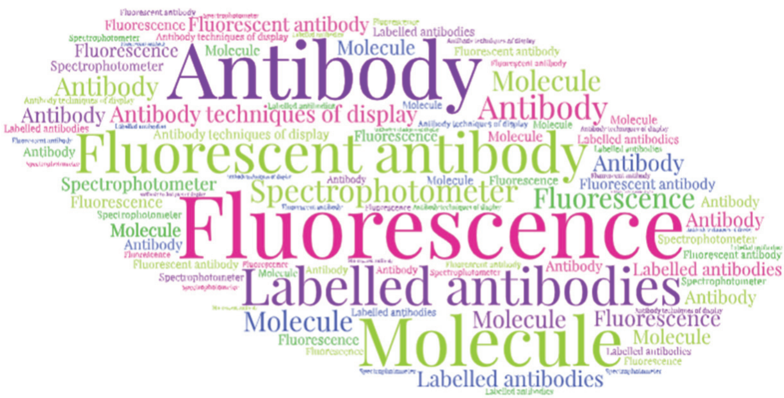
3. Results

3.1 Findings and Feedback on the IBL-activity

Out of the 35 students attending the course of Immunological Biotechnologies, 33 students were present on the days when the IBL-activity was conducted. Four students were unable to respond due to connection issues, so the results of the activity were evaluated based on the responses of 29 students.

The results of the word clouds, used to assess prior knowledge, generated interest and sometimes led to discussions and debates among students and the instructor, as well as between student groups. An example of a word cloud created in class is provided (Figure 2).

Figure 2 - Example of a word cloud built with students' responses



The word clouds, used to gather information after a bibliographic search, allowed for an engaging introduction to the topic. Questions that required ordering the phases of the laboratory or the steps of a particular technique proved to be the most challenging. At the end of the two IBL sessions, students were asked to provide anonymous feedback on various aspects (engagement, usefulness, interest, time spent, and clarity of the experience's main thread), rating them on a scale from 1 (not at all) to 5 (extremely). The results, presented in Figure 3, represent the averages of the responses; the average rating for all evaluated parameters settled at Figure 4.

Figure 3 - Average results (29 students responding out of 35 attending) of satisfaction with the IBL-activity: the parameters evaluated were rated on a scale from 1 (not at all) to 5 (extremely)

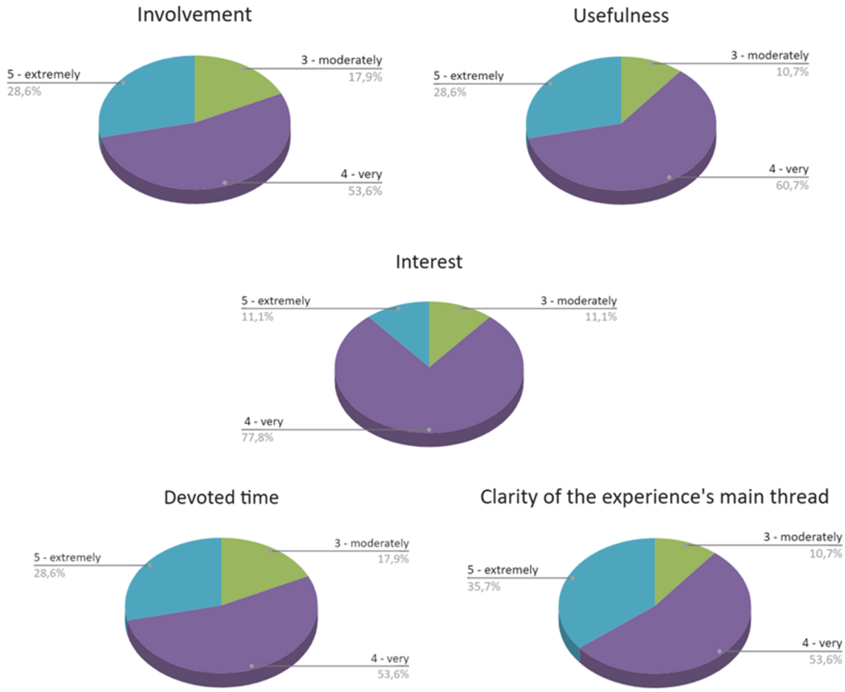
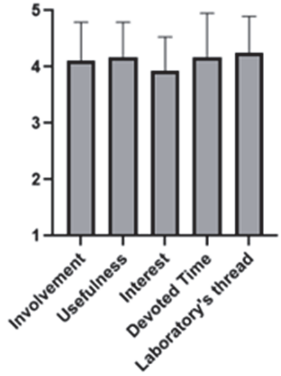


Figure 4 - Percentages of student responses about the satisfaction with the IBL-activity: the parameters evaluated were rated on a scale from 1 (not at all) to 5 (extremely)



Students were also asked to share the most important thing they learned and to provide suggestions, ideas, and observations on the IBL-activity. Here are some of their responses (Table 1).

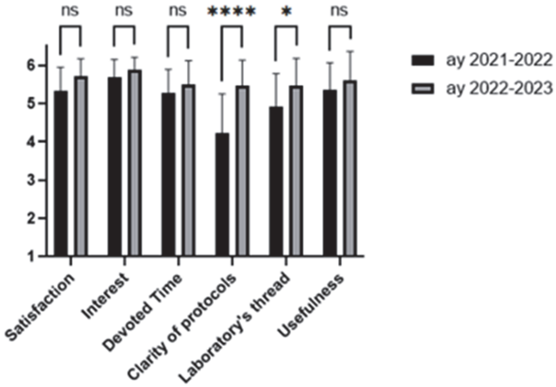
Table 1 - Students' testimony of learning and point of view on IBL experience

Students' testimony of learning	Students' point of view on IBL experience
• "How to carry out laboratory activities" • "Active search for informations" • "Features of different analysis techniques • "The importance of reviewing previously used techniques and organising ideas before implementation" • "Logical/methodical organisation of experiments"	• "A Kahoot game at the end of the lesson would be fun and bring some healthy competition" • "It's perfect as it is!" • "It would be helpful to have a final recap of the logical thread" • "Videos would be useful" • "It was helpful; it should be continued" • "Active involvement was useful for better understanding of concepts" • "Reduce the number of protocols to be ordered"

3.2 Comparison of overall satisfaction for the laboratory activity in the 2021/2022 and 2022/2023 a.y.

At the end of the practical activity, an additional feedback form was submitted to the students to assess their satisfaction. The module consisted of a series of questions to which students could rate their responses on a scale from 1 (not at all) to 6 (extremely). All 35 attending students responded to the feedback activity. The same module had been already used in the previous a.y., where there were 25 attending and responding students. Figure 5 represents the results.

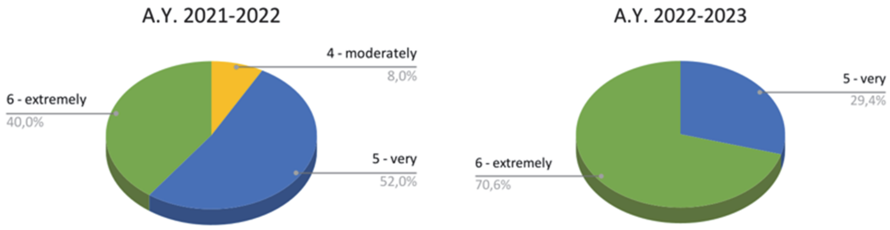
Figure 5 - Comparison of average ratings of satisfaction with the laboratory activity in the 2021/2022 a.y and the 2022/2023 a.y.



*Note: In 2022/2023 a.y the IBL-activity was introduced and there were 35 attending students, in the 2021/2022 a.y. there were 25 attending students. The parameters evaluated were rated on a scale from 1 (not at all) to 6 (extremely). ns: not significant, * $p < 0.1$, **** $p < 0.0001$, calculated using a two-way ANOVA test.*

Regarding overall satisfaction, the percentages of ratings given by students are also shown in Figure 6.

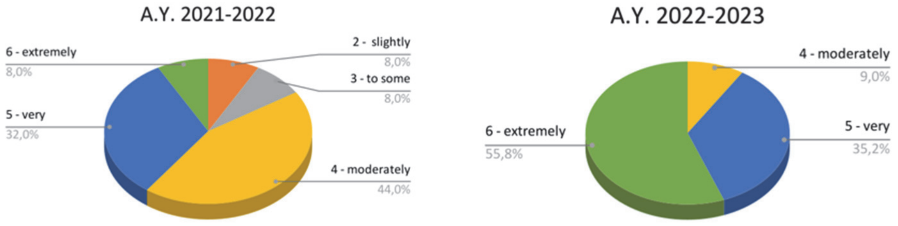
Figure 6 - Perceived level of satisfaction by the students in the 2021/2022 a.y and the 2022/2023 a.y.



Note: Percentages of student responses on a scale from 1 (not at all) to 6 (extremely) to the question regarding satisfaction about the laboratory activity; comparison between the two a.y. under study (25 students for the 2021/2022 a.y., 35 students for the 2022/2023 a.y.).

In Figure 7 a significant difference is evident in terms of protocol clarity. The handouts provided to students, containing the description of all the steps of the practical activity, were identical in both a.y. The percentages of ratings given by students for this aspect are shown in Figure 7.

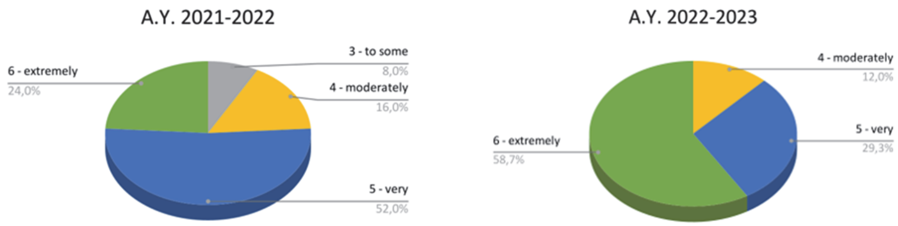
Figure 7. Perceived level of clarity of the protocols by the students in the 2021/2022 a.y and the 2022/2023 a.y.



Note: Percentages of student responses on a scale from 1 (not at all) to 6 (extremely) to the question regarding the clarity of the provided protocols; comparison between the two a.y. under study.

In terms of clarity of the laboratory's main thread, here below the graphs represent the extrapolated data referred to this area of analysis (see Figure 8).

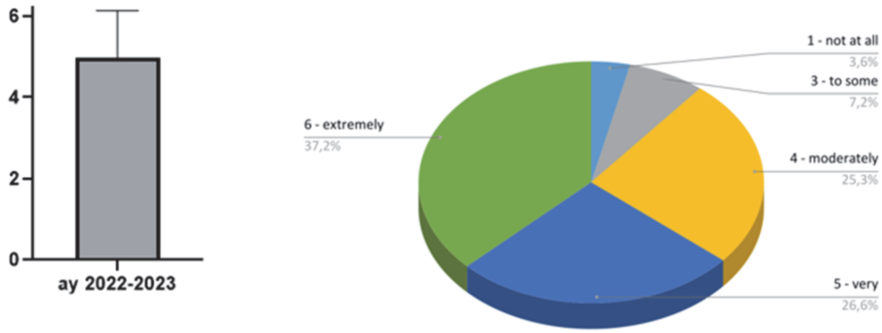
Figure 8 - Clarity of the laboratory experience's main thread



Note: Percentages of student responses on a scale from 1 (not at all) to 6 (extremely) to the question regarding the clarity of the laboratory experience's main thread; comparison between the two a.y. under study.

At the end of the practical activity, students were also asked to assess the usefulness of the IBL-activity in preparing them for the various laboratory activities. Figure 9 shows the average satisfaction ratings obtained on a scale from 1 to 6 (left panel) and the percentages of student responses (right panel).

Figure 9 - Usefulness of the IBL-activity perceived by the students



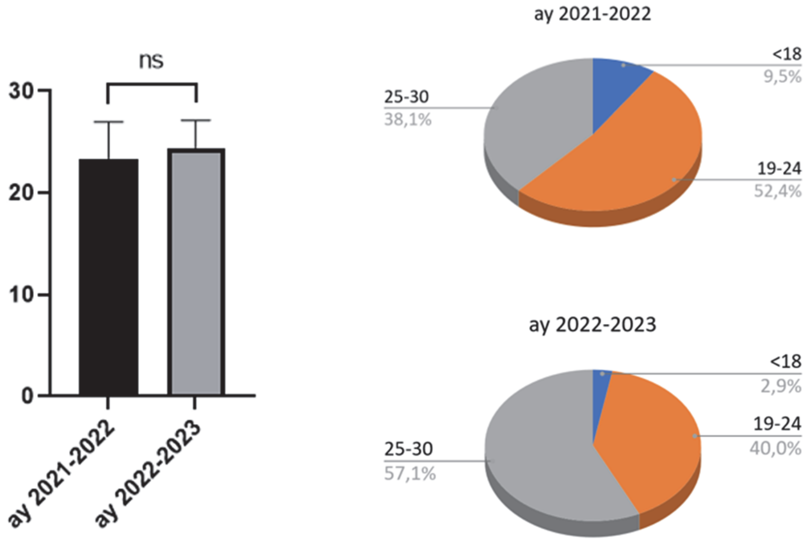
Note: data (average ratings on a scale from 1-not at all to 6-extremely) on the right and percentages of responses on the left on the perceived usefulness of the IBL-activity by students (35 answers).

3.3 Comparison of Final Exam Results for the 2021/2022 and 2022/2023 a.y.

During the 2022-2023 a.y. a challenge, aimed to assess their understanding of the techniques and to identify any critical points, was introduced midway through the laboratory experience. Students, divided into groups, had to answer ten questions related to the techniques they had used up to that point. The average of correct answers was 71.4%; the results were discussed and additional explanations were provided to students regarding critical questions.

In the 2022-2023 a.y., a change was also made to the final exam. The laboratory quiz was scheduled not at the end of the semester but two weeks after the end of the practical activities. The following figure (Fig. 10) displays in the left panel the overall average scores (0-30 scale) obtained by students in the laboratory quiz in the right panel the percentages of the range scores achieved by the students in the two a.y. analysed.

Fig. 10 - Data on student assessment after the final quiz



Note: On the left panel, the averages of the results obtained in the same type of quiz by students from the two a.y. under examination are represented. On the right panel, comparison of the percentages of students who achieved different range scores (<18/30, 19-24/30, 25-30/30) in the two a.y. under examination.

In terms of students' percentage who took the exam in the first session, in the 2021-2022 a.y., 16% of enrolled students took the exam in the first session, while in the 2022-2023 a.y., the students' percentage was 54.3%. After the second session, the percentage rose to 44% in the 2021-2022 a.y. and to 71.4% in the 2022-2023 a.y.

4. Discussion

4.1 Students' feedback on the IBL-activity

From the analysis process of the 29 students' responses emerged interesting data connected to the IBL-activity feedback.

The world cloud activities created to collect data in terms of prior knowledge demonstrate the possibility to integrate interactive moments, among students and with the teacher.

The activities designed to stimulate the reflection on the phases connected to the laboratory procedure underlined the difficulty for students to focus on the main steps regarding the practical activity: the low rate of success (25% correct responses), in fact, shows that this reflection activity could be powerful to put the basis of specific formative steps to sustain student scientific literacy (Keselman, 2003; Pedaste et al., 2015).

In terms of students' feedback, the data gathered put in evidence that in general the students declared to be very engaged during the inquiry process (53.6%). The perception of usefulness of the activity was evaluated by the majority of students as really useful (60.7%) and in general the interest was very high (scale point 4; 77.8%). In terms of devoted time spent on the IBL-activity and the related clarity of the whole process, students were very satisfied (scale point 4 - 53.6%). They were asked to rate these aspects on a scale from 1 (not at all) to 5 (extremely). It's important to affirm that in general, the IBL-activity was really appreciated both in terms of the organisation of the experience and in relation to the engagement with respect to the teaching and learning process, which is therefore powerful, effective and student centred (Kember, 1997).

4.2 Comparison of overall satisfaction for the laboratory activity in the 2021/2022 and 2022/2023 a.y.

The analysis, connected to the satisfaction of the laboratory activity and the related comparison between the results of the 2021/2022 and 2022/2023 a.y., put in evidence interesting data to inform a complex overview of the experience.

The assessment criteria used to explore the impact allowed us to better investigate the students' perceptions: one particularly interesting result is the percentage of students who gave the highest rating, which increased from 40% to 71%.

In terms of general satisfaction, the average rating increased meaningfully:

in fact, in relation to the 2022-2023 a.y. students are extremely satisfied (70.6%) and very satisfied (29.4%), in contrast with the previous a.y. when students' perception is divided between moderately (8%), very (52%) and extremely satisfied with the laboratory experience (40%).

Also, in relation with the areas connected to the interest and the devoted time, it seems that the total average has slightly increased.

The students' perception of protocol clarity significantly improved after the introduction of the IBL-activity (**** $p < 0.0001$) compared to the previous year. The percentage of students who considered the protocols to be very clear increased from 8% to 56%; the percentage of students rating the clarity of the protocols as 4 decreased from 44% to 9%. The clarity of the laboratory experience's main thread also significantly increased (* $p < 0.1$), furthermore after the introduction of the activity, the percentage of students who gave the highest rating to this parameter increased from 24% to 56%.

Approximately 90% of students rated the usefulness of the IBL-activity higher than 4.

To conclude, the laboratory experience proposed this year established an improved experience for the students, who perceived the usefulness of the activities in connection with the specificity of the teaching course, related contents and connected competences.

4.3 Comparison of Final Exam Results for the 2021/2022 and 2022/2023 a.y.

The middle challenge experience highlights the power of introducing stimulating activities to sustain reflection and self-assessment processes during the learning path of the students. In fact, this activity seems to be powerful to monitor the learning progress both from the point of view of students and of the teacher, who has been able to acquire important data to support a continuous redesign of his/her teaching and support the learning experience. The gamification process appears to be important to sustain the formative assessment process embedded during the IBL laboratory module (Demaria et al., 2019).

The final quiz average score did not show a significant change in the two analysed a.y. and the percentage of correct answers given by students only increased from 74% to 78.4%. However, what is particularly interesting is the increase in the percentage of students who achieved a score higher than 25/30 on the exam, which rose from 38.1% in the 2021-2022 a.y. to 57.1% in the 2022-2023 a.y.. Furthermore, the percentage of students who took the exam in the first session has increased by more than three times in the two a.y. under consideration. The data show that, through the direct support of self-directed learning skills (Bruner, 1990) and specific knowledge and competences promoted by the IBL methodology, students seem to be more self-confident for the final examination and this allows the students themselves to feel effective in their preparation so as to participate in the first exam attempt. Despite the small sample size, it is evident that the IBL methodology may be a valuable support in supporting the development of specific STEM competences, such as the ability to work in teams, the development of critical thinking with respect to practical laboratory activities, and the acquisition of skills related to the exploration and solving of concrete problems in disciplinary practice (Demaria, Barry & Murphy, 2019).

5. Conclusions and future perspectives

In general, the experience structured following the guided level of the Inquiry Based Learning (Banchi & Bell, 2008) and designed through the 5E model (Pedaste et al., 2015), seems to sustain a real process of active learning (Archer-Kuhn et al., 2020), with a learning by doing philosophy (Gibbs, 1988, Healey & Roberts, 2004) and a student-centred approach (Kember, 1997).

Also, if the number of students was not wide, it is possible to affirm that, in connection with the research question n° 1 dedicated to the engagement improvement, the structure of the activity stimulates students' involvement in class, sustaining and increasing the general satisfaction and also the perception of usefulness and related interest. In terms of the awareness improvement, the clarity of the laboratory experience increased after the IBL-activity and students perceived scaffolding in preparing them for the various laboratory activities thanks to the adoption of this approach.

Finally, in relation to the students' final performance, it was not a significant statistical difference regarding the final assessment grades.

In terms of research limitations, after the analysis of the data it is possible to affirm that it could be important to increase the time dedicated to the IBL-activity to maximise an effective support of students during the formative experience.

As a final limitation connected to the results of the IBL-activity and in direct connection with the not statistically significant comparison of the final exam results, the main issue could be related to the fact that the cohorts analysed are different. This statement means that students have different characteristics than variables that may affect experience and final assessment average are multiple, complex and can influence the assessment of the overall impact of IBL-activity. For this reason, it will be important to include an initial pre-test in the next a.y., to assess the students' prior knowledge and to scaffold the activities' design and the implementation.

Below, some future research perspectives will be described.

First of all, starting from a careful study of the results of the laboratory quiz, it will be essential to identify the weak points, possibly reformulate the questions and review the experience to implement these shortcomings. For this, it could be important to introduce a small IBL-activity at the beginning of each laboratory day (for example, tidying up the work phases of that particular day) to support the development of critical thinking skills in the personal discovery and deeper understanding of the inquiry learning process (Archer-Kuhn, B. et. al, 2020).

Furthermore, at the end of the IBL-activity and before the practical laboratory could be interesting to ask students to create a Padlet in which they hypothesise the workflow of experimentation to push the activity of IBL even more towards an open investigation.

Finally, at the end of the laboratory, it should be important to organise a meeting at which all the groups present their data and a related debate activity in plenary on the results obtained. This process will be crucial to sustain a debriefing moment and to create a discussion flow to explore the aspects that have (or have not) worked.

Author contributions: RT (PhD, Professor of the Immunological Biotechnology course in which the IBL-activity was conducted) conceived and designed the IBL-activity, FP (PhD student in Psychology and Cognitive Science) supervised the design of the IBL-activity, FP and AL (PhD, Full Professor in Education and Special Pedagogy) trained RT for the IBL-activity, RT and FP wrote the paper, AL read the paper and provided suggestions and comments.

References

Alfieri, L., Brooks, P.J., Aldrich, N.J., Tenenbaum, H.R. (2011). Does discovery-based instruction enhance learning?. *J Educ Psychol,* 103(1), 1-18.

Archer-Kuhn, B., Wiedeman, D., & Chalifoux, J. (2020). Student engagement and deep learning in higher education: Reflections on inquiry-based learning on our group study program course in the UK. *Journal of Higher Education Outreach and Engagement*, 24(2), 107-122.

Banchi, H., & Bell, R. (2008). The many levels of inquiry. *Science and children*, 46(2), 26.

Bybee, R., & Landes, N. M. (1990). Science for life and living: An elementary school science program from Biological Sciences Improvement Study (BSCS). *The American Biology Teacher*, 52(2), 92-98.

Bruner, J. (1990). *Acts of Meaning*. Harvard University Press.
De Jong, T., & Van Joolingen, W. R. (1998). Scientific discovery learning with computer simulations of conceptual domains. *Review of educational research*, 68(2), 179-201.
Demaria, M., Barry, A., & Murphy, K. (2019). Using inquiry-based learning to enhance immunology laboratory skills. *Frontiers in immunology*, 10, 2510.
Dewey, J. (1933). *How We Think: A restatement of the relation of reflective thinking to the educative process*. D.C. Heath.
Duran, L. B., & Duran, E. (2004). The 5E instructional model: A learning cycle approach for inquiry-based science teaching. *Science Education Review*, 3(2), 49-58.
Gibbs, G. (1988). *Learning by Doing: A Guide to Teaching and Learning Methods*. Further Education Unit.
Healey, M., & Roberts, J., Ed. (2004). *Engaging students in active learning: case studies in geography, environment and related disciplines*. University of Gloucestershire, Geography Discipline Network and School of Environment.
Kember, D. (1997). A reconceptualisation of the research into university academics' conceptions of teaching. *Learning and Instruction* 7, 255-275.
Keselman, A. (2003). Supporting inquiry learning by promoting normative understanding of multivariable causality. *Journal of Research in Science Teaching*, 40, 898-921. doi: 10.1002/tea.10115.
Lehtinen, A., & Viiri, J. (2017). Guidance provided by teacher and simulation for inquiry-based learning: A case study. *Journal of science education and technology*, 26(2), 193-206.
Lents, N.H., Cifuentes, O.E. & Carpi A. (2010). Teaching the Process of Molecular Phylogeny and Systematics: A Multi-Part Inquiry-Based Exercise. *CBE-Life Sciences Education*, 9, 513-523.
National Research Council. (1996). *National science education standards.* National Academy Press
Parappilly, M.B., Siddiqui, S., Zadnikb, M.G., Shapter, J. & Schmidt, L. (2013). An Inquiry-Based Approach to Laboratory Experiences: Investigating Students' Ways of Active Learning. *International Journal of Innovation in Science and Mathematics Education*, 21(5), 42-53.
Pedaste, M., & Sarapuu, T. (2006). Developing an effective support system for inquiry learning in a Web-based environment. *Journal of Computer Assisted Learning*, 22(1), 47-62.
Pedaste, M., Mäeots, M., Leijen, Ä., & Sarapuu, S. (2012). Improving students' inquiry skills through reflection and self-regulation scaffolds. *Technology, Instruction, Cognition and Learning*, 9, 81-95.
Pedaste, M., Mäeots, M., Siiman, L. A., De Jong, T., Van Riesen, S. A., Kamp, E. T., ... & Tsourlidaki, E. (2015). Phases of inquiry-based learning: Definitions and the inquiry cycle. *Educational research review*, 14, 47-61.
Spronken-Smith, R. (2012). Experiencing the process of knowledge creation: The nature and use of inquiry-based learning in higher education. In *International Colloquium on Practices for Academic Inquiry*. University of Otago (pp. 1-17).

Thaiposri, P., & Wannapiroon, P. (2015). Enhancing students' critical thinking skills through teaching and learning by inquiry-based learning activities using social network and cloud computing. *Procedia-Social and Behavioral Sciences*, 174, 2137-2144.

Uno, G. (1999). *Handbook on teaching undergraduate science courses: A survival training manual*. Thomson Custom Publishing.

Wiseman, E., Carroll, D.J. Fowler, S.R. & Guisbert, E. (2020) Iteration in an Inquiry-Based Undergraduate Laboratory Strengthens Student Engagement and Incorporation of Scientific Skills. *Journal of the Scholarship of Teaching and Learning*, 20 (2), 99-112.

Transforming higher education: From Flipped lessons and MOOCs to lifelong learning for archaeologists

Alexandra Chavarría Arnau*, Cecilia Dal Bon^

Abstract

This paper explores the transformative impact of flipped learning and Massive Open Online Courses (MOOCs) on higher education, specifically in the field of medieval archaeology at the University of Padova. It delves into the implementation of these innovative approaches, their effects on student performance, and the valuable insights gained from student feedback. Additionally, it highlights the global reach of MOOCs created as a complement to these courses, including their multiple functions and implications also for lifelong learning. The findings suggest that blending online and traditional teaching can create a dynamic and inclusive educational experience that caters to the needs of traditional students, professional archaeologists who want to improve their skills and competencies and enthusiasts of archaeology.

Keywords*:* innovative teaching and learning, interaction, medieval archaeology, upskilling, reskilling.

Article submitted: 11/09/2023; accepted: 08/11/2023
Available online: 13/12/2023

1. Introduction: Creating hybrid learning environments

The COVID-19 pandemic served as a catalyst for the adoption of online teaching tools, and even as universities returned to normality, the benefits of

* Department of Cultural Heritage: Archaeology, History of Art, Cinema and Music, University of Padova, Italy. E-mail: chavarria@unipd.it.

^ Digital Learning and Multimedia Office, University of Padova, Italy. E-mail: cecilia.dalbon@unipd.it.

The submission is the product of the joined effort of both authors.

Doi: 10.3280/exioa2-2023oa16826

online learning have become evident. Flexibility, increased accessibility for students with disabilities, and convenience for those with multiple commitments have all contributed to the growing appeal of online education.

The interest in online education among students in Italy has been underlined by the Ministry of Culture, which has recently reported how during the Covid emergency there was a huge increase of learners in online high education universities especially from students who had already completed basic studies and wanted to develop a second-degree grade (*laurea magistrale*)[1].

Educators who were receptive to exploring remote teaching technologies, beyond merely replicating traditional face-to-face methods through video conferencing, experienced the advantages of online teaching and were inspired to reevaluate and refine their lesson content and teaching strategies.

Of special interest – also fostered by some universities after the initial "return to normality" – has been the development of blended methods which merge the flexibility and inclusivity of the online experience with that of in-person classes.

One effective method to leverage the advantages of this blended learning system is the implementation of flipped teaching. Flipped teaching entails utilizing online lessons to facilitate independent student learning of course content (for instance, through pre-recorded videos) before the in-person class sessions. This approach frees up valuable class time for more engaging and interactive activities.

In this context, we introduce the flipped integrated teaching experience, which has been implemented since 2021 within the courses on medieval archaeology at the University of Padova. It combines online material and in-person activities, creating a holistic educational approach, and has demonstrated significant enhancements in structuring the lesson content, encouraging student learning and improving learners' competencies. The course

[1] According to the ANVUR report on higher education and research system published in June 2023, the increase in the number of enrolments over the past decade has benefited telematic universities most significantly. While traditional universities have recorded an increase of about 2,000 students, telematic universities have seen them grow by 180,000. In the academic year 2021/22, 11.5 per cent of university students are enrolled in telematic universities, compared to 2.5 per cent in the academic year 2011/12. For traditional universities, while state universities recorded a slight decrease of about 19,000 students (-1.2%), non-state universities saw an increase of about 22,000 students (+21.3%). Certainly, the expansion of the educational offerings of telematic universities has enabled many students, especially workers, to embark on a university career. In the academic year 2021/22 as many as 101,000 students (45.2% of the total) came from a previous experience in traditional universities: a figure that is on the rise compared to the academic year 2011/12, when this percentage stood at 40.7%.

has also incorporated progressive and continuous assessment methods to certify learner's proficiency in a wide range of contents and skills.

A highly valuable instrument in refining and conceptualizing this method has been the simultaneous creation of a MOOC series on medieval archaeology, currently comprising three courses. These MOOCs have played a pivotal role in shaping the content and structure of the course by offering various activity formats for exploration. Furthermore, these MOOCs, which have the option to be incorporated as flipped learning materials within the course, have been instrumental in developing strategies for online interaction between the teaching staff and remote learners. In my experience, they have also illuminated the existence of a vast global community of learners, eager to engage with our lessons.

This insight has sparked further reflection on the influence we could wield in the realm of lifelong education - not only limited to recreational access, but also with the possibility of serving to facilitate continuous professional development in our field, archaeology. Our discipline evolves rapidly, particularly in the realm of research methodologies, and it is crucial for professionals to stay abreast of these advancements. There is an increasing imperative for educational institutions to broaden their reach and offer lifelong, skills-based training to a wider audience, catering to individuals at any stage of their lives.

2. A three-step model for a flipped learning experience

Since 2021, a flipped teaching method has been tested for the Medieval Archaeology course of the degree in archaeology at the Cultural Heritage Department of the University of Padova. The course is typically held in the third year of the three-year course in archaeology (63 hours / 9 CTS), and it is mainly based on the handbook Post-Classical Archaeologies (Brogiolo & Chavarría Arnau, 2020). It started during the Covid period in the academic year 2019-2020, with approximately 70 students enrolled in Moodle, followed by 100 in 2020-2021, 120 in 2021-2022, and 140 in 2022-2023.

The course delves into the historical period spanning from the 5th to the 15th centuries, covering not only conventional topics like cities, countryside, trade, churches, and cemeteries but also aspects that have relevance to both our present and future. These additional subjects open the door to discussions that transcend students' existing knowledge levels, encompassing issues such as climate change, environmental shifts, dietary and health concerns, pandemics, migrations, territorial conflicts and frontiers, local and global market dynamics, and religious diversity.

As it is a course with a large number of students who possess varying levels of knowledge (it is a mandatory course for archaeologists and an optional elective for historians, art historians, and tourism students), and encompasses different age groups (with the majority falling between 18 and 25, but including some lifelong learners), it is guided by three primary objectives:

- To enable each student to customize their learning journey by progressing through gradual stages.
- To encourage active learning and student participation, not only during lessons but also through participatory exercises.
- To modify the assessment method by eliminating the final exam, thus fostering progressive learning through exercises that allow both the instructor and the students themselves to monitor their knowledge development.

The course (lasting six hours per week over three days) was organized following a more or less fixed 3 step scheme consisting of:

- STEP 1: Pre-recorded video lessons (ideally part of blended course hours but can also be pre-lesson homework) and readings;
- STEP 2: In-class interactive seminars including questions from the students on the topics of the pre-recorded lessons, discussion on these topics, and deepening of some aspects of the pre-recorded lessons. Alternatively, a specialist guest for specific lectures.
- STEP 3: Exercises (some participatory, some individual, some in pairs or groups) which can also be discussed during the in-class time.

By providing students with pre-class pre-recorded videos (in my case prepared during the lockdown) as well as readings, I ensure that students arrive in class somewhat familiar with the concepts of the lesson and ready to engage at a deeper level during the in-class time.

The most difficult part of preparing this kind of course relates to what happens in the classroom- how to avoid traditional passive lectures and make the students feel the need and advantages of coming to class, since they already accessed the content online. First of all, in-class sessions should be designed to build on the pre-class phase, addressing any student misconceptions and consolidating concepts as well as engaging students in solving problems and thinking critically about the content, creating a dynamic learning environment (Bligh, 1971; Prince, 2004; Patton, 2015).

The inclusion of guest lecturers, a feature highly appreciated by students, enriched the discourse.

In order to achieve interaction, in case spontaneous participation does not occur, it is useful to prepare activities which involve the engagement of all the students (for example through Wooclap). Various strategies can be employed to encourage participation, including:

- Creating a relaxed and welcoming atmosphere in the classroom by physically positioning oneself closer to the students to foster a sense of proximity.
- Addressing students by their names and encouraging them to use each other's names.
- Asking students to respond to their peers' questions and inviting them to challenge your ideas or those of other researchers quoted during the lessons.
- Avoiding criticism of student questions or comments in front of the class.

I strongly recommend that students refrain from taking notes, even though this may be quite challenging for them and, in some cases, lead to frustration. While note-taking is undeniably a valuable skill, likely to prove useful, if not essential, in their future workplaces, many students tend to mechanically transcribe instructors' words without engaging in critical thought or reflection on the content (French & Kennedy, 2016, p. 8). Therefore, I recommend taking notes during the pre-class phase, where they can replay the video content as many times as necessary, and instead, reserving their in-class time for active listening and thoughtful reflection. This approach enables them to actively participate in discussions, which is the primary purpose of being physically present in class.

In general, after overcoming the initial challenge of speaking in front of the class, there will always be a group of students who feel more confident about participating actively. It's crucial to make an effort to involve all students who wish to take part in discussions, even if they are hesitant to take risks. Equally important is not to pressure students who, despite enjoying the discussions and possibly contemplating answers on their own, prefer to remain silent. They can be encouraged to engage in alternative activities, such as participatory Padlet walls.

This flipped classroom approach has been found useful for instructors to devote in-class time to the students without worrying about the time otherwise needed to deliver the whole content of the course (Al-Samarraie et al., 2020). According to French & Kennedy, 2016: "Attending lectures provides students with an important opportunity to make connections and build relationships with peers. It also transforms the act of learning into a collective experience that can facilitate a shared communal understanding among students" (p. 10).

3. Exercises as Learning Tools: Encouraging Reflection and Integration

Another significant innovation in the course were the exercises that replaced (by student choice) the final exam. These exercises were carried out once every

15 days (in total, eight assignments were delivered) and their main objectives were to:

- Stimulate reflection on lesson topics;
- Connect concepts from different lessons;
- Enable review of the contents through maps or tables;
- Encourage the students to research online for further information on the lesson content or on particular subjects (for example an archaeological site).
- Foster constructive criticality by having students evaluate their peers' exercises (peer-review) through a specific rubric similar to what the professor uses for student assessment.
- Serve as a final exercise (course 2023), where a short "scientific text" with notes and bibliography that they had elaborated in previous exercises is transformed into a five-to-eight-minute podcast episode about a medieval archaeological site of the territory[2].

Apart from the last exercise, which was more time-consuming, all the other assessments were calculated between 2 and 4 hours work each.

Some (optional) participatory activities were also offered as relevant study tools for all the students, in particular two Padlet walls: one with a content timeline and another with a chronologically organized annotated list of the main protagonists of the period covered.

Exercises guide students back to the pre-class materials, compelling them to revisit and engage with the content. They also serve the valuable purpose of offering students consistent and constructive feedback, enabling them to assess their progress, pinpoint areas for enhancement, and fine-tune their learning strategies (Hattie & Timperley, 2007). They not only facilitate gradual content mastery but also foster the development of additional critical skills, such as synthesis abilities, peer review skills, teamwork aptitude, and digital literacy.

Assignments and their evaluations enable continuous monitoring of student advancement over the course of the semester, affording instructors the chance to implement timely adjustments to teaching and learning methodologies (Eyal, 2012).

Moreover, the Moodle platform, coupled with integrated tools (especially video management analytics), facilitated the following capabilities monitoring all student activities, providing teaching staff with real-time insights into assignment progress; assessing students' development by comparing exercise results and the frequency of video lesson views and evaluating individualized student learning and offering tailored assessments based on their initial starting points.

[2] Source: https://mediaspace.unipd.it/channel/PODCAST+Veneto+Medievale/303920292.

4. Satisfaction Levels and Perceived Learning Outcome

Although students view this teaching and assessment method as very demanding (although in reality and with the lack of a final exam they would have 162 hours for steps 1 and 3[3]), their overall experience was highly positive.

When surveyed both during and at the end of the course (via the Padlet platform[4]), students expressed the following perceptions:

- They found the level of learning achieved to be highly satisfactory.
- The novel assessment methods enabled them to acquire skills with substantial value for their future educational and professional growth, extending beyond the scope of the course.
- Their interactions with me and their fellow students became more engaging and productive.

Fig. 1 - Word cloud from the student's answers

---

[3] A credit (ECTS) typically corresponds to 25 hours of work, including classes and self-study. Therefore, a course worth 9 credits like this corresponds to 63 hours of classes and 162 hours of self-study (including the flipped part and the exercises).

[4] These evaluation tool was created as a way to implement the Student Evaluations of Teaching (SET) which, as many researchers have highlighted present serious problems (Carpenter Witherby & Tauber, 2020; Harvey 2022; Heffernan 2022; Hornstein & Law, 2017; Kreitzer & Sweet-Cushman 2022; Stroebe, 2020), all of them underlining that most SET has a poor correlation with student learning, that SET is heavily influenced by factors that have little to do with course quality and effectiveness (Heffernan 2022). SET is influenced by the personal characteristics of the instructor, as well as the individual biases of students (Wallace, Lewis & Allen, 2019). Instead of rewarding those who instruct in challenging courses and grade strictly, Stroebe (2020) has asserted that SET encourages grade inflation, rewards poor teaching. Furthermore, it causes high stress among academic staff and can be adopted by colleagues as a tool to bully and target other academics.

Additionally, students observed that this approach, facilitated by digital tools, offered significant advantages in terms of time flexibility. They could comfortably absorb the course content at their own pace, a flexibility extended to the completion of assignments, accommodating various schedules.

Setting aside the **Student Evaluations of Teaching (SET)** for the course, which, while not unfavorable, didn't quite match my initial expectations, it is noteworthy that the course enrollment has doubled since I adopted this teaching method three years ago. This substantial increase in student enrollment appears to be a compelling indicator of the method's effectiveness and appeal.

5. Designing Success: Strategies for Effective Course Delivery and Engagement

To ensure the success of this course, which may seem somewhat unconventional compared to traditional approaches due to the instructor's distinct role as more of a facilitator than a content deliverer, meticulous course design is essential[5]. Here are some key considerations:

- Clear communication: Communicate the course structure and expectations clearly to students from the very first class. Discuss in detail your syllabus from the first day going through the course schedule, assessment methods, and learning objectives. This transparency helps students know what to expect and how to succeed in the course.
- Emphasis on benefits: Emphasize the expected benefits for the students to help them understand the rationale behind an approach that may initially feel unfamiliar or uncomfortable.
- Structured modular design: It is crucial to structure the course into well-defined modules or units right from the beginning. This approach provides clarity and organization for both the instructor and students. Each module should have a clear learning objective and build upon the previous one, allowing students to progress logically through the material.
- Logical sequence: Ensure that the modules follow a logical sequence, creating a smooth flow of information. This helps students understand how concepts connect and build upon each other, promoting a deeper understanding of the subject matter.
- Diverse presentation methods: To engage students effectively, employ a variety of presentation methods. This includes using videos, readings, and interactive activities. By diversifying the content delivery, you can cater to different learning styles and maintain student interest throughout the course.

[5] On the role of the instructor as facilitator see Patton, 2015.

In this sense, MOOCs serve as compelling examples of best practices in course planning, as they are characterized by their diverse array of activities and multimedia components, as well as their incorporation of ongoing assessments.

6. MOOCs as a Source of Inspiration and Best Practices

Since 2020, three Massive Open Online Courses with content related to medieval archaeology have been produced thanks to two grants for innovative teaching from the University of Padova and an Erasmus project on Innovative didactics[6]. All of them have been uploaded in the international platform Future Learn and are still running[7]. The multimedia content was also uploaded to Mediaspace[8] in order to make all the video contents available also in creative commons CC-BY SA open content.

The three MOOCS are focused on aspects developed in medieval archaeology classes and like a blended course, the MOOCs combine short readings with video lessons including high-quality images that echo traditional lessons with an instructor and slides (but in much more dynamic and condensed format); exercises (individual and participatory); videos of laboratories at the University of Padova; short lessons by specialists; and a couple of "trips" in the form of a video visit to some sites quoted in the course, under current excavation or research. Each "step" (which corresponds to a reading activity, video, or exercise) ends with an open forum in which students can leave comments or ask questions.

Delivered in English, the courses have attracted around 4000 students, many from anglophone countries (United Kingdom, United States, Canada, Australia) but also with good numbers from Europe, Africa, and Asia. The global reach of the internet, and in particular the ability of students from different time zones to access material at an appropriate time of day (unlike webinars broadcast during European daytime or early evening and therefore after midnight in other time zones), allowed a significantly increased internationalisation of the teaching process.

---

[6] Editor: Learning how to Teach, Teaching how to Learn. Facing Challenges of Global Change in Higher Education Using Digital Tools for Reflective, Critical and Inclusive. Learning on European Historical Landscapes. Erasmus+ GRANT_NUMBER: 2020-1-HR01-KA226-HE-094696.

[7] https://unipd.link/enlightening-the-dark-ages, https://unipd.link/HistoricLandscapeArchaeology, https://unipd.link/change_of_era.

[8] https://unipd.link/channel-enlightening-the-dark-ages.

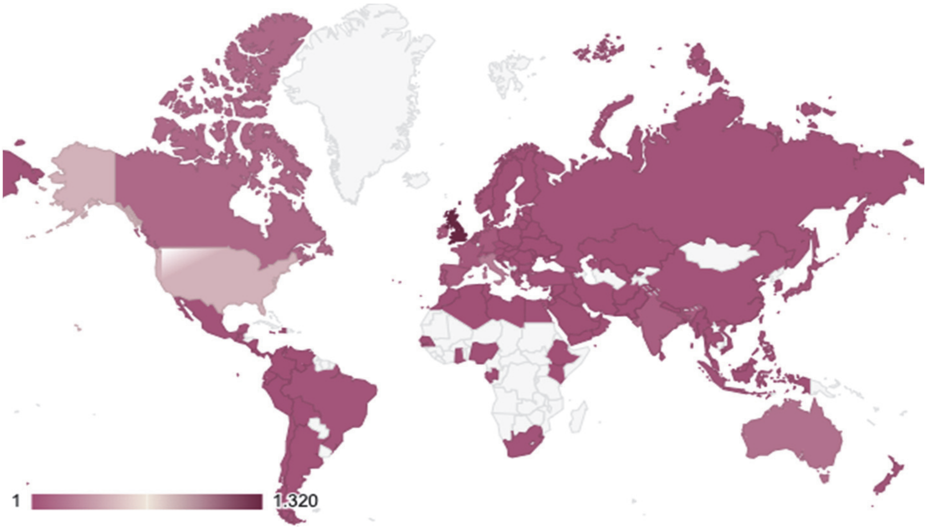


Fig. 2 - Global reach of the 3 courses of medieval archaeology produced by the University of Padova

The courses have received very positive feedback from attendees, who appreciated the innovative nature of the content, its multidisciplinary character, and the variety of exercises. However, the element that the students emphasized the most (and one important for an online course), was the strong component of interactivity between teacher-student and student-student, encouraged by the instructor through the "comments section" by answering student's questions, fostering discussions, and encouraging students to upload supplementary links to further material by acknowledging their contributions. Currently, more than 10,000 comments have been posted.

7. Bridging Gaps and Fostering Lifelong Learning in Italian Universities

Our MOOCs have been primarily designed to serve two main objectives:

1. Support for university Courses: Originally, these MOOCs were created to complement our university-level medieval archaeology courses. Each MOOC corresponds to one of our actual courses, including medieval archaeology, Christian archaeology, and landscape archaeology. They serve as valuable materials for the blended part of these courses, enhancing the in-class experience. Additionally, they function as interactive study materials for students who may not attend the in-person classes, providing them with a comprehensive learning resource.

2. Introductory Courses for Enthusiasts: Another critical role of these MOOCs is to act as introductory courses for passionate individuals, often retirees, who pursue archaeology for recreational purposes. These individuals display a strong interest in exploring the captivating world of archaeology, and our MOOCs provide them with an accessible and engaging avenue to satisfy their curiosity.

We are actively exploring a third function for future courses, which involves catering to professionals who completed their studies years ago but now need to update and improve their knowledge to acquire new skills and competencies that bridge the gap between their formal education and the evolving demands of the job market.

The rapid pace at which digital innovations and hard sciences are being applied to archaeological research underscores the necessity for field archaeologists and professionals in administration and museums to continually expand their knowledge base to remain competitive in their jobs or improve their career opportunities. Some of the critical areas in archaeology where we can offer insights and updates include: digital technologies for visualization of ancient buildings, materials, and landscapes; application of chemical studies, such as archaeometries and stable isotopes, to archaeological materials; biological analyses applied to human and animal bones, seeds, or pollens, shedding light on ancient ecosystems and lifestyles; and effective public engagement, among many others. Furthermore, archaeology is a field that continuously evolves due to ongoing discoveries from new excavations and new research – a wellspring of information and discussions that professionals can leverage to their advantage.

In recent years, there has been a growing call for education and training systems to foster and support accessible and inclusive learning opportunities to a broader range of individuals, offering innovative avenues for upskilling and reskilling in the context of prior work and life experiences to help individuals to remain employable and competitive,[9] something which also aligns with the social mission of universities[10].

---

[9] At an international level, UNESCO, the Council of Europe and the European Commission have played an active role in promoting lifelong learning for decades, but the 2030 Agenda for Sustainable Development (adopted in 2015) has reinvigorated this concept and reconnected it with its humanistic origins, in particular with one stand-alone goal – SDG 4 – which underlines inclusive and equitable quality education and promotes lifelong learning opportunities for all (Atchoarena 2021 - with further references on the subject of longlife learning).

[10] See Atchoarena (2021, pp. 314-315) for longlife learning as the "third mission" of the Universities but remembers also how low fertility rates implying a shrinking recruitment base and a fast-growing population of older adults, constitutes a further

8. Conclusions

This paper has explored the transformative impact of flipped learning (using online resources) and Massive Open Online Courses (MOOCs) in the context of higher education, with a specific focus on the field of archaeology. The implementation of these innovative approaches has not only improved student performance but has also enriched the educational experience by promoting engagement, inclusivity, and lifelong learning.

The development of blended learning methods, combining the advantages of online and in-person classes, has shown promise. Flipped teaching has proven effective in structuring lesson content, enhancing student learning, and improving competencies. Blending online material with in-person activities offers a dynamic and interactive educational experience.

Additionally, the creation of MOOCs on archaeology has not only expanded the reach of the course but has also revealed a global community of learners eager to participate in these lessons, raising questions about the potential impact of online education on lifelong training and skills development in the field of archaeology.

Italian higher education institutions should consider embracing a wider audience than classical students, offering lifelong and skills-based training to meet the diverse needs of learners at various stages of life, especially today seen the rapid evolution of new methods, instruments and knowledge that are transforming archaeological practice and interpretation. Furthermore, human and social sciences, such as archaeology, can play a vital role in preserving and promoting local culture while fostering a strong connection between academic institutions and their communities.

Blended methods and MOOCs can serve as effective tools in achieving these goals, providing interactive and accessible learning experiences. By continuously refining teaching strategies, incorporating feedback, and embracing technological advancements, educators can ensure that higher education remains dynamic, inclusive, and relevant in a rapidly changing world.

motivation for universities to find new “clients” and fields of action, such as targeting workers or senior citizens.

References

Al-Samarraie, H., Shamsuddin, A. & Alzahrani, A.I. (2020). A flipped classroom model in higher education: a review of the evidence across disciplines. *Education Tech Research Dev,* 68, 1017-1051. Doi: 10.1007/s11423-019-09718-8.

ANVUR report on higher education and research system published in June 2023: https://www.anvur.it/wp-content/uploads/2023/06/Sintesi-Rapporto-ANVUR-2023.pdf.

Atchoarena, D. (2021). Universities as Lifelong Learning Institutions: A New Frontier for Higher Education?. In: Van't Land, H., Corcoran, A., Iancu, D.C. (eds), *The Promise of Higher Education. Essays in Honour of 70 Years of IAU* (pp. 311-319). Springer.

Brogiolo, G.P. & Chavarría Arnau, A. (2020). *Archeologie PostClassiche. Temi, strumenti, prospettive*. Roma, Carocci.

Bligh, D. A. (1971). *What's the use of lectures?*. Middlesex, Penguin Education.

Carpenter, S. K., A. E. Witherby & S. K. Tauber (2020). On Students' (Mis) Judgments of Learning and Teaching Effectiveness. *Journal of Applied Research in Memory and Cognition,* 9 (2), 137-151. Doi: 10.1016/j.jarmac.2019.12.009.

Eyal, L. (2012). Digital assessment- the core role of the teacher in a digital environment. *Educational Technology & Society*, 15(2), 37-49.

French, S. & Kennedy, G. (2016). Reassessing the Value of University Lectures. *Teaching in higher Education*, 22(6), 1-16. Doi: 10.1080/13562517.2016.1273213.

Harvey, L. (2022). Back to Basics for Student Satisfaction: Improving Learning Rather than Constructing Fatuous Rankings. *Quality in Higher Education*, 28(3), 265-270, doi: 10.1080/13538322.2022.2050477.

Heffernan, T. (2022). Sexism, Racism, Prejudice, and Bias: A Literature Review and Synthesis of Research Surrounding Student Evaluations of Courses and Teaching. *Assessment & Evaluation in Higher Education*, 47(1), 144-154. doi: 10.1080/02602938.2021.1888075.

Kreitzer, R. J., Sweet-Cushman J. (2022). Evaluating Student Evaluations of Teaching: A Review of Measurement and Equity Bias in SETs and Recommendations for Ethical Reform. *Journal of Academic Ethics* 20(1), 73-84. Doi: 10.1007/s10805-021-09400-w.

Hattie, J. & Timperley, H. (2007). The Power of Feedback. *Review of Educational Research*, 77 (1), May, 81-112. Doi: 10.3102/003465430298.

Hornstein, H. A., and Law, H. F. E. (2017). Student Evaluations of Teaching Are an Inadequate Assessment Tool for Evaluating Faculty Performance. *Cogent Education*, 4(1), 1304016. DOI: 10.1080/2331186X.2017.1304016.

Patton, C. M. (2015). Employing Active Learning Strategies to Become the Facilitator, Not the Authoritarian: A Literature Review. *Journal of Instructional Research*, 4, 134-141. DOI: 10.9743/JIR.2015.17.

Prince, M. (2004). Does active learning work? A review of the research. *Journal of Engineering Education*, 93(3), 223-231. Doi: 10.1002/j.2168-9830.2004.tb00809.

Singh, J. Steele, K., Singh, L. (2021). Combining the Best of Online and Face-to-Face Learning: Hybrid and Blended Learning Approach for COVID-19. Post Vaccine, &

Post-Pandemic World. *Journal of Educational Technology Systems*, 50(2), 140-171. Doi: 10.1177/0047239521104786.
Stroebe, W. (2020). Student Evaluations of Teaching Encourages Poor Teaching and Contributes to grade Inflation: A Theoretical and Empirical Analysis. *Basic and Applied Social Psychology,* 42(4), 276-294. Doi: 10.1080/01973533.2020.1756817.
Wallace S. L., Lewis, A. K. & Allen, M. D. (2019). The State of the Literature on Student Evaluations of Teaching and an Exploratory Analysis of Written Comments: Who Benefits Most?. *College Teaching*, 67(1), 114, DOI: 10.1080/87567555.2018.1483317.

Computer and chemistry: Facilitating the learning process of the infrared spectra of water and carbon dioxide

Marco Bortoli*, Laura Orian^

Abstract
A computational laboratory is proposed for secondary school students to facilitate the learning process of the Infrared (IR) spectra of water and carbon dioxide. In the context of the greenhouse effect, which is the macroscopic phenomenon related to the rate of cooling of our planet in response of being warmed by the sun, students can learn its molecular origin with the support of computer through the simulation of the vibrational spectra of water and carbon dioxide. Input files as well as data are provided so that the laboratory can be proposed even when computational facilities are not available. In particular, the role of computer in chemistry teaching and learning is established because molecular models let the students visualize the subnanometric world which remains elusive in daily experience.
Keywords*:* carbon dioxide, computational activity, greenhouse effect, infrared, Johnstone's triangle, water.

First submission: 28/09/2023; accepted: 08/11/2023
Available online: 13/12/2023

Introduction

'Chemistry is difficult' is the frequent complaint of students. 'It's hard to teach chemistry' is commonly reported by chemistry teachers at all levels.

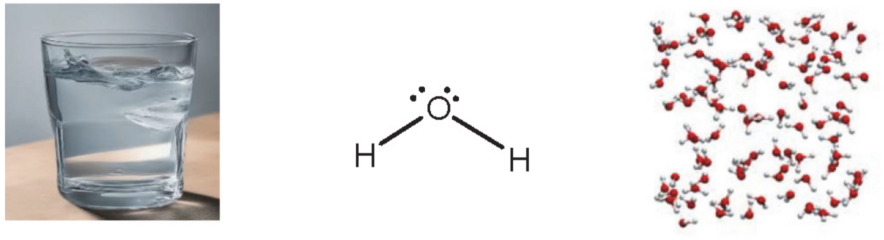
* Department of Chemistry and Hylleraas Centre for Quantum Molecular Sciences, University of Oslo, 0315 Oslo, Norway.
^ Dipartimento di Scienze Chimiche Università degli Studi di Padova Via Marzolo 1 35131 Padova Italy
Il contributo è frutto di un lavoro condiviso in ogni sua parte.
Ringraziamenti.

Excellence and Innovation in Learning and Teaching (ISSNe 2499-507X), 2023, 2

Doi: 10.3280/exioa2-2023oa16829

Johnstone (Reid, 2019, 2021) has well contextualized the difficulties in learning chemistry by observing that chemists can see things at three levels. Matter can be described in terms of its properties and behavior, which are observed with the senses. This is the approach children learn in their early childhood. But chemistry has a peculiar symbolic language which is used to describe these observations and this coding is part of chemistry educational programs. Finally, chemists draw explanations for the observed phenomena using atoms and molecules, which are not visible, because they belong to the subnanometric world. The invisible structure and organization of matter makes understanding a challenging effort. These three aspects of chemical knowledge are connected like the corners of a triangle (Jonhstone's triangle), but it is not trivial to establish such links and, in particular, the rationalization of phenomena through particle-level interpretation creates a true cognitive barrier for the students and represents perhaps the major challenge in chemistry learning (Johnstone, 2010).

Figure 1 - (a) Liquid water; (b) Chemical formula of water; (c) Snapshot from a Molecular Dynamics simulation of a sample of liquid water



(a) (b) (c)

In Figure 1, the case of water is shown: on the left, liquid water can be seen; in the middle, the chemical formula of water is written, which encodes in a universal language the message that water is a chemical substance characterized by identical composition independently from the different samples in which it is present, i.e., a drink, swamp mud or sweat. Finally, on the right, a snapshot of an atomistic simulation of water is shown, from which macroscopic physico-chemical properties of water can be inferred such as its liquid state at room temperature and pressure, its density, and its boiling point.

Also, for this simple and universally known example, it is not straightforward to link the three descriptions. In particular, Figure 1 (a) and 1 (c) show water at a different length scale, and the macro-sub nano transition is performed using computer modeling. Nowadays there are experiments that allow to 'see' atoms and molecules, thus providing a proof of concept to the particle nature of matter, but computer simulations have proved to be faithful and reliable tools to represent the features of the sub nanometric world. Yet, one should not forget that they are based on mathematical and physical equations and rely also on a well-defined coding. While the former can be almost ignored, at least at school level, the latter aspect deserves some attention because it can generate confusion and misconception, In Fig. 1 (c), each water molecule is formed by three spheres representing the three constituent atoms i.e., two hydrogens and one oxygen, connected by two identical segments representing the chemical bonds between each hydrogen and oxygen, The non-linear structure and the connectivity H-O-H (rather than H-H-O as erroneously suggested by the chemical formula H_2O) stem from complex physical concepts (quantum mechanics) or, alternatively, from an elegant chemical formalism (Lewis formulas, Figure 1 (b)) which allows to write chemical structures identifying the position and connectivity of atoms in a molecule without solving the electronic problem using quantum mechanical equations. In addition, the ball and stick representation and the color itself of the atoms are potential sources of misconception because they may erroneously suggest that atoms are colored spheres, bonds are rigid sticks, hydrogen is white and oxygen is red, and so on. Thus, the simulation allows to see the sub nanometric structure of water in a snapshot in analogous way to observing the fluid at macroscopic level, but the students must be aware of the representation code employed.

The example of water is a very simple case and is useful in the context of this work. In addition, it encompasses the great potential as well as the relevant issues related to the use of the computer in learning chemistry. Indeed, teachers can use the computer and technology in the class to stimulate curiosity and approach difficult concepts of chemistry at all three levels of Johnstone's triangle and this is the topic of the present work, which illustrates an example focused on the molecular vibrations of water and carbon dioxide through which they can take advantage of the computer in the class. This activity has been proposed on several occasions in the past years by the authors in very different circumstances, both to students from the secondary school and to chemistry undergraduates attending computational chemistry courses, after basic courses of physical chemistry. The level of detail was of course modulated on the level of knowledge of the students, but the approach is identical and includes the observation of the phenomenon, its representation, and its correct explanation; notably, not all three levels of Johnstone's triangle are necessarily introduced in the computational laboratory, depending on the age and chemistry background of the students, but are here discussed for completeness. Very recently, an accurate similar laboratory for undergraduates, including experimental and computational tasks, has been proposed by Hall and co-workers (Hall & Gunning, 2023).

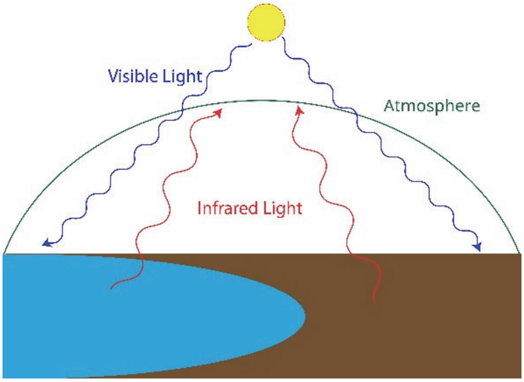
In this work, we will describe the computational activities as they can be proposed to secondary school students, who are less familiar with radiations and have no knowledge of quantum mechanics, providing all necessary data and advice to run the simulations also when not all computational facilities are available.

Discussion

The computational laboratory is intended for secondary school students (aged 16-18). It takes approximately four hours and should be organized in a computing room (or online). Students can work in small groups of 2-3 people. Ideally the teacher should introduce the topic of greenhouse effect, better if using open questions or brainstorming, or showing a video, or even involving the students in the construction of a small green house (one hour). In addition, due to its importance in modern society, global warming and its short and long-term consequences are a central topic of many scientific and political discussions and should be included in the introductory presentation. Quite often, global warming and the greenhouse effect are erroneously considered to be the same. On the contrary, the greenhouse effect is a natural phenomenon, which has allowed life on earth, whereas global warming is an effect caused by human emissions of greenhouse gases. Moreover, the greenhouse effect is explained to kids as well as to young learners who remain most of the times unaware of the physical chemistry behind it. Furthermore, quite often, it is related exclusively to carbon dioxide and/or to minor greenhouse gases, neglecting that the most important greenhouse gas is water vapor. The greenhouse effect is summarized in Figure 2 showing the sun radiation which passes through the atmosphere and warms the oceans and the lands, which in turn radiate infrared (IR) energy (heat) back to the atmosphere. Some gases can trap this energy, which remains inside the atmosphere. If the concentration of these gases in the atmosphere increases, more IR energy is trapped by the atmosphere, and this causes the global warming effect.

A second hour should be dedicated to the physical-chemical description using the symbolic language of chemistry. Focusing on water and carbon dioxide, the teacher should recall their chemical formulas and structure, introduce their three-dimensional geometry with molecular models, investigate the possible deformations from the equilibrium structure and their representations, review the electromagnetic spectrum and in particular the infrared region and the thermal effects of the infrared radiation. All these concepts are found in the school textbooks. It's the ability of the teacher to summarize them or to organize a more active lesson based for example on flipped classroom.

Figure 2 - The greenhouse effect



Finally, in the last two hours the students work in the computing room and through the guided protocol, which will be illustrated in this paper, visualize, interpret, and understand the molecular structure and vibrations of water and carbon dioxide molecules, from which the greenhouse effect originates.

Approaching chemical problems at macroscopic level

The teacher can introduce the topic by showing some images or videos or by proposing a brainstorming, aiming at defining what a greenhouse is and why it is used to cultivate crops and plants. Numerous examples can be found on the Web, but these are mostly videos which include 'the whole story' of the greenhouse effect, with an explanation adapted to the target public. The observation may efficiently be limited to the phenomenon which can be reproduced in a greenhouse, enforcing the concept that *the greenhouse effect is natural* and focusing on water vapor and carbon dioxide. When presenting the activity, the brainstorming approach seems suitable to let students share their thoughts and misconceptions emerge. The teacher can also involve the students in building a small greenhouse with jars or plastic bags, to let them reproduce the warming effect ("Modelling the greenhouse effect"). In Table 1, examples of general questions about the macroscopic problem are listed with their connection to scientific evidence and knowledge required to interpret properly the phenomenon.

Table 1 - General questions to start the introductory discussion

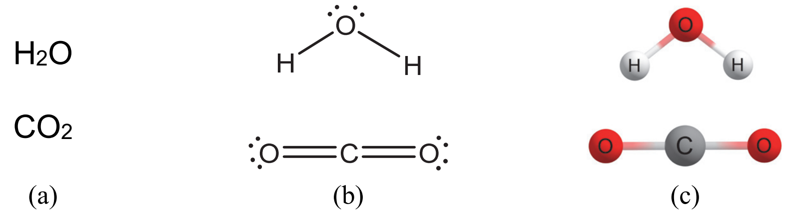
What is a greenhouse?	In a greenhouse, the temperature is higher and favors plants' lifecycle.
The electromagnetic spectrum	The sun light is an electromagnetic radiation. Bodies with higher temperature emit radiations with higher energy.
Infrared radiation and heat	Infrared radiation can be used to transfer energy in the form of heat
What is the role of atmosphere?	The atmosphere is like the glass of the greenhouse. It contains gases (including water vapor and carbon dioxide) which let the sun (body at higher temperature) radiation reach the planet, but trap (absorb) the IR radiation (heat) emitted by the earth.

Within this description, the greenhouse effect is apparently not related to molecular aspects and, although correct, the scientific knowledge remains a bit vague. The computational laboratory experience we have set up aims at explaining HOW the greenhouse effect results in trapping infrared radiation emitted from our planet and trapped by some gases in the atmosphere, focusing on water vapor and carbon dioxide.

Approaching the symbolic language of chemistry

When describing matter at molecular level, chemists use formulas i.e., a symbolic language which encodes different information. In basic chemistry courses, both at school and at the university, students learn to handwrite and sketch different chemical formulas of different complexity. In Figure 3, different chemical formulas of water and carbon dioxide are shown. Molecular formulas show the actual number of atoms within each molecule, while structural formulas represent how atoms are connected in the molecule. The strongest limitation is that the three-dimensional aspect of the molecules is lost. The computer is thus a valuable tool to visualize molecules as 3D objects and this aspect of this laboratory may inspire other activities, i.e., facilitate the 3D representation of molecules. Anyway, although 3D molecular representation is not the focus, it is important to stress that ball-and-stick models are not exactly a snapshot of the molecule, i.e., they are models which can be accurate and useful, but are representations of the real molecules. Thus, students must be aware of the information coding they are using, like atom colors, which are assigned based on Hofmann's croquet ball models (1865) and currently employed in the Corey-Pauling-Koltun (CPK) notation (Corey & Pauling, 1952; Koltun, 1965), stick representation of bonds, ball size, stick length and overall molecular shape which are rigid while real molecules at room temperature vibrate. Despite their simplicity, we can describe water and carbon dioxide and the procedure leading from their molecular formula to their 3D structure.

Figure 3 - Molecular formula (a), structural formula (b), and ball-and-stick representation of water and carbon dioxide



H_2O and CO_2 are the chemical formulas of water and carbon dioxide, respectively. Knowledge of the fundamentals of chemical bonding and Lewis theory, which is explained also in the textbooks of the secondary school, is mandatory to move from the molecular formula to the structural formula. Lewis representation gives reason also of the bent structure of water and the linear structure of carbon dioxide, respectively. Finally, the 3D structure can be built using the computer. The students can use the molecular editor Avogadro (Hanwell et al., 2012, 2023), which is a free software available for all platforms, and draw with the mouse each molecule in separated sessions. It is not important that the molecule is drawn with precision: Avogadro allows the pre-optimization of molecular structures, i.e., the automated modification of bond lengths, angles and dihedrals leading to the most stable structure.

Then, the molecular structure can be determined with increased accuracy by running a geometry optimization using quantum chemistry methods (DFT). For students at the secondary school, these methods can be used as a black box, because the formalism of quantum mechanics is beyond the curricula of their studies.

Approaching the sub-nanometric nature of matter

The third corner of Johnstone's triangle regards the sub-nanometric nature of matter i.e., its composition of atoms and molecules. This is the area in which the use of the computer can have the strongest impact as it allows to visualize 3D structures of atoms and molecules that compose matter. This experience aims at teaching students how to understand the role of water and carbon dioxide in the greenhouse effect through the analysis of their calculated IR absorption spectra.

Introductory notions on light and matter should be qualitatively explained based on the level of knowledge of the participants (Table 2). In particular, the students must understand that IR absorption is associated to energy transfer as heat and involves the interaction of light with matter. It causes rotations of the molecules of a sample and vibrations i.e., deformation of their structure, and is thus strictly related to the chemical nature of the sample. This interaction with the IR radiation explains the spectroscopic signals and the greenhouse effect as well. In fact, the greenhouse gases like water and carbon dioxide absorb the IR radiation emitted form the earth and the oceans and in turn re-emit it so that heat remains trapped in the atmosphere. The accumulation of heat causes the well-known warming, a phenomenon which has allowed the development of life on earth and still makes it possible but can lead to excessive raise of the temperature if the amount of greenhouse gases increases in an uncontrolled way. Thus, the resonance frequencies (vibrational energy) of the greenhouse gases fall in the IR energy range. At molecular level, not all vibrations are excited by (absorb) the IR radiation, but only those which are accompanied by a change of the molecular dipole moment. Therefore, elements of molecular symmetry showing the most common types of normal modes (symmetric and asymmetric stretching and bending, Figure 4) should be presented and their effect on the molecular dipole moment clarified.

Table 2 - Basic notions needed to understand the proposed activity.

Topic	Explanation
Molecular motion	Molecules are not fixed in space but move around by translating, rotating and vibrating. Each of these motions mode is made up of discrete (quantized) levels that can be visited by the molecule.
Normal Modes	A different set of coordinates. Each coordinate, instead of describing the position of an atom, describes a motion mode i.e., a particular translation, rotation, or vibration.
Molecular dipole moment	The vectorial sum of all bonds' dipole moments. Bond dipole moments can be defined recalling the electronegativity of the different atoms.
IR absorption	IR absorption involves energies that target molecular vibrations. It is detected only if the targeted vibration involves a change in the molecular dipole moment. It can be measured or calculated.

A full step-by-step procedure of the computational lab activity is reported in the Supporting information with all the inputs and outputs necessary. First, the free software Avogadro can be employed to draw and pre-optimize the molecules of water and carbon dioxide. If the computational software Gaussian (Frisch et al., 2016) is available, the students can carry out the calculations of the spectra inserting the coordinates obtained from the pre-optimization in the provided input templates (see Supporting Information) and calculate the IR spectra. In case computational facilities are not available, we have provided the results of the calculations (see Supporting Information). The obtained outputs can be visualized with the software ChemCraft (Andrienko, 2023) that shows the calculated molecular vibrations and the obtained IR spectrum. Each group can then analyze the different vibrational modes obtained from the calculation

(Figure 4). Table 3 shows an example datasheet that can be used to collect the results. The teacher can then proceed to discuss the results of one of the two compounds. Additional details on the physical properties of the vibrations can be highlighted and confirmed by the numbers obtained e.g., the fact that bendings are found at lower energies than stretchings or that normal modes that are equivalent by symmetry have the same energy. The second compound should be left as a test for the students to do on their own.

Figure 4 - Vibrational modes of water. In the stretching vibrational mode, the OH bond lengths can change in a symmetric fashion (a) or asymmetrically (b); the bending vibrational mode affects the HOH angle amplitude (c)

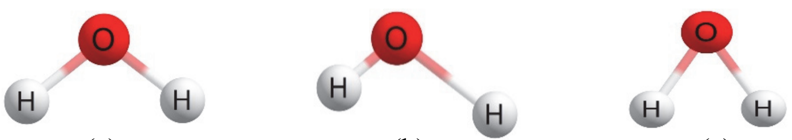


Table 3 - Example datasheet for the analysis of the calculated results

Compound				
Vibration nr.	Wavenumber	Intensity	Mode type	Visible in spectrum?
1				
2				
3				
4				

Evaluation and assessment

The evaluation of the activity is carried out by grading the report sheets (see an example in Table 3) for both compounds for each group. One point is given if the field is correct, none if not. A passing score of 60% of correct answers and an excellence score of 90% were used in the test sessions for the activity. We evaluated the activity on two classes of 21 and 24 students and in both around 90% of the students passed, with more than half exceeding the excellency level. The most common mistakes involved mainly the second compound that was carried out by the students without the teacher's guidance and regarded the recognition of the mode type. The aggregated results should be shared with the students to assess which were the most common errors and try to understand why the underlying concepts were not fully understood.

Finally, an open discussion should conclude the activity to put the calculations into the greenhouse effect context. Students should be asked to try and make a connection between the calculated IR spectra and the macroscopic greenhouse effect exerted by water and carbon dioxide. The teacher should act as a guide to make sure that the link between the molecular properties and the macroscopic effect they have in the greenhouse effect is clearly outlined. If there is a good response from the class, the discussion can be furthered asking the students to make predictions on the possibility of some of the other substances present in the atmosphere to be or not to be (this is the case of the abundant molecular oxygen and molecular nitrogen) greenhouse gases. Since typically students enjoy looking at molecular vibrations, exercises can be proposed to classify them for different molecules and predict if they are IR active. To this purpose, at the end of the lab, the teacher can propose to install an app on the mobile phone, MolAr ("MolAR"), which allows to visualize the vibrational normal modes of a lot of molecules with their classification and eventually prepare interactive exercises.

Conclusions and perspectives

The greenhouse effect is a good example of a pressing environmental challenge that can be used in a secondary school activity to explore all three levels of chemistry (Reid, 2019, 2021). Our computational laboratory aims at explaining the origin of this phenomenon through the calculation of the IR spectra of two fundamental components of the atmosphere, water and carbon dioxide, using a robust protocol. The procedure can directly show, using the symbolic language of chemistry, how the macroscopic atmospheric effects are caused by the intrinsic properties of microscopic objects.

The use of all three levels of chemistry in the same experience is often hard to find in secondary school curricula that usually focus on only one of the aspects, leaving students with a series of uncorrelated pieces of knowledge that are hard to assimilate. With the combination of calculations, that give access to the elusive microscopic world, and the introduction of more interactive teaching strategies actively involving students, we believe that it will be possible to create more effective chemistry programs encompassing all the corners of Johnstone's triangle that will result in enhanced competence and likely in students saying 'Chemistry is fun!' and teachers replying, 'It's a pleasure to teach chemistry!'.

References

Andrienko, G. A. (2023). Chemcraft - graphical software for visualization of quantum chemistry computations (Version Version 1.8, build 654). Retrieved from https://www.chemcraftprog.com.

Corey, R. B., & Pauling, L. (1952). Molecular Models of Amino Acids, Peptides, and Proteins. *Review of Scientific Instruments, 24*(8), 621-627. doi: 10.1063/1.1770803.

Frisch, M. J., Trucks, G. W., Schlegel, H. B., Scuseria, G. E., Robb, M. A., Cheeseman, J. R., . . . Fox, D. J. (2016). *Gaussian 16 Rev. C.01*. Wallingford, CT.

Hall, W. P., & Gunning, L. (2023). Physical Chemistry in Context: Using Quantum Mechanics to Understand the Greenhouse Effect. *Journal of Chemical Education, 100*(3), 1333-1342. doi: 10.1021/acs.jchemed.2c00550.

Hanwell, M. D., Curtis, D. E., Lonie, D. C., Vandermeersch, T., Zurek, E., & Hutchison, G. R. (2012). Avogadro: an advanced semantic chemical editor, visualization, and analysis platform. *Journal of Cheminformatics, 4*(1), 17. doi: 10.1186/1758-2946-4-17.

Hanwell, M. D., Curtis, D. E., Lonie, D. C., Vandermeersch, T., Zurek, E., & Hutchison, G. R. (2023). *Avogadro2: an open-source molecular builder and visualization tool*. (Version 1.97.0). Retrieved from https://www.openchemistry.org/projects/avogadro2/.

Johnstone, A. H. (2010). You Can't Get There from Here. *Journal of Chemical Education, 87*(1), 22-29. doi: 10.1021/ed800026d.

Koltun, W. L. (1965). USA Patent No. US3170246A.

Modelling the greenhouse effect. Retrieved from https://edu.rsc.org/experiments/modelling-the-greenhouse-effect/1543.article.

MolAR. Retrieved from https://mtzgroup.github.io/molar/about/.

Reid, N. (2019). A tribute to Professor Alex H Johnstone (1930-2017) His unique contribution to chemistry education research. *Chemistry Teacher International, 1*(1). doi: 10.1515/cti-2018-0016.

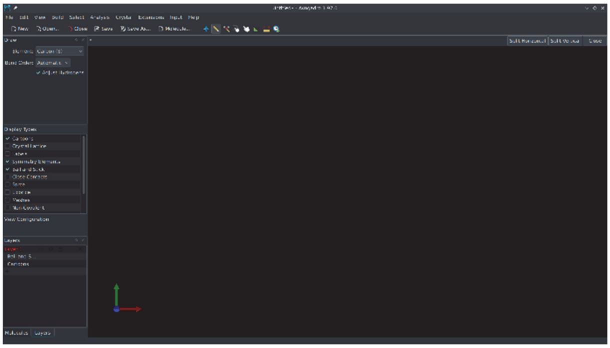
Reid, N. (2021). *The Johnstone Triangle: The Key to Understanding Chemistry*. The Royal Society of Chemistry.

Appendix

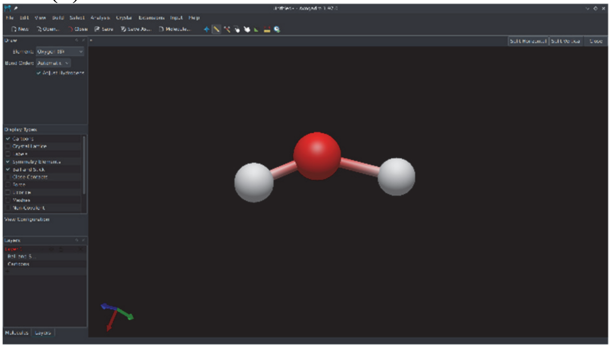
IR Spectra calculation procedure

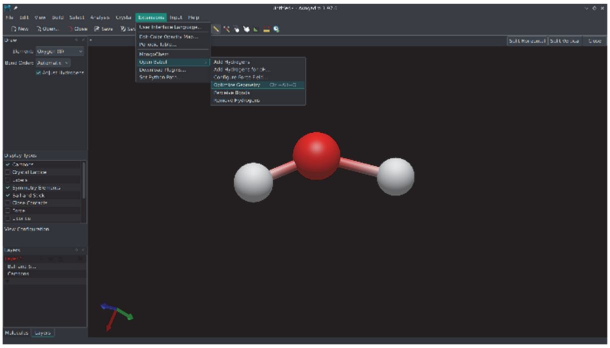
To calculate the IR spectrum of water or carbon dioxide the first step is to create the 3D model of the molecule. The free software Avogadro (https://www.openchemistry.org/projects/avogadro2/) will be used to draw the spatial structure of the molecule and then pre-optimize the geometry with the in-built force field engine. After launching, Avogadro presents a black window where molecules can be drawn (Figure S1, a). Using the pencil tool atoms of different elements can be added (Figure S1 b). As the drawn molecular structure is usually not good, a pre-optimization is carried out that should bring the molecule closer to its equilibrium geometry (Figure S1, c). The coordinates of the pre-optimized structure can be extracted and used for the DFT calculation using Gaussian (Figure S1, d).

Figure S1 - Avogadro 2 steps to obtain the initial pre-optimized coordinates of water. Initial Avogadro 2 screen (a); Drawing tool to insert the required atoms (b); Force field geometry optimization menu (c), and cartesian coordinates editor (d)

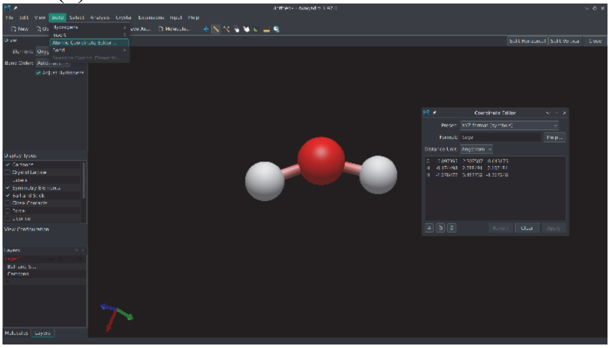


(a)





(c)



The actual IR spectrum is calculated at the DFT level with Gaussian. The template input for the calculation is the following:

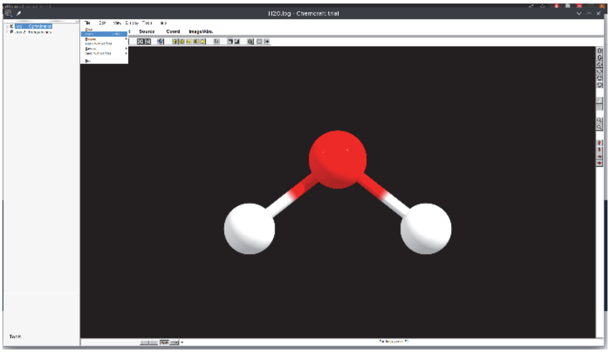
```
%mem=8GB
%nprocshare=8
%chk=opt.chk
#p b3lyp/6-311G(d,p) opt freq

title

0 1
O     -0.032562940    0.000000000    -0.421603299
H     -0.032562940    0.759337000     0.174439701
H     -0.032562940   -0.759337000     0.174439701
```

The first line is the amount of RAM requested for the calculation, the second the number of CPUs, and the third the name of the checkpoint file that will be created. These can be changed in relation to the available computational resources. The line starting with #p is the so-called *route* and it contains all the parameters for the calculation. In this case the functional B3LYP and the basis set 6-311G(d,p) are chosen. In addition, a geometry optimization (opt) and a frequency calculation (freq) are requested. The route line is followed by a blank space, the title line that contains the name of the calculation, and by the molecule specification. The latter starts with a line containing the charge (0) and the multiplicity (1 for a singlet) of the molecule and is followed by the molecular coordinates. In this example the coordinates for a molecule of water are reported. They can be substituted with the coordinates of the molecule for which the IR spectrum must be calculated. **IMPORTANT:** the use of blank lines in Gaussian is very precise and exactly one blank line must separate route from title and title from molecule specification. Moreover, the input file must always end with a blank line otherwise the calculation will not run.

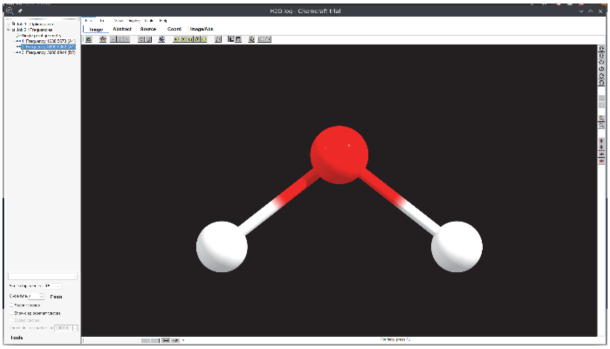
The gaussian calculations can be run by executing the g16 command on the created input file. It will create a text file with .log extension. If the calculation correctly ended, the last line of the .log file should read "Normal termination of Gaussian". In case the Gaussian software is not available we have provided the output files as supplementary material.

The outputs can be opened with the software ChemCraft (https://www.chemcraftprog.com) to visualize the molecular vibrations and the IR spectrum. ChemCraft is a paid software that offers a trial period and can therefore be downloaded and used for free for a period of 150 days. The main steps needed to open the Gaussian results and visualize the vibrations and IR spectrum are reported in Figure S2.

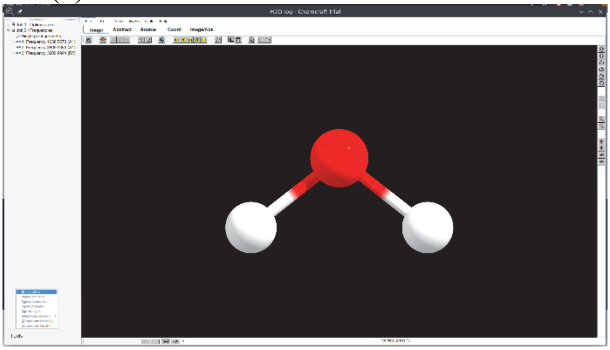
Figure S2 - ChemCraft steps to visualize the molecular vibrations and the IR spectrum. Initial ChemCraft screen and open file menu (a), molecular vibrations list under Frequency section in the left-hand side of the screen (b), the spectra visualization menu available when the entry Frequencies on the left hand side is selected (c), and the IR spectrum visualized from ChemCraft (d)



(a)



(b)



(c)

Amministrazione: v.le Monza 106 - 20127 Milano - Tel. 02/2837141 - Fax 02/26141958 - e-mail: riviste@francoangeli.it

Autorizzazione del Tribunale di Milano n. 42 del 8.02.2016 - Direttore responsabile: Stefano Angeli - Semestrale - Copyright © 2023 by FrancoAngeli s.r.l., Milano, Italy. II semestre 2023, finito di stampare dicembre 2023.

Stampa: Global Print srl, via degli Abeti 17/1, Gorgonzola, Milano.

ISSNe 2499-507X

FrancoAngeli
La passione per le conoscenze

Ediizione fuori commercio