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An international case study: The Metaverse in the classical high school[1]

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Abstract

The exchange of best practices at an international level on the use of new technologies applied to teaching is also becoming increasingly frequent today. However, few studies delve into how classical high schools in Italy are changing their didactics in this line. In fact, there are some gaps between theory and practice when it comes to developing digital skills, sharing innovative teachings, and assessing competencies. The present study aims to describe how STEAM teachers of a classical high school in Bagheria, near Palermo, in Sicily, used the metaverse for their subjects. In fact, a mathematics teacher, following a fruitful collaboration with a French school for the use of innovative teaching, involved colleagues from other disciplines in using the metaverse to motivate student learning in their subjects. A case study design from qualitative research designs was used. The participants were teachers and students and were determined by a convenient sampling method. The study data were obtained through a semi-structured interview form. The research data were analyzed using thematic analysis. The results showed that all the teachers were enthusiastic about using the metaverse to motivate the learners, and the students improved the 4Cs (critical thinking, communication, collaboration, and creativity). Future research could test whether these findings can be confirmed using artificial intelligence programs to facilitate learning.

1 Introduction and background

The exchange of best practices at an international level on the use of new technologies applied to teaching is also increasingly frequent today (European Commission, 2006; European Union, 2013; Lemon & Garvis, 2016; Wilson et al., 2011). However, there are few studies that delve into how classical high schools in Italy are actually changing their didactics (Cacciamani et al., 2018; La Paglia et al., 2011; Menabò et al., 2021; Romano et al., 2023).

Since the 2000s, due to the increasingly pressing technological acceleration, the need has been

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felt in the educational field in order to increase a new study mentality in students (Musso et al., 2022). In fact, in an increasingly dynamic world, it is necessary to train students with a flexible mentality, capable of multidisciplinary thinking, who know how to find connections between different disciplines to respond more effectively to the complex problems of society (Bicer, 2021; Garibay, 2015; Ladson-Billings, 2014).

During the National Science Foundation conference in 2001, this pedagogical problem was addressed in the United States: here, the acronym STEM (Science, Technology, Engineering, and Mathematics) was used for the first time to indicate the disciplines necessary for the innovation and progress of countries. Subsequently, studies in these areas also multiplied in Europe (Breiner et al., 2012; NGSS Lead States, 2013; Zeidler, 2016). In 2006, Europe encouraged the development of digital competencies. It defined them in the EU framework of key competencies for all citizens as the abilities to "use the computers to retrieve, assess, store, produce, present and exchange information, and to communicate and participate in collaborative networks via the Internet" (European Commission, 2006, p. 16). In 2013, the European Commission published a Digital Competence Framework based on five areas and 21 competencies, including digital literacy (Ferrari, 2013).

STEAM courses are also spreading to underline the importance of the connection between scientific and humanistic subjects, which add Art to scientific subjects (STEM), thus underlining the importance of creativity in solving problems (Conradty & Bogner, 2018). Thanks to Human-Centered-Design (HCD), the humanistic part (meanings) and the scientific part (methods) merge and become concrete and real through the intelligent and ethical use of technologies (tools) (Zoltowski et al., 2012). Human-centered design is an approach to problem-solving used in process, product, and service design by involving the human perspective in all steps of the problem-solving process (Sanz-Camarero et al., 2023). Human involvement takes place initially observing the problem within context, brainstorming, conceptualizing, developing concepts, and implementing solutions (Cooley, 1989).

These courses, according to the National Education Association (NEA, 2015), aim to develop students in the 4 Cs, the skills considered indispensable for citizens in the 21st century: (i) Critical thinking: the ability to find the solution to a problem by examining all the details in an analytical and objective way. (ii) Communication: ability to dialogue with other people. (iii) Collaboration: ability to develop in the STEM approach through the teaching methodology of project work to be carried out in teams. (iv) Creativity: finding innovative solutions and implementing transversal thinking (Jang, 2016).

We want to overcome a didactic method centered on the teacher who teaches his/her subject through traditional lessons to give space to more active forms of learning centered on the student (Hubwieser, 2013; Margot & Kettler, 2019). Among other things, some studies have demonstrated the importance of such courses in overcoming the gender gap and achieving full inclusion of female students in scientific fields (Hwang & Taylor, 2016; Lam et al., 2008).

There are numerous STEM experimentations in America (Johnson et al., 2020; National Academies of Sciences, Engineering, and Medicine, 2019), Asia (Dong et al., 2020; El-Deghaidy et al., 2017), Africa (Abouserie et al., 2022), Oceania (Consult Australia, 2019), in Europe (Mundry et al., 2009; Marco-Bujosa et al., 2017).

In Italy, the first high school to organize its curriculum according to the STEM approach was the

high school of Rovereto (Northern Italy) in 2018 (Nicolli, 2020). The "Francesco Scaduto" classical high school of Bagheria is among the first in Southern Italy to activate this experimentation in 2021. The additional hour of mathematics was dedicated to coding, robotics, and the metaverse, relevant topics in our digital age. Pupils can study and apply these disciplines' knowledge creatively and innovatively, developing problem-solving and critical thinking skills and preparing them for future challenges (Pocalana et al., 2023).

Above all, after the Covid-19 pandemic, in the STEM/STEAM field, during the mathematics hour, the use of virtual reality and the metaverse (Asiksoy, 2023; Eşin & Özdemir, 2022; Gogen, 2022; Kye, 2021; Ruiz-Martín & Bybee, 2022; Topraklikoglu & Ozturk, 2023).

Recent studies show that the metaverse will be increasingly used in education (Damar, 2021). For this reason, it will become increasingly urgent to have teachers able to know how to use it in ordinary teaching (Suh & Ahn, 2022).

However, the fact that a student can show himself/herself through the metaverse thus presents lights and shadows (Türk et al., 2022). On the one hand, the metaverse amplifies the participatory dimension because users can create content and virtual spaces to interact with other users. On the other hand, the potential risks of the metaverse must be kept in mind: physiological dangers, privacy violations, false information and manipulations, abuse and sexual content, and psychological risks (Arif & Hayati, 2022; Reed & Joseff, 2023).

Faced with these challenges, the urgency to compare the good practices of STEM/STEAM courses among the various countries emerged (Sahlin & Styf, 2021): this is one of the typical activities of the school internationalization process.

The concept of internationalization (De Witt et al., 2015; Egekvist et al., 2015) is defined as an intentional process of integrating international, intercultural, and global dimensions into education to improve the quality of education.

In this study, the dimension of internationalization manifested itself as a form of external collaboration, i.e., through an intentional process to organize and create collaboration among schools from other countries and build intercultural understanding (Freeman et al., 2019). It was, therefore, a question of going beyond the realization of international activities and involving the school as an organization of ever wider processes (Björkman, 2008; Yemini, 2014).

The comparison among countries highlights the main gaps between the theory and practice of STEM/STEAM education: a) the lack of adequate human resources (Scaradozzi et al., 2019): i) there is still a gap between training and action since technological skills are not always adequate for educational needs (Moreno-Guerrero et al., 2021; Silva-Díaz, 2023; Spante et al., 2018); ii) in schools, not all teachers of the same course of study are ready to work with virtual reality and artificial intelligence (Eşin & Özdemir, 2022); b) the assessment system is still focused on content rather than skills that promote innovation, creativity, critical thinking and problem-solving skills (Reyes & Enrique, 2020).

These problems have also been found to varying degrees in our country (Eguchi, 2014). On the other hand, comparing with best practices at an international level has allowed some teachers to promote educational innovation in the STEAM field (Pariso & Marino, 2019).

The present study shows the didactic innovation results documented in the STEAM course of the classical high school "Francesco Scaduto" in Bagheria (Sicily, Italy).

In general, education in Italy is regulated by the Ministry of Education and Merit (MIM). The Italian legal system provides for different cycles of education (MIM, 2005): First cycle (primary school from 6 to 11 years) and Second cycle (secondary school, indicated in yellow in Figure 1), which includes: lower secondary school (from 11 to 14 years old) and upper secondary school (from 14 to 19 years old). Upper secondary schools include 6 types of high schools (classical, scientific, linguistic, human sciences, art, music).

From the 2010/2011 school year, the reform of the second cycle of education and training came into force: this is divided into five-year education courses (high schools, technical institutes, vocational institutes) and vocational education and training courses (VET) of regional jurisdiction. The professional technical institute is a type of school that provides technical preparation and professional qualification for access to various sectors of the working activity (MIM 2010).

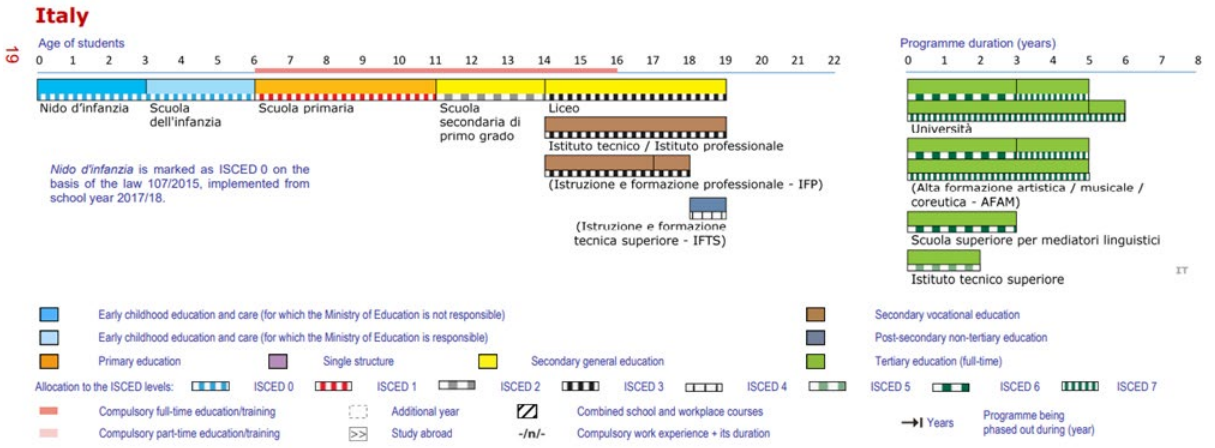

Figure 1 Education in Italy (European Commission/EACEA/Eurydice, 2022)

Table 1 Organization of subjects of the classical high school

Subject per week	First two years		Second two years		Last year
	1° year	2° year	3° year	4° year	5° year
Italian Language and literature	4	4	4	4	4
Latin Language and culture		5	5		4
Greek Language and culture	4	4	3	3	3
Foreign Language and culture	3	3	3	3	3
History	2	2	3	3	3
Geography	1	1	-	-	-
Mathematics	3	3	2	2	2
Philosophy	-	-	3	3	3
Physics	-	-	2	2	2
Natural Sciences	2	2	2	2	2
Art	-	-	2	2	2
Physical education	2	2	2	2	2
Religion or alternative subject	1	1	1	1	1
Total hours	27	27	31	31	31

The STEAM study course offers, in addition to the normal curriculum, an enhancement of History of Art in English (CLIL) in the two-year period (one hour a week), an extra hour of Mathematics for the entire five-year period (for a total of 4 hours per week in the two-year period and 3 hours per week in the second two-year period and final year), one hour of Natural Sciences (chemistry, biology, earth sciences) for the entire three-year period (for a total of 3 hours per week) (MIM, 2010).

To promote educational innovation in the three-year period 2020-2023, a collaboration has been established between the STEAM course of the "Francesco Scaduto" classical high school in Bagheria and the Saint Germain International High School en Laye (Paris, France). The key aspects of the collaboration are (i) Innovation in mathematics and (ii) Protagonism of students in the training/experimentation path on virtual and augmented reality in the mathematical field (Dubois, 2023).

The general objectives of the collaboration were: (i) To form a learning community on virtual reality and the metaverse for mathematics and logic; (ii) Training teachers and students in the use of a digital tool for an innovative pedagogy; (iii) Promote pedagogical continuity without borders; (iv) Innovate in teaching; (v) Encourage students to communicate in a foreign language in very concrete situations of teamwork, give meaning to foreign language learning; (vi) Learn to identify a problem and find technical solutions in a limited time working in an international team; (vii) Discover the metaverses, their potential and their risks.

Highlighting the results obtained in the didactic innovation of mathematics and metaverse, we wanted to implement the good practice born in the international arena and extend it to the teachers of the STEAM course of the "Scaduto" classical high school. In addition to the mathematics teacher, professors of Latin and Greek, Art, Physical education, Earth sciences, and English participated in the study.

Therefore, the present study aims to describe how the teachers of the STEAM course have implemented the use of the Metaverse in their subjects.

The research questions are: (i) How did the best practices pass between the Mathematics teacher who worked with the Saint Germain International High School en Laye (Paris, France) and the teachers of the STEAM course to implement the use of the Metaverse in their subjects? (ii) To what extent has the new teaching methodology increased the 4Cs of the students?

2 Method

This study uses a constructivist approach that emphasizes the social nature of learning. On the one hand, according to Dewey (1938), interaction with others and learning by doing are the fundamental elements that give meaning to learning. On the other hand, Kolb (1984) underlines the importance of reflection through concrete learning experiences.

As Cowan (2006) states, there are three types of reflection: reflection for action, reflection in action, and reflection on action, depending on the position of reflection with respect to action. Reflection for action takes place before an action and involves reflections in which students specify their needs, aspirations, and goals for a subsequent learning activity. Reflections in action are reflections made in the middle of the action, which consist of both retrospective and anticipatory thoughts. It implies taking stock of the situation: what is happening? What progress has been made? What is left to do? Finally, action-reflection covers reflections made after a learning experience, which attempt to analyze and summarize the experience and extract generalizations that can be carried forward in subsequent activities (Ottesen, 2007).

2.1 Design

According to Yin (1989), we use a case study, a qualitative research method that serves to understand the social and educational reality deeply. In particular, the moments of the case study are the following (Coggi & Ricciardi, 2008): (i) Definition of the research scope, (ii) Selection and

negotiation of case access involving definition of the case, conceptualization of the object of study, choice of fonts and tools, (iii) Fieldwork involving: role negotiation, data collection, (iv) Organization of available records: reduction, coding, triangulation, (v) Drafting of the report.

2.2 Participants and procedure

The participants were 10 teachers (7 women and 3 men) of the STEAM course and 53 students (18 males and 35 females) from 14 to 16 years old (first, second, and third year of the STEAM course of the "Scaduto" classical high school). Among the teachers, a sample of convenience or availability was chosen. Among the third-year students, a disabled girl actively participated in the experiment. The opportunity to collect data was too important to lose, also considering the double difficulty of the teachers: a) to adopt common methodologies among teachers of the same course; b) getting involved in research activities because they are often perceived as a burden on teaching.

2.3 Measures

Overall, the research took place over 3 years, and it can highlight three functionally related phases, as shown in Table 2.

Table 2 Research timing

	Theoretical framework	Fieldwork	Conclusions
Phase 1	(i) Study and critical analysis of the scientific literature used in the international case study (November 2020) (ii) Application of the methodology used in the teaching of mathematics to that of other disciplines (September 2021) (iii) Methodological design of the research (September 2021) (iv) Search for data collection tools (interviews) (September 2021)		
Phase 2		(i) Collaboration in the experimentation between the teachers of the STEAM course (September 2021- June 2023) (ii) Carrying out of routes innovative in the classroom (September 2021- June 2023) (iii) Interviews with teachers and students to collect data on the results of the new teaching (September 2021- June 2023)	
Phase 3			(i) Analysis of the results (July 2023) (ii) Drawing up conclusions (August 2023) (iii) Dissemination of results (September 2023)

Phase 1 envisaged the following topics of study and discussion between the teachers: a) The results of the international experimentation between the “Scaduto” high school and that of Paris-

Saint-Germain en Lay; b) Documents of the scientific literature; c) Didactic with the Metaverse; d) the methodological design of the research; e) Data collection tools (interview questions).

In Phase 2, following the international collaboration, the teachers began to change some aspects of their teaching: (i) Classroom setting: The school has been equipped with classrooms/laboratories that allow the execution of experiments in safety. The classrooms have been equipped with modular desks (student and teacher workstations for interactive teaching), stackable chairs, and mobile shelving to guarantee flexibility in the classroom configuration and facilitate work on digital communication, cybersecurity, robotics, metaverse, and artificial intelligence. They are open spaces where students can express themselves individually and develop group projects. (ii) Teaching methodology used: a) Inquiry-Based Learning (IBL): It allows students to learn by investigating as in the scientific world. The pupils, guided according to the degree of autonomy achieved, are confronted with the phenomenon they are studying, ask themselves questions, formulate hypotheses, verify them through experiments, and discuss the results. The types of investigations that can be conducted in the classroom are: Confirmatory inquiry (the student already knows the object of the investigation in all its characteristics but seeks confirmation on an aspect on which he will investigate further), Structured inquiry (the student has partial knowledge of the phenomenon being investigated and, through a procedure suggested by the teacher, must arrive at the correct conclusions), Open Inquiry (students choose both the problem and the method of inquiry), Guided and/or exploratory inquiry (students investigate a totally new problem by structuring the inquiry and the methodology to be adopted). The teacher has the role of tutor. (b) Project-Based Learning (PBL): It is a teaching and learning model in which students are placed at the center of the design by stimulating questions or solving problems. Students collaborate in designing, problem-solving, decision-making or research, and creating a product at the end of the project. The phases of the work are conception, feasibility study, design, realization, checking, and presentation of the final product. This process can be summarized with the 5 E (Ruiz-Martin & Bybee, 2022): Engage (the student must feel involved in what he will do and must find out about his tasks by asking the teacher), Explore (the student explores the object of his work with experiences, collecting data, noting information and observations), Explain (the student at home must take stock of the situation of the data collected and explain how they can be framed to achieve their research objectives), Elaborate (the student must produce an elaborate, to be presented to the teacher and the class, containing his/her own conclusions and discoveries), Evalue (the student will have to self-evaluate his own work also together with the other students, perhaps in a group discussion in class). The evaluation methods occur through a) Evaluation of the group work and each component by the teacher through a checklist, b) Evaluation of the delivered project sheet, c) Self-assessment of group work, and d) Evaluation of the skills acquired through reality tasks.

In Phase 3, the data collected were analyzed and interpreted, and the conclusions were drawn. In particular, in the STEAM course at “Scaduto” high school, each teacher involved in the research has carried out courses centered on the use of the metaverse, deepening the legal, ethical, and educational aspects connected to the creation of virtual worlds.

Moreover, the Mathematics teacher trained the students on the conscious use of the platforms linked to the Metaverse and chose to use the “Cospaces” platform because it was considered educationally safer for the age group involved. It allows: (i) students to create in 3D, code, and explore their creations in VR or AR; (ii) teachers to create and share assignments with the class, assign individual assignments to students or create collaborative group assignments, monitor their

work in real-time online from their class in the "Students" section.

During the time of Mathematics, the teacher has tackled topics that are not normally covered in the first year of a classical high school, such as, for example Non-Euclidean Geometries (see metaverse at the following link: https://edu.cospaces.io/KTD-CDL). In this specific case, after an initial introduction, students were provided with teaching materials containing the information necessary to create the museum of geometries, leaving room for them to decide which models to study (Figure 2). The students carried out the design, and the decisions, both the structure of the museum and which models to choose, were taken after a series of comparisons in the presence of the teacher, both during curricular and non-curricular hours.

Figure 2 Photos from student creations (Cospace): Mathematics metaverse

In Latin and Greek, the students created a virtual space that presented the importance of the banquet in ancient Rome (Figure 3).

Figure 3 Photos from student creations (Cospace): Latin and Greek metaverse

In physical education, they have created virtual spaces for sports facilities (Figure 4). In Science, they have created worlds with stars and planets. In Arts, they have created examples of eco-sustainable architecture.

Figure 4 Photos from student creations (Cospace): Sports Metaverse

2.4 Data analysis

Data analysis aims to make sense of the information obtained by treating it and organizing it to explain and interpret the phenomenon under study and respond to the problem posed (Pedone, 2015). As qualitative research, a discourse analysis was conducted using a classical approach. "Research objectives" are not formulated but "field of analysis" since the interest is focused on reproducing the discourse related to the object of study in experimental situations. The process of generating the categories is carried out at a first level, based on the constant comparison between units of analysis, which are analyzed as they are collected in the field. In our case, the units of analysis chosen were the lines. At a second level, the categories are compared to arrive at the interpretation of the data (Bryman, 2016). Table 3 shows an example of the abstraction process analysis.

Table 3 Examples of analyses showing the abstraction process

Unity of meaning	Code	Category	Theme
Request:			
At which stage did you feel most motivated?			
Answer:			
I was especially involved in the moment of the working groups, because we talked to each other to put our ideas together.	Teamwork	Collaboration	4Cs

2.5 Validity, reliability, and ethical considerations

Unfortunately, one of the most frequent criticisms associated with the case study approach is its low validity and reliability (Bryman, 2016). Finally, we took into account the ethical standards of the British Educational Research Association (2018), according to which all persons and institutions involved in research in any way were protected as much as possible from any harm they could suffer as a result of their participation. All individuals who contributed data to the study knew in advance how the data would be used, stored, and disclosed and had the right to withdraw from participating. Progress was monitored through teacher meetings.

3 Findings

From the analysis of the results of the interviews with students and teachers, the following categories emerged, deduced from the theoretical framework presented previously: (i) Perception of development of the students' 4Cs (Collaboration, Communication, Critical Thinking, Creativity), (ii) Perception of the usefulness of the internationalization, (iii) Perception of the usefulness of the Metaverse to acquire disciplinary skills.

3.1 Student results

Students who participated in the study (54% male, 46% female) stated that using the Metaverse in school has increased: Very much (77%) their ability to collaborate with peers; Very much (69%) and their ability to know how to communicate the contents of the subjects in an innovative way; Very much (100%) their critical thinking skills, knowing how to identify pros and cons of a problem; Very much (77%) increased their creativity.

In particular, in relation to the presence of the 4Cs in the teaching used, the students stated that they had improved in:

(i) Collaboration: This means that the student knows how to interact in a group and understand

different points of view. One student (age 14) said: “I especially liked being able to collaborate with comrades I knew less.” Another (14 years old) added: “I really enjoyed collaborating and comparing my ideas with my teammates because we created a satisfying work, putting all of us on the line for its creation."

(ii) Communication: It means that the student knows how to understand and communicate messages in different ways. A student (14 years old) said: “I liked the fact that thanks to the metaverse, you can be in different places and communicate with other people while not being together in real life.”

(iii) Critical thinking: It means that the student can compare different aspects of reality, highlighting their pros and cons. One student (15 years old) said: “I also enjoyed expressing and presenting this new innovative method of study that strengthens creativity, the ability to collaborate with others, and critical thinking.”

(iv) Creativity: It means that the student knows how to create new products to convey specific disciplinary information. A student (14 years old) said: “I loved using Cospaces, being able to be creative and include school content at the same time.” A student (15 years old) added: “I liked the development of creativity most of all because much creativity is needed to know how to build a world and to insert something constructive.”

In relation to the international experience, all the students underlined their enthusiasm both for having worked in an international group and for being able to put into practice what they had learned in ordinary teaching.

In relation to the perception of the usefulness of the Metaverse in acquiring disciplinary skills, it emerged that this tool "helps to be more dynamic in carrying out activities that could be boring" (student, 14 years old). In fact, "virtual reality, if used correctly and responsibly, can guarantee student advantages. The topics covered in class can be simpler or more fun to learn, collaboration leads to the formation of a united class ready for any situation (a real team), and there can be more cultural exchanges. The pupils can feel more at ease, work methodically, and increase their creativity by sharing projects and opinions" (student, 14 years old). However, we must avoid "becoming too dependent on technology, since the latter certainly represents a resource for learning, but at the same time it must be strictly controlled, to avoid problems of various kinds” (14-year-old student) companions to come up with new ideas” (student, 14 years old).

3.2 Teacher results

Similarly, compared to STEAM teachers who participated in the study (7 women and 3 men), the qualitative analysis showed if and how the 4Cs were developed in their school activity using the Metaverse.

(i) Collaboration: All the teachers confirm that the experience gained has helped increase the student's social skills. The Science teacher said: “They split into groups and created several virtual works. Then, I took it into account for the evaluation. The boys did great." The Latin and Greek teacher said: “Working as a team with a colleague who had an international collaboration behind her, she motivated me to implement the work in my discipline.”

(ii) Communication: The professors have noticed that the students have put themselves on the line to communicate disciplinary content through virtual reality in an autonomous and original way, attractive for conveying those themes to peers. The Art teacher said: “The boys independently

created the works on the Metaverse by effectively communicating topics of sustainable architecture and bio-architecture. The entire process, from conception to execution, was factored into the evaluation."

(iii) Critical thinking: The teachers confirm that with the use of the Metaverse, the students have learned not only to get to know the instrument better but, above all, to ask themselves questions about the pros and cons of the various possible technical solutions to convey a disciplinary content best. The Math teacher said, "It has been observed that, compared to the methodologies used in previous years, this one has fostered creativity and developed a collaborative spirit such that it made learning processes and cognitive development easier." The Science teacher said: "Also, taking advantage of a refresher course on Augmented reality and virtual reality, I used various programs and apps. The boys used them to communicate information on astronomical geography. They split into a group and created the virtual report, carefully weighing the pros and cons of each app in relation to the content to be inserted. Then, I took it into account for the evaluation. The boys did great."

(iv) Creativity: The Latin and Greek teacher said: "I was struck by the natural speed and creativity with which the students found the technical solutions to the design problems of the Banquet in the ancient world." In relation to internationalization, the Latin and Greek teacher said: "Feeling part of a wider context helps to broaden the horizons of one's ordinary work."

In relation to the perceived usefulness of the Metaverse in acquiring disciplinary skills, the Latin and Greek teacher underlined: "I found it innovative to apply the metaverse to the teaching of Latin and Greek because these subjects are usually considered to be far from the current challenges. This experience has shown that it is possible to bring the world of science closer to that of humanities integrated and not juxtaposed". The Physical Education teacher said: "The kids used the Metaverse to create environments with sports facilities. Naturally, to do this, they had to study the measurements of the fields well. They were completely autonomous from the beginning to the end of the process. It was wonderful. Next year, I would like to do better; this year, I was experimental. I want to create the sports structures of the various team sports and go into more detail".

In summary, the qualitative part of the research showed us that students perceive a development of the 4Cs using the metaverse to study the various disciplines.

On the other hand, the results of the interviews with the teachers confirmed the students' perception because the teachers admitted that using the metaverse to acquire specific disciplinary skills facilitated motivation.

4 Discussion

Considering the literature review, the research questions, the results of the qualitative analysis through the interviews of students and teachers showed:

a. At the Italian school system level:

(i) Generativity of good practices shared internationally: A transfer of good practices took place between the Mathematics teacher who worked with France and the teachers of the same STEAM course to implement the use of the Metaverse in their subjects (Eşin & Özdemir, 2022). The international experience with France has enriched the educational innovation already present at the school, confirming that a virtuous management of international mobility funds is possible. In

this way, the opportunities to go abroad do not turn out to be closed experiences but become generative for the entire start of school.

(ii) Didactic synergies at the level of the same course: The fact that teachers of different disciplines and classes have collaborated on the teaching methodology, choosing once more centered on the student rather than on the teacher, has made learning more active and motivating (Hubwieser, 2013; Margot & Kettler, 2019).

(iii) Spreading of best practices: Increasingly, the school as an organization will have to focus on the dissemination of best practices also at an international level to advance the diffusion of educational innovation (Björkman, 2008; Sahlin & Styf, 2021). Moments of reflection will certainly be necessary for the teachers of the same course to understand how much of what works at an international level can also be useful for one's own local context. What works in one country may not work in another (De Wit, Hunter, Howard & Egron-Polak, 2015).

b. At the pupil education level:

(i) Development of the 4Cs of students: Student interviews showed that the new teaching methodology developed the 4Cs of students (Aguilera & Ortiz-Revilla, 2021; Park et al., 2021; Ruiz-Martin & Bybee, 2022; Jang, 2016). Interaction with others and learning by doing have been highly motivating elements that have given meaning to teaching and learning (Dewey, 1938; Guilford, 1956) thanks to constructing learning objects through a collaborative approach. According to HCD, an extremely important element was the active participation of a special needs student in the planning activities of the metaverse: the experimentation, therefore, had repercussions in the field of inclusion (Hwang & Taylor, 2016; Pietri, 2019). Furthermore, the continuous reflection on the learning experiences has contributed to greater awareness on the part of the students with respect to the entire path followed (Cowan, 2006; Kolb, 1984; Virtue & Hinnant-Crawford, 2019). Naturally, not all the children nor the teachers were familiar with virtual reality or the metaverse, however its use, despite the initial perplexities, helped to develop a flexible mentality in everyone (Asiksoy, 2023; Eşin, & Özdemir, 2022; Göçen, 2022; Kye, 2021; Topraklıkoğlu & Öztürk, 2023).

(ii) Metaverse and real life: By communicating very different disciplinary contents with the metaverse, students learned to break down a problem or phenomenon into its different stages (Bicer, 2021; Garibay, 2015; Ladson-Billings, 2014). This way of proceeding forges transversal skills that can be used in school, life, and work (Canfarotta & Casado-Muñoz, 2019).

c. At the teacher training level:

(i) From content assessment to competencies: The use of new tools in teaching has also favored a change in the evaluation method, which is no longer centered only on a summative evaluation of the learning contents. In these learning paths, the assessment consisted of the entire process that led to the creation of the spaces of the metaverse in the various disciplines (Lopes, 2023; Reyes & Enrique, 2020).

(ii) Lights and shadows of the Metaverse: Despite the perplexities about the use of the metaverse in teaching (Arif & Hayati, 2022; Reyes & Enrique, 2020; Singla et al., 2023; Zoltowski, 2012), this tool will continue to be tested in the educational field in the future (Damar, 2021; Menabò et al., 2021). Therefore, teachers who could use it in ordinary teaching were considered in school as an important factor, which motivated other colleagues to use it (Suh & Ahn, 2022).

(iii) The teacher's personal growth has an important social effect: the fact that the group of teachers who participated in the research got involved without receiving additional compensation for the research demonstrates that intrinsic motivation in their work is the most determining element of empowerment. In fact, at the school level, teachers and students grow together, feeling infected by the passion and creativity of the heterogeneity of the group and obtaining more satisfaction in schoolwork (Burns, 1992). Furthermore, the good results achieved with the STEAM course of the classical high school encouraged other teachers of the Linguistics and Human Sciences courses of the "Scaduto" high school to experiment on the same topic in the year 2023/2024.

(iv) Quality of educational innovation fosters trust in institutions: In this way, one of the dimensions of civic and political commitment can increase, which is the general trust in institutions, in this case, the school. This trust reflects the belief that authorities and institutions are fulfilling their duties satisfactorily (Witschgeet et al., 2019).

4.1 Limitations and future directions

While this study has its educational significance, it does have limitations.

First, it is a qualitative study. Therefore, the results cannot be generalized, given the peculiarity of the context and the small sample of participants.

Furthermore, the non-probabilistic sample, despite being a practical method for those who carry out research in the educational world and do qualitative research, is based on a subjective criterion: the participants, therefore, are not chosen at random. Finally, it should be kept in mind that not all educational centers have the same broadband connections that make using the metaverse possible.

As future lines of research, the use of the metaverse could be investigated through quantitative research throughout the school to observe to what extent teachers can use virtual reality and to what extent they use it in ordinary teaching. Thus, it could be understood how to disseminate the results of this study among the teachers of the whole school and bring into a system a good practice shared by a single course.

4.2 Conclusion

In conclusion, the present study observed two aspects of the gap between theory and practice of STEM/STEAM education: a) the gap between training and action in teachers with the need to implement technological skills in ordinary teaching (Moreno-Guerrero et al. al., 2021), both at a personal and collegial level, within the same course (Eşin, & Özdemir, 2022); b) an evaluation system still focused on content rather than on skills (Reyes & Enrique, 2020). The results showed that the international experience that began in France has indeed become generative. The teachers of the same STEAM course of the "Scaduto" classical high school used the same methodology of work on the metaverse used in the previous international experience in France. This study, therefore, presents how a virtuous use of technology is possible at the collegiate level in school. On the other hand, the students also knew how to collaborate. They developed critical thinking and the ability to communicate, knowing how to choose the most appropriate and creative technical solution to the problem they faced each time. The assessment of learning focused not only on the specific disciplinary contents but on the entire creative process of the metaverse environments and the development of the 4Cs.

5 Statement of researchers

5.1 Researchers contribution rate statement

The authors confirm their contribution to the paper: study conception and design: Author 1 and Author 2; data collection: Author 1 and Author 2; analysis and interpretation of results: Author 2 and Author 1; draft manuscript preparation: Author 2 and Author 1. All authors reviewed the results and approved the final version of the manuscript.

5.2 Conflict statement

All authors declare that they have no conflicts of interest.

5.3 Support and thanks

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