



UNIVERSITÀ  
DEGLI STUDI  
FIRENZE

# FLORE

## Repository istituzionale dell'Università degli Studi di Firenze

### **Teachers' perceptions on stem teaching with digital technologies in the lower secondary school**

Questa è la Versione finale referata (Post print/Accepted manuscript) della seguente pubblicazione:

*Original Citation:*

Teachers' perceptions on stem teaching with digital technologies in the lower secondary school / Alice Roffi; Stefano Cuomo; Gabriele Biagini. - ELETTRONICO. - 1:(2023), pp. 6136-6141. (Intervento presentato al convegno 17th International Technology, Education and Development Conference Valencia, Spain. 6-8 March, 2023. tenutosi a Valencia (SPAIN) nel 6-8 March 2023) [10.21125/inted.2023.1622].

*Availability:*

This version is available at: 2158/1344793 since: 2024-04-26T08:05:14Z

*Publisher:*

IATED

*Published version:*

DOI: 10.21125/inted.2023.1622

*Terms of use:*

Open Access

La pubblicazione è resa disponibile sotto le norme e i termini della licenza di deposito, secondo quanto stabilito dalla Policy per l'accesso aperto dell'Università degli Studi di Firenze (<https://www.sba.unifi.it/upload/policy-oa-2016-1.pdf>)

*Publisher copyright claim:*

(Article begins on next page)

# TEACHERS' PERCEPTIONS ON STEM TEACHING WITH DIGITAL TECHNOLOGIES IN THE LOWER SECONDARY SCHOOL

A. Roffi, S. Cuomo, G. Biagini

*University of Florence (ITALY)*

## Abstract

Scientific knowledge and skills are key aspects needed to be active citizens able to make informed decisions regarding scientific questions that may arise from everyday life and in this respect, formal education plays an important role. However, the Italian context showed a low level of scientific competence and knowledge in students of secondary schools. An appropriate integration of digital technologies into STEM teaching practice may help in promoting learning retention and interest towards the discipline, thanks to the several affordances of Information and Communication Technology (ICT) for STEM education. This study explored teachers' experience and perceptions of STEM teaching collecting data about their practices, and their perception of opportunities and challenges of using ICT. With the support of the Scholastic Office of Tuscany, a survey was carried out through an online questionnaire addressing Italian STEM teachers and including questions on their experience in STEM Teaching and on their use of Digital technologies. The questionnaire was filled in by 234 Italian teachers on a voluntary basis. The results reported the description of teachers' practice for STEM teaching, in particular showing the widespread use of Guided Discovery strategies and the main challenges they faced to stimulate students' interest in the discipline. Teachers believe that the major difficulty that students encounter is the transfer of knowledge to the real world. From a technological point of view, teachers often integrated them during STEM lessons, while those not using them claimed the difficulty in accessing technological tools in the Institute and the lack of confidence in the use of technologies for teaching. Thus, these results highlighted, on one side, the teachers' need for an improvement of the infrastructure of the institute and, on the other side, a need for training about the integration of digital technologies into the teaching practice, thus overcoming the challenges and hurdles they faced in their current practice. This requires an approach that involves the whole Institute, creating synergy and collaboration between all school actors.

Keywords: STEM teaching, ICT, Teacher's perceptions.

## 1 INTRODUCTION

Scientific knowledge and skills are key aspects needed to be active citizens able to make informed decisions regarding scientific questions that may arise from everyday life. Formal education plays a fundamental role to develop STEM (Science, Technology, Engineering, Mathematics) literacy and promote scientific culture among the new generation [1]. However, the Italian context showed a low level of scientific competence and knowledge in students at secondary schools compared with other OECD countries (e.g. PISA, 2018), particularly referred to students' ability to explain scientific phenomena, evaluate and design scientific research, interpret data and evidence, and use their knowledge in new situations [2]. Besides, another critical aspect reported in the literature is the progressive decrease in interest and motivation in science learning during and beyond lower secondary school [3] [4], which may be linked to the difficulties identified in science learning, as the abstract nature of certain topics requiring the direct observation of phenomena [5] [6].

In this perspective, the literature has highlighted that an appropriate integration of digital technologies into STEM teaching practice may help face these issues for the several affordances of Information and Communication Technology (ICT) for STEM education [6] [7] [8]. In fact, the possibility to exploit the visual component for teaching scientific concepts or phenomena not easily explored in the classroom may provide, under certain circumstances, an added value [6] [9]. More in detail, the use of innovative technologies in STEM teaching, as X-Reality (including virtual reality, augmented reality and mixed reality), can positively impact students, in terms of improvement of motivation and interest towards the disciplines, learning outcome and cognitive load reduction, making easier the processing of complex experiments [4] [5] [6] [8] [9] [10].

Unfortunately, the use of technologies presents some hurdles, both from technical and pedagogical point of view, as emerged during the pandemic period [11] and documented in previous reports as Teaching and Learning International Survey (TALIS) 2018 [12] [13]. More specifically, even before the pandemic period, the OECD data on TALIS shows that in Italy the 17% of teachers in the lower secondary school claimed a high need for professional training on ICT for teaching, in agreement with the average percentage of OECD countries (18%) [12].

From teachers' side, an important concern in science teaching relies on their readiness for STEM education rethink and redesign, since actually it is moving from traditional instruction approaches mainly based on knowledge acquisition to strategies that give much more space on experience with real problems of daily life and to permit students to actively participate in acquiring knowledge [5] [14]. In fact, among those active strategies, Inquiry Based learning (IBL) is gaining increasing attention as a strategy for STEM teaching and its efficacy has been demonstrated by several studies, also supported by technologies [6] [8] [15]. IBL involves students in similar processes of scientists, formulating hypotheses, testing them through observation or experiments and reaching the final reflection phase that could represent the end of the process or could give a start to another cycle of generation of hypotheses and testing [15]. However, this strategy could present some difficulties during their phases, which could hinder their application both from students' and teachers' perspectives, especially during the design phase [16] [17]. Therefore, the possibility to integrate digital technologies in IBL strategy has been demonstrated to provide the proper support to overcome this issue [17].

Thus, considering the role of teachers in this complex scenario, it is important for pedagogical innovation to focus on their attitudes and beliefs towards STEM teaching and the support that technologies may offer in the STEM area, identifying the positive and critical aspects also in order to improve the training practices. The importance of professional training and the need for the proper pedagogical (i.e. instructional, assessment tools) and technological tools for STEM education implementation in classrooms are some key aspects raised by teachers in a systematic review of teachers' perceptions of STEM by Margot and collaborators [18].

Based on this background, the descriptive study presented here aims at exploring teachers' experience and perceptions of STEM teaching using ICT, collecting data about their practices and current challenges and difficulties, following these Research Questions (RQ):

- RQ1: What are teachers' experience with STEM teaching and their perceptions of students' difficulties?
- RQ2: What is the role of digital technologies in STEM teaching and learning and the reasons for not using them?

## **2 METHODOLOGY**

To explore teachers, experience with STEM teaching and technologies and the perception on challenges and difficulties in STEM teaching and learning a survey was carried out, including a questionnaire (N=11 items) structured in three areas:

- General Information: gender, discipline, workplace.
- Experience in STEM Teaching: teaching strategies, challenges in STEM teaching and perceptions about students' difficulties in STEM learning.
- Digital technologies' use in STEM teaching: use of technologies and the relative frequency and motivation of use.

The questionnaire was implemented through a Google Form and with the support of the Scholastic Office of Tuscany was delivered via email to the network of Italian STEM teachers (primary and secondary) between March and June 2022. For the purposes of this paper, we focus on the data related to the lower secondary school. The questionnaire was filled in by 234 Italian teachers (N=187 female and N=47 male) on a voluntary basis, coming from different Italian Regions (see Figure 1): 133 were both Mathematics and Science teachers, 77 were Technology teachers, 14 Science teachers and 10 Mathematics teachers.

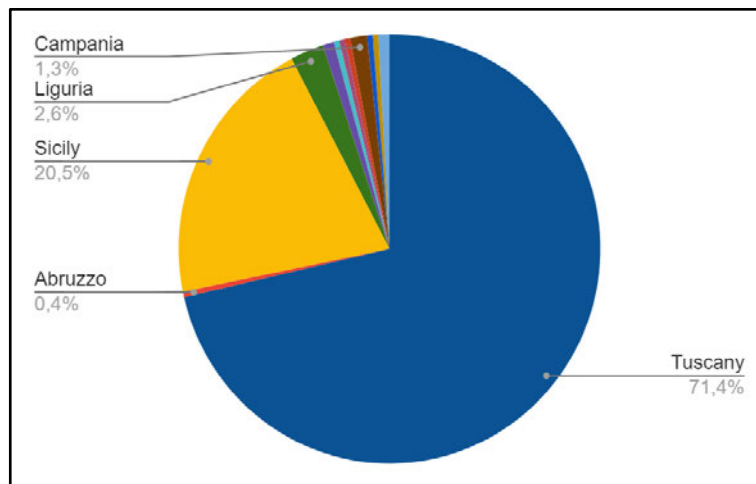


Figure 1. Workplace of teachers.

In the following paragraph, results are reported to answer the leading RQs of the study, presenting the data gathered on teachers' perceptions related to their experiences on STEM teaching and their use of digital technologies for learning facilitation.

### 3 RESULTS

#### 3.1 RQ1: What is teachers' experience on STEM teaching and their perceptions of students' difficulties?

Regarding the question about strategies for teaching STEM disciplines, teachers were free to choose more than one option among those indicated in the questionnaire (Receptive, Directive, Exploratory, Collaborative, Guided Discovery, Simulations and Self-Regulating Strategies): 73,5% of participants (172/234) use several strategies for STEM teaching, in particular, 50 out of 234 participants used 2 strategies, 66 out of 234 used 3 strategies and 56 out of 234 used 4 strategies. Few participants used only 1 (11,5%, 27/234) or 5 or more strategies (15%, 35/234). The most used teaching strategy for STEM disciplines is the Guided Discovery indicated by 77,4% of teachers (181/234), followed by the Collaborative strategy indicated by 76,5% of participants (179/234). Directive, Receptive and Exploratory strategies have been used by 43,6% (102/234), 40,2% (94/234) and 39,3% (92/234) of participants respectively, while Self-Regulating and Simulations strategies are the least used, being selected only by 17,5% (41/234) and 16,7% (39/234) of participants (Figure 2).

Focus on the question related to the challenges of STEM teaching, "stimulating and nurturing students' interest" is the most opted answer, being selected by 74,4% of participants (174/234), followed by the "consistency of the equipment with respect to the disciplines", as stated by 42,7% of participants (100/234), and by the aspect related to "deconstructing inadequate visions of the discipline" identified by the 35,9% of participants (84/234). "Dealing with students' prior knowledge" (28,2%, 66/234), "Integration with other disciplines" (27,8%, 65/234), "Need to spend time for updating" (22,2%, 52/234), "Lack of adequate teaching supports, with particular reference to manuals" (17,5%, 41/234) is the less selected options.

Some further comments have been added by 7 teachers regarding the challenges faced, pointing out that 1) more time in the curriculum should be devoted to STEM teaching activities (6/234), 2) serious mistakes on the representation of the disciplines are present in the school books (1/234) and 3) students face difficulties with the specific technical language of STEM (1/234).

Focusing on students' difficulties in STEM learning, 56% of teachers (131/234) consider the "Transfer of Knowledge to the real world" the main problem, followed by "Identification of studying methods" (47%, 110/234) and by "Understanding Concepts" (41,5%, 97/234). The aspects related to the

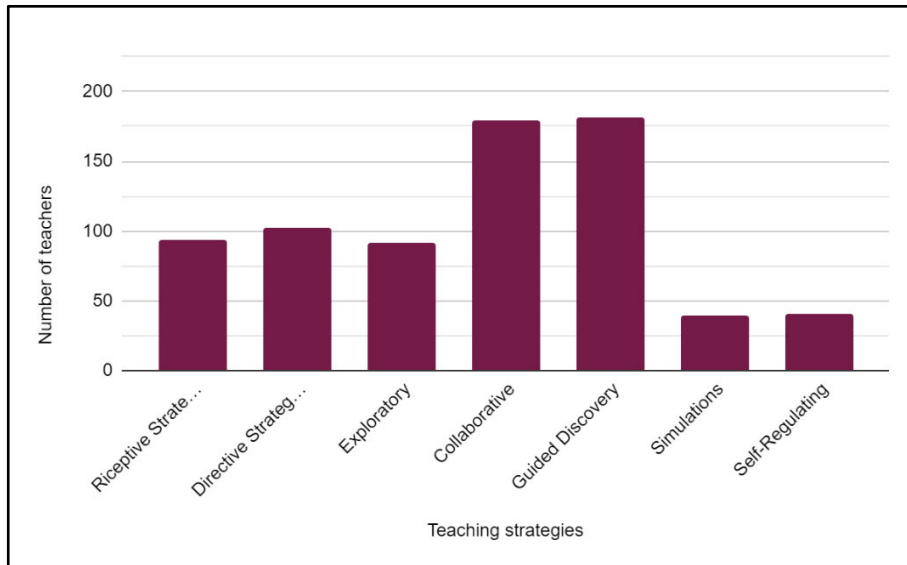


Figure 2. Teaching strategies.

“Development of students’ interest towards STEM” (29,9%, 70/234) and “Students’ engagement during teaching activities” (14,5%, 34/234) are the less selected options. Finally, while 1 teacher did not find any particular difficulties of students in STEM learning, others (4/234) underlined further aspects to be considered such as: students’ preconceptions (1/234), acquisition of technical languages (2/234), acquisition of autonomy (1/234).

### 3.2 RQ2: What is the role of digital technologies in STEM teaching and learning and the reasons for not using them?

Most teachers (229/234) declared to use digital technologies for STEM teaching and, among them, 49,3% (113/229) use them often, 35,4% sometimes (81/229), 10,5% Always (24/229) and 4,8% (11/229) rarely. Considering the reason behind their use for STEM activities, 83,4% (191/229) use digital technologies to “Explain abstract concepts requiring visual support to be understood” and 52% (119/229) for “Practice training, 32,8% (75/229) “To make vicarious experiences in the laboratory” and 20,5% (47/229) “To show/visit not accessible places or difficult to reach” (see Figure 3). One teacher did not answer this question. Further in-class activities with the use of technologies have been indicated by 3 teachers and included documentation, research, the creation of conceptual maps and synthesis, and for evaluation.

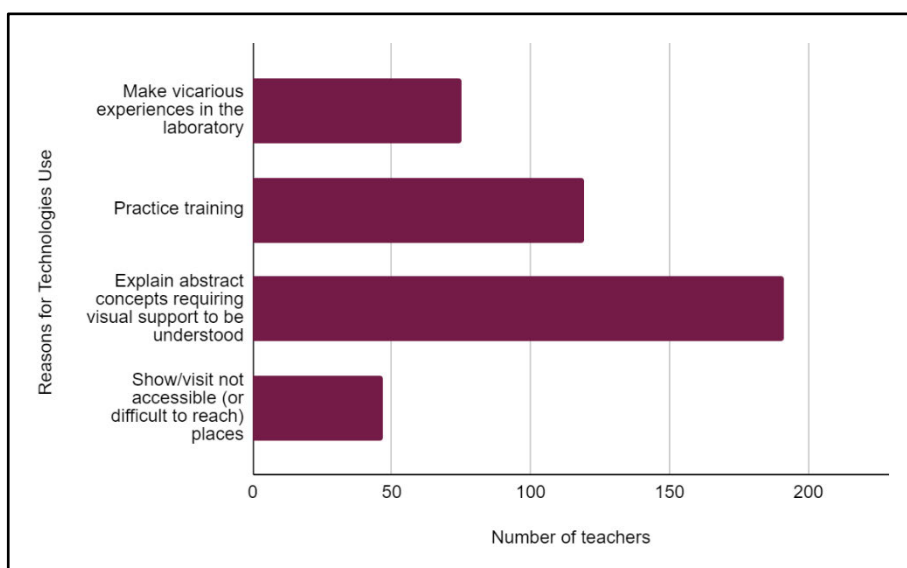


Figure 3. Reasons for Teachers’ use of Digital Technologies for STEM teaching.

Finally, 5 teachers did not use digital technologies during their teaching for the following reasons: “Difficulties of students of using digital technologies for learning” (1/5), “Lack of time for using them in class” (1/5), “Difficulty in accessing technological tools in the Institute” (2/5) and “Lack of confidence in the use of technologies for teaching” (2/5).

## 4 CONCLUSIONS

This study explored teachers’ experience and perceptions of STEM teaching and learning with digital technology, with particular attention on teaching strategies, challenges, and students’ difficulties. Regarding STEM teaching, teachers declared to use different teaching approaches for STEM disciplines that may indicate the availability to adapt their teaching practice to the context, but further studies of qualitative nature could be interesting to identify the driving factor(s) (argument, students’ characteristics, context constraints, ...) and their role in choosing the proper strategy. The most used teaching strategy is the Guided discovery, in which students actively build their knowledge by problem-solving or inquiry-based learning in a process like those of professional scientists, in line with the literature evidence that reported the widespread use of this strategy [15].

Moving to the challenges faced in STEM teaching, teachers declare that the major problem is promoting students’ interest towards STEM. This is a well-known [4] and complex issue in STEM learning, and one of the possible reasons may reside in the abstractness of some scientific concept [4] [5] that requires direct demonstration to be understood, not always possible in the classroom [5]. Moreover, in this study teachers pointed out that one of the difficulties of students in STEM learning is the problem of the transfer of knowledge to the real world, which could be another aspect impacting the interest towards the disciplines. In this view, the use of digital technology for STEM teaching may help in fostering interest and making scientific concepts more concrete, especially using X-Reality, which can favor visualization and interaction [5]. In fact, teachers are aware of the affordance of digital technology, and they often were used to integrate them into their practice, mainly for explaining abstract concepts requiring visual support to be understood and for practice training.

Another important topic raised by the teacher’s answer is related to the reason for not using digital technologies, underlining that the main difficulty is the access to technological tools in the Institute and the lack of confidence in the use of technologies for teaching. Thus, these results underlined on one hand the teachers’ need for an improvement of the infrastructure of the institute (i.e. digital and laboratory equipment), making access to digital tools easier and more consistent with the specific discipline. On the other hand, they claimed a need for training about the integration of digital technologies into the teaching practice, thus overcoming the challenges and hurdles they faced in their current practice. This requires the involvement of the Institute, including all the actors in the school context, in order to create a collaborative environment [18] [19].

Finally, it is worth mentioning the limitation of this study: the first one is related to the sample, in particular in terms of size and heterogeneity (workplace, disciplines) that prevent it from generalising the results. Secondly, this descriptive study did not provide a deeper insight into the main issues raised, which requires further study of qualitative nature in order to better understand teachers’ perceptions of STEM teaching and to find some possible solutions.

## REFERENCES

- [1] Falloon, G., Hatzigianni, M., Bower, M., Forbes, A., & Stevenson, M. (2020). Understanding K-12 STEM education: A framework for developing STEM literacy. *Journal of Science Education and Technology*, 29(3), 369-385.
- [2] <https://www.oecd.org/pisa/publications/pisa-2018-results.htm>
- [3] Potvin, P., & Hasni, A. (2014). Interest, motivation and attitude towards science and technology at K-12 levels: a systematic review of 12 years of educational research. *Studies in science education*, 50(1), 85-129.
- [4] Weng, C., Otanga, S., Christiano, S. M., & Chu, R. J. C. (2020). Enhancing students’ biology learning by using augmented reality as a learning supplement. *Journal of Educational Computing Research*, 58(4), 747-770.

- [5] Cai, S., Liu, C., Wang, T., Liu, E., & Liang, J. C. (2021). Effects of learning physics using Augmented Reality on students' self-efficacy and conceptions of learning. *British Journal of Educational Technology*, 52(1), 235-251.
- [6] Arici, F., Yildirim, P., Caliklar, Ş., & Yilmaz, R. M. (2019). Research trends in the use of augmented reality in science education: Content and bibliometric mapping analysis. *Computers & Education*, 142, 103647.
- [7] Makransky, G., Petersen, G. B., & Klingenberg, S. (2020). Can an immersive virtual reality simulation increase students' interest and career aspirations in science?. *British Journal of Educational Technology*, 51(6), 2079-2097.
- [8] Ibáñez, M. B., & Delgado-Kloos, C. (2018). Augmented reality for STEM learning: A systematic review. *Computers & Education*, 123, 109-123.
- [9] Garcia, V., Conesa, J., & Perez-Navarro, A. (2022). Videos with Hands: An Analysis of Usage and Interactions of Undergraduate Science Students for Acquiring Physics Knowledge. *Journal of Science Education and Technology*, 1-19.
- [10] Roffi, A., & Cuomo, S. (2022). STEM teaching and learning with innovative technologies in the upper secondary school: A scoping review. *Italian Journal of Educational Technology*. Advance Online Publication. Doi: 10.17471/2499-4324/1291
- [11] Carretero Gomez, S., Napierala, J., Bessios, A., Mägi, E., Pugacewicz, A., Ranieri, M., Triquet, K., Lombaerts, K., Robledo Bottcher, N., Montanari, M. and Gonzalez Vazquez, I. (2021) What did we learn from schooling practices during the COVID-19 lockdown, EUR 30559 EN, Publications Office of the European Union, Luxembourg, doi:10.2760/135208, JRC123654.
- [12] OECD (2019). *TALIS 2018 Results (Volume I): Teachers and School Leaders as Lifelong Learners*, TALIS. Paris: OECD Publishing. <https://doi.org/10.1787/1d0bc92a-en>
- [13] OECD (2020). *School education during COVID-19: Were teachers and students ready?*. Paris: OECD Publishing. <https://www.oecd.org/education/Italy-coronavirus-education-country-note.pdf>
- [14] Huang, B., Jong, M. S. Y., Tu, Y. F., Hwang, G. J., Chai, C. S., & Jiang, M. Y. C. (2022). Trends and exemplary practices of STEM teacher professional development programs in K-12 contexts: A systematic review of empirical studies. *Computers & Education*, 104577.
- [15] 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.
- [16] Arnold, J. C., Kremer, K., & Mayer, J. (2014). Understanding Students' Experiments—What kind of support do they need in inquiry tasks?. *International Journal of Science Education*, 36(16), 2719-2749.
- [17] Kyza, E. A., Constantinou, C. P., & Spanoudis, G. (2011). Sixth graders' co-construction of explanations of a disturbance in an ecosystem: Exploring relationships between grouping, reflective scaffolding, and evidence-based explanations. *International Journal of Science Education*, 33(18), 2489-2525.
- [18] Margot, K. C., & Kettler, T. (2019). Teachers' perception of STEM integration and education: a systematic literature review. *International Journal of STEM education*, 6(1), 1-16.
- [19] Ranieri, M., Bruni, I., & de Xivry, A. C. O. (2017). Teachers' professional development on digital and media literacy. Findings and recommendations from a European project. *Research on Education and Media*, 9(2), 10-19.