Teacher education is a deeply pedagogical process rooted in values, ethics, and the social purpose of schooling. Globally, it sits at the core of educational quality and fairness, as research in comparative and international education demonstrates: the training of teachers directly influences students' learning chances, social inclusion, and the democratic aims of schools. Teachers are not simply transmitters of curricula, but active professionals whose convictions, reflective skills, and ability to manage the complexities of classroom life give shape and substance to the educational experience itself.

The pedagogical dimension of teacher education frames teaching as a relational, context-aware, and ethically grounded profession rather than just a set of procedural skills. From a research perspective, this demands robust research methodologies that can critically examine the complex realities of schools and inform evidence-based policies. Equally important is the connection between theory and practice, which helps to bridge the persistent gap between universities and schools.

The contributions gathered in this volume reflect the richness and diversity of experiences showcased during the ATEE Spring Conference 2024, held at the University of Bergamo from May 29 to June 1, 2024. The volume presents 70 selected papers out of more than 300 presented by researchers representing over 40 countries.

This broad spectrum of studies highlights promising directions that can inspire renewed inquiry and concrete proposals aimed at improving contemporary educational systems.

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ATEE Spring Conference 2024

# ATEE Spring Conference 2024

# Teacher education research in Europe: trends, challenges, practices and perspectives

May 29th – June 1st, 2024
S. Agostino, Bergamo

Edited by Nicole Bianquin and Francesco Magni

UNIVERSITÀ DEGLI STUDI DI BERGAMO

2025

UNIVERSITÀ DEGLI STUDI DI BERGAMO | Dipartimento di Scienze Umane e Sociali

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BOOK OF PROCEEDINGS

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# Digital technologies and collaborative activities for science teaching in the upper secondary school: a qualitative study on teacher's perspective

Alice Roffi, *University of Florence,* alice.roffi@unifi.it

## Abstract

Currently science teaching is facing a challenging moment, in which the main literature evidence claims the need for student-centered approaches, giving more emphasis on the active role of students in knowledge co-construction and on experience with real life problems. This qualitative research describes the design and implementation of the educational scenario on chemistry learning in a secondary upper school, analysing the perception of teachers reported in the reflective diary and in the interview. The results reported positive perception of teachers of educational activities carried out that produce benefits on students learning and teacher's competence. The approach presented seems to have potential for improving science learning and further studies are needed to understand its effect in different contexts and with different science topics.

**Keywords:** science learning; technology; simulation; collaborative learning; secondary school.

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## 1. Introduction

Currently science teaching is facing a challenging moment, in which the main literature evidence claims the need for student-centered approaches, giving more emphasis on the active role of students in knowledge co-construction and on experience with real life problems (Al-Balushi, et al. 2023). As underlined by Fiorentini (2018), one of the aspects that contribute to the crisis of science teaching is related to the contrast between the mainly transmissive strategy used in class with the laboratory and problems based teaching able to involve students and promote learning and scientific skills (Fiorentini, 2018; Jeong, et al., 2019). The switch towards a more student centered approach is not easy to implement and represents a critical issue for teachers of secondary school, in terms of their readiness to perform such a change, since how to teach science turns out to be one of the major training needs (Eurydice, 2022). Regarding the resources to sustain this student-centered strategy, the digital tools provided several advantages in science teaching (Hillmayr et al., 2020, Correia et al., 2019, Landriscina, 2013; Kim and Jin 2022): the simulation-based learning can lead to several benefits and can improve students understanding of concepts, especially the more abstract ones (Correia et al., 2019). Furthermore, the meta analysis of Hillary and collaborators (2020) underlined that a larger effect size on learning outcomes was obtained using dynamic tools for mathematics and for intelligent tutoring systems, together with simulations programs (as software for geometry), while medium effect on learning outcomes was reported for the simulations of virtual laboratories. An interesting aspect is the greater effect on learning gain detected when students collaboratively worked in pairs with digital tools (Hillmayr et al., 2020). In the constructivist perspective, the digital technologies are cognitive tools, that can (i) support cognitive processes, especially those of lower level, thus lightening the cognitive load, (ii) involved students in cognitive activities that cannot be implemented otherwise and (iii) sustain the performance of problem-solving activities, thus allowing students to generate and test hypotheses (Lajoie, 2000).
Based on these premises, the approach adopted in this research foresaw the design of collaborative activities for science learning in the context of upper secondary school. The students experienced the social co-construction of knowledge (Vygotskij, 1978) with the use of digital, intended as a "cognitive tool", supporting students' cognitive processes (Lajoie, 2000; Ranieri, 2011). This study documented the perception of the teacher on the designing and implementation of the educational scenario based on collaborative activities supported by technology for science learning, focusing on the positive and critical aspects emerged during the activities that impacted both students' learning and the teacher's competences.
The Research Questions (RQs) that guided the study are the following:
RQ1: If and to what extent a collaborative methodological approach supported by technology can promote students' learning?
RQ2: If and to what extent a collaborative methodological approach supported by technology can promote further beneficial impacts on students and the teacher?

## 2. Methodology

### *2.1 The co-design of educational scenario*

In 2023, the teacher and researcher co-designed the educational scenario, using a digital game, supporting the conceptualization phase of the design (Ceregini, et al. 2019). It was then implemented in one class of the 4th-level of an upper secondary school of the Liguria region (Italy) during February - May 2023 (n° students 11, 2 females and 9 males, mean age= 17,82). The co-design process was divided into three steps:

- The first step involved theoretical training for teachers, held by the researcher, on the topics of LD and the planning of collaborative activities supported by digital technologies. Furthermore, the tools to support the design were presented, also providing practical activities for their use, to make the teacher confident in their use;

- The second step aimed to define the learning objectives, the content of the teaching activity and choose the best pedagogical strategy, also considering the different contextual constraints. This phase is defined in the literature as "conceptualization" (Pozzi, et al. 2016). For this phase, a digital game was used, the 4Ts game. This game supported the teacher in the definition of the 4 dimensions of the model: Task (activities to be completed), Time (the timeline of the activities), Team (the size of the group) and Technology (the technological resources necessary to complete the activity);
- The third step involved further in-depth design level, using a specially structured template, to explain in detail the structure of the modules, their duration, the related phases, specifying what the teacher does and what the student does in each teaching sequence.

The educational scenario designed in this phase dealt with the chemical theme of Acids and Bases and it was structured in three Modules as described below:

- In Module 1, the students are involved in the proposal of a laboratory procedure aimed at recognizing which is a strong electrolyte and a weak electrolyte, also executing this procedure in the laboratory. The teaching strategy is the collaborative peer review, in which students are divided in groups to develop the procedure and then each group revise the procedure of another group;
- In Module 2, the students are engaged in participatory lectures and practical laboratory tests on the main chemistry theories on Acid and Bases topic (as, Arrhenius, Bronsted and Lowry, Lewis), and on the main concepts related to pH (as definition, calculation of the pH of strong/weak acids and bases). The teaching strategy is the heuristic lessons;
- In Module 3, students are encouraged to transfer the knowledge acquired into the real context, through the collaborative production of a report on buffer solutions in the human body. This activity foresees a first step of searching for information online, followed by the discussion on their relevance and the final production of a report. Similarly to Module 1, the teaching strategy adopted was the collaborative peer review.

In this scenario, digital technologies are used to support the following processes: (i) The development of a laboratory procedure to recognize strong electrolyte from weak one (Simulative technology, Phet Simulation, to support the concept understanding); (ii) The identification of the key concepts of a topic (Interactive presentation, Mentimeter, to support the process of discussion); (iii) The concepts synthesis (Collaborative board, Padlet).

### *2.2 Tool for data collection*

The qualitative tools used for data collection were the reflective diary and the semi-structured interview.
The reflective diary was a tool for the documentation *in itinere* of the implementation phase of Acids and Bases scenario, guiding the teacher in the reflection about three moments of scenarios implementation:

- Before activities implementation: focusing on resources preparation, underlining the usefulness of them and the eventual further needs;
- During activities implementation: focusing on the following aspects, significant learning situations happened during the scenarios, students' participation, and technological support;
- After implementation: focusing on suggestions for future implementation.

The semi-structured interview was performed at the end of the scenario implementation in order to go deeper into the teacher's perception of the methodology used to design and conduct the educational scenario, the effects on the students as well as further positive aspects or critical issues emerged in the reflective diary. The interview was carried out on Zoom platform following the stimulus questions:

1. In general, how do you think the implementation of the educational scenario went?
2. What were the positive/critical aspects? Any learning situations to report?
3. What was the reaction of the students?
4. In your opinion, was the course effective in terms of learning science?
5. Can the approach used, i.e. collaborative activities integrated with technologies, also be effective for other science topics you teach?
6. Has your approach to design collaborative activities changed compared to before, and if so in what aspects in particular?
7. How did the integration of digital technologies go during the activities?
8. Were they helpful or did they hinder learning?
9. Would you propose this route again next year? If so, what would you change?
10. Is there anything else you would like to add?

### *2.3 Data analysis*

Qualitative data analysis of the reflective diary and semi-structured interview was carried out with the web app QCAmap. From a methodological point of view, these qualitative data were analysed following the procedures for thematic analysis by Braun and Clarke (2006).
Regarding the reflective diary, an inductive analysis was conducted based on a data-driven coding procedure with themes resulting from the data (Braun & Clarke, 2006). As for the semi-structured interview, the analysis followed a deductive approach: the categories identified in the analysis of the reflective diary were used for the analysis of the interview (Braun & Clarke, 2006). The interview indeed went deeper into the elements that emerged from the reflective diary. As well-known, the approach of deductive analysis is driven by the researcher's theoretical or analytical interests in the area (analyst-driven) (Braun & Clarke, 2006).

## 3. Results

### *3.1 RQ1: If and to what extent is a collaborative methodological approach supported by technology able to promote students' learning?*

To answer RQ1, the categories "Impact of collaborative activities", "Support of technologies and critical issues" and "Challenges faced by the teacher and suggestions" derived from the analysis of reflective diary and interview were considered.
Regarding the category "Impact of collaborative activities", teacher explained that the collaborative activities supported by technologies had positive impact on students learning outcomes, demonstrating by the high grades reached by them in the final test with only 3 students that did not reached the minimum learning objectives and the others obtained good results (From the interview "*I did a test and it went well, I practically only had 3 failures and I got one 10, even though she/he is already very good, some 9, some 8 and then three students that reached the minimum objectives*").
Another important positive moment occurred when students developed the laboratory procedure in group, that led to the correct interpretation of the experimental results with a theoretical model (From the diary "*Almost all of the students managed to interpret the experimental data with a conceptual model, thus making the connection between macro and micro which is one of the cornerstones of the study of chemistry*").
Moving to the category "Support of technologies and critical issues", the teacher reported that digital technologies were very helpful for students, both as a support for the learning process and as a means to keep the attention high: the simulative platform used (Phet Colorado) helped them in understanding the microscopic level of the phenomena, while the use of interactive presentation (Mentimeter) permitted to focus much more on the key concepts of the Acids and Bases topic (From the diary "*The use of simulation programs is certainly of great help in visualizing and understanding the microscopic aspect of the phenomena. One of the most notable difficulties in the study of chemistry is in fact the capacity for abstraction and correlation between macro and micro*"). The interview confirmed this aspect, underlining also that technology makes chemistry learning easier.

Finally, considering the category "Challenges faced by teacher and suggestions", the teacher documented that during the implementation of educational scenario, the main critical issue faced was to follow the frailer students in the process of deductive reasoning, and this was done offering a proper scaffolding (From the diary "*The main challenge was to lead the most vulnerable students to deductive reasoning and was addressed by guiding the students step by step*"). Another difficulty was having to deal with some shortcomings in multidisciplinary skills, as mathematical skills applied in a different context. Thus, the teacher had to guide these students to the solution, addressing also these mathematical difficulties.

### *3.2 RQ2: If and to what extent does a collaborative methodological approach supported by technology promote further beneficial impacts on students and the teacher?*

To answer RQ2, the categories "Impact of collaborative activities", "Further Aspects", "Management of educational activities" derived from the analysis of reflective diary and interview were considered. Regarding the category "Impact of collaborative activities", the teacher reported that the collaborative activities had a positive impact on students, permitting the expression of shyer students (From the interview "*For example, I noticed some guys who managed to get unstuck. I am referring in particular to two students who are shy, who are really afraid to say things, in this way I have seen them grow*"). In the category "Further Aspects", it was reported that in general the educational scenario led to active participation of students, even though in the final phases of the it decreased due to the tiredness of students in the last period of school year (From the diary "*Although the class is generally active during lessons, a certain tiredness and difficulty in concentrating was noted. However, this is normal considering that, at the end of the year, the workload inevitably increases*"). Accordingly, some difficulties were faced by the teacher during the educational scenario, and they were related to a group of students that didn't work with a proper commitment (From the diary "Only one group worked superficially and was recalled several times").

Considering the positive impact on the teacher herself, she perceived an improvement in her design competence, indicating a greater understanding than before of how to design and implement a collaborative activity (From the interview "*So I would say that it went well, the positive aspects let's say that it was above all for me that I learned to better structure what could be a teaching unit"*).

Finally, the category "Management of educational activities" described the dynamic of educational activities, highlighting the deviation with respect to the initial design and the subsequent adaptation of the educational scenario according to the needs. So, these elements contribute to identifying the positive dynamics and the hurdles faced in favour of the future designs and conduction of educational activities. In the first module, not all laboratory procedures entered in the peer review process, since many students were absent during that activity. For this, the teacher added an hour to update these students on the previous step, otherwise they cannot be able to carry out the subsequent activities. In the third module, it was not possible to carry out all the foreseen activities, due to the few hours available and to the tiredness of students at the end of the school year, reported both in the reflective diary and in the interview. However, the teacher provided students with a list of references to use for completing the report on buffer solutions in the human body.

| Category | Description | Anchor Sample of Reflective Diary | Anchor Sample of Semi-structured Interview |
|---|---|---|---|
| **Management of educational activities** (RD: 16; I: 4) | In this category are coded all the phrase or clause referring to the modality of teachers of managing the educational activities | *The groups were decided by the teacher trying to put together students with the same level of ability. No specific figures were identified. In the first part the students worked in their places. For collaborative activities the class was organized into islands by joining the desks.* | *(...) the part of acids and bases in the human body, we had expected them to do the research online, but since we arrived a little too close to the end of school, my colleague gave some ideas, (...) and we made a padlet with all the references they looked for* |
| **Impact of collaborative activities** (RD: 15; I: 6) | In this category are coded all the phrase or clause referring to the impact of collaborative activities on students, in terms of learning, engagement and interest | *The group work was certainly fruitful, and I believe that some managed to unlock their reasoning skills.* | *Precisely related to this fact, there were two guys who were really passionate about this thing and so when I showed the group's work, I saw that some of them were really engaged.* |
| **Support of technologies and critical issues** (RD: 5; I: 6) | In this category are coded all the phrase or clause referring to the use of technologies during the educational activities, highlighting benefits and drawbacks | *Technologies are also welcome tools that allow us to keep our attention alive.* | *In general, we were already using them, because maybe they used videos, simulations so the kids are quite used to it, it's certainly their language.* |
| **Challenges faced by the teacher and suggestions** (RD: 6; I: 2) | In this category are coded all the phrase or clause referring to the challenges faced by teacher and the suggestions for future improvements | *The main challenge was to lead the most vulnerable students to deductive reasoning and was addressed by guiding the students step by step.* | *Unfortunately, the only thing that happened in my opinion is that since we did it a little late in the year and the students were tired and therefore I had a little difficulty keeping their attention alive* |
| **Further aspects** (RD: 0; I: 2) | This category is foreseen only for the Semi-structured Interview to collect all the elements of the text that not fit the other categories | - | *Let's say that until now planning was done on topics. And therefore, without going into such detail about the things to do. But I recognized that planning done this way, which takes a lot of time, is certainly more effective.* |

*Table 1: Category emerged from the inductive analysis of the Reflective Diary (RD) of teachers used also for the deductive analysis of the Semi-structured Interview (I). Numbers in brackets refer to the frequencies of the coded extracts.*

## 4. Discussion and conclusion

The results of the current study documented positive results for students and teachers. Considering the learning dimension of the RQ1, the teacher perceived an improvement of students' learning demonstrated by the high value reached by the overall students in the final test, and by the important results in the understanding dimension, connecting the experimental results with the theoretical model. This latter was further supported when using digital technologies, particularly referring to the simulation Phet Colorado, that permitted the visualization phenomena not easily explored in the real context. The use of the simulation in science learning was documented in the literature, for the possibility to understand the more abstract concepts. In fact, one of the useful features of digital technologies in supporting scientific learning is related to the possibility to visualize objects, phenomena or reactions otherwise difficult to observe, for promoting learning (Kim & Jin, 2022). Correia and collaborators (2019) described the use of Phet simulations for another chemistry topic, gas behaviour, that makes the understanding of the gas behaviour at microscopic level, through the change of variables and the observation of the relative effects (Correia et al., 2019). In this perspective, for Landriscina (2013) the interactive characteristic of simulation is the discriminating element from other forms of knowledge representation and underlines its potential to create a relation of interpretation and synergy between the human mind and the computer: using a simulation, the students generally interact indirectly with the model through the mediation of the program interface (Landriscina, 2013).

Another aspect that emerged is related to the positive impact of collaboration among students, especially on shyer students, that in this context were able to express themselves. In fact, as reported in the literature, collaborative activities require mediation during their execution (Jeong, et al., 2019; Ranieri, 2022): in this context, the scaffolding provided by teachers for frail students or to support specific reasoning processes may facilitate the collaboration among students. Moreover, the literature highlights numerous benefits of involving students in these student-centered strategies, as the collaborative learning activities (Al-Balushi, et al. 2023; Day and Bryce, 2013; Johnson and Johnston, 2003). In addition to positively impacting learning (Day and Bryce, 2013), they enhance the development of additional skills, such as sharing ideas, active listening, and problem-solving (Johnson and Johnston, 2003).

In conclusion, the present qualitative research described a positive perception of teachers of the approach used for the design and implementation of collaborative activities supported by technology in science learning. The approach involved students that highly participated, also leading to benefits in chemistry concept understanding (especially the comprehension of the relation between microscopic and macroscopic level), and collaboration among peers. According to teachers' perception, in this scenario, the technology offered a valid support to students' cognitive process and facilitated the concept learning. The teacher also perceived a positive impact on their competence both in terms of how to design collaborative activities in science learning and in terms of their conduction in class, supporting students when needed. Some critical aspects also emerged: one of these was supporting the weaker students in the process of deductive reasoning, which was addressed by providing appropriate scaffolding (particularly guiding them step by step in the reasoning process). Another issue was the decline in students' attention toward the end of the educational scenario, although it remains unclear whether this was due to the specific activity or the time of the school year. Despite these shortcomings, the approach seems to have some potential for enhancing science teaching and learning, but further research is needed to evaluate its impact in different contexts and on various science topics.

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