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Escape room in 3D virtual worlds: Reflections on new digital skills for innovative teaching by special educational teachers in training

Escape room in mondi virtuali 3D: riflessioni sulle competenze digitali per una didattica innovative da parte di insegnanti di sostegno in formazione

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ABSTRACT The introduction of virtual worlds and digital escape rooms in education marks a significant milestone for inclusive education. This study explored the impact of 3D Learning Virtual Worlds and escape rooms on the motivation and digital skills of 840 special education teachers in training at the University of Foggia. Using the DigiComp 2.2 framework and the FrameVR.io platform, participants created immersive virtual worlds and designed educational escape rooms during their internships. Results showed significant improvements in digital skills, particularly in problem-solving and digital content creation. Moreover, the System Usability Scale (SUS) analysis highlighted a positive perception of the usability of virtual worlds, with room for improvement. The study confirms the potential of virtual worlds in promoting active and inclusive learning, offering new opportunities for the digital transformation of education.

KEYWORDS Virtual Worlds; Educational Escape Rooms; Digital Skills; Educational Inclusion; Gamification.

SOMMARIO L'introduzione di mondi virtuali e escape room digitali nella didattica rappresenta una svolta significativa per l'educazione inclusiva. Questo studio ha esplorato l'impatto dei 3D Learning Virtual Worlds e delle escape room sulla motivazione e sulle competenze digitali di 840 insegnanti di sostegno in formazione presso l'Università degli Studi di Foggia. Utilizzando il framework DigiComp 2.2 e la piattaforma FrameVR.io, i partecipanti hanno creato mondi virtuali immersivi e progettato escape room educative durante il loro tirocinio. I risultati mostrano miglioramenti significativi nelle competenze digitali, in particolare nelle aree del problem solving e della creazione di contenuti digitali. Inoltre, l'analisi della System Usability Scale (SUS) ha evidenziato una percezione positiva dell'usabilità dei mondi virtuali, con margini di miglioramento. Lo studio conferma il potenziale dei mondi virtuali nel promuovere l'apprendimento attivo e inclusivo, suggerendo nuove opportunità per la trasformazione digitale dell'educazione.

PAROLE CHIAVE Mondi Virtuali; Escape Room Educative; Competenze Digitali; Inclusione Educativa; Gamification.

1. Introduction

In the contemporary educational landscape, digital transformation has opened new avenues for improving teaching practices, providing educators with innovative tools to address the needs of an ever-evolving society (Aljawarneh, 2020). Among these innovations, three-dimensional virtual worlds and digital escape rooms are emerging as impactful pedagogical resources capable of promoting active learning, collaboration, and the development of transversal digital skills (Tricarico, 2021; Wolf et al., 2024). For special education teachers, in particular, the use of these technologies represents a unique opportunity to design inclusive and personalized learning environments tailored to meet the special educational needs of students (Haleem et al., 2022).

In recent years, escape rooms have gained increasing popularity in education due to their ability to combine active learning and gamification within a single engaging environment. These experiences allow students to develop key competencies such as critical thinking, problem-solving, and collaboration while tackling challenges and puzzles in simulated contexts. According to Clarke et al. (2017), integrating escape rooms into educational pathways not only enhances motivation but also fosters significant and enduring knowledge acquisition.

Recent studies highlight how the use of escape rooms has been successfully adopted across various disciplines, including science, medicine, mathematics, and language education (Foster & Warwick, 2018; Fotaris & Mastoras, 2022; Nicholson & Cable, 2020). In particular, digital and virtual reality-based escape rooms represent a significant evolution, as they allow the creation of more immersive and customized environments. For example, Liu et al. (2022) and Arrue et al. (2025) demonstrated that the use of virtual escape rooms in medical training courses significantly improved participants' clinical skills and teamwork.

A distinctive feature of escape rooms is their flexibility: they can be adapted to different skill levels and designed to meet specific educational objectives. This aspect is particularly important for inclusive education, where the personalization of learning experiences is crucial. As noted by Benassi (2019), escape rooms facilitate experiential learning through engaging storytelling, helping students connect theoretical concepts with practical applications.

Despite the numerous advantages, designing effective escape rooms requires advanced technical and pedagogical skills. Additionally, it is crucial to ensure that these experiences are accessible and inclusive for all students, as emphasized by Clarke et al. (2017). Integrating escape rooms into virtual worlds offers a promising solution to overcome these challenges, providing teachers with versatile tools to create innovative educational environments.

The adoption of virtual worlds as innovative educational tools has recently sparked growing interest in the educational landscape. These interactive three-dimensional environments provide a unique opportunity to overcome the limitations of physical spaces and offer engaging and personalized learning experiences (Filippone et al., 2024/a). Their use is particularly promising in the field of inclusive education, offering new ways to motivate students and promote meaningful learning, especially for those with special educational needs (SEN).

Virtual Worlds enable students to immerse themselves in learning contexts that combine playful and interactive elements, fostering active engagement (Filippone et al., 2024/b). The cooperative learning experience described by Filippone et al. (2023/a) demonstrates how such environments can enhance peer collaboration, problem-solving, and autonomy, making the learning process more participatory and inclusive.

Digital escape rooms within virtual worlds, for example, provide an educational format that stimulates students' curiosity and motivation. These activities integrate gamification and experiential learning elements, promoting the development of transversal skills such as critical thinking and creativity. The ability to explore and build virtual worlds on platforms like FRAME not only enhances digital competencies but also offers students a strong sense of ownership and responsibility (Rossi et al., 2023).

Virtual worlds are inclusive spaces designed to meet diverse educational needs. Students with autism spectrum disorders or other disabilities can benefit from virtual environments that reduce physical and social barriers, enabling them to actively participate in the educational process. The use of personalized avatars, for instance, allows students to express their identity in a safe and authentic way, fostering self-esteem and inclusion (Filippone et al., 2023/b; Aseeri & Interrante, 2021).

Recent research has shown that learning in virtual worlds can amplify concentration and working memory through the use of enhanced visual stimuli and immersive environments (Han, 2020). Furthermore, the Universal Design for Learning (UDL) methodology applied to virtual worlds ensures that experiences are accessible to all students, regardless of their abilities.

The integration of virtual worlds into teaching represents a significant turning point in the digital transformation of education. They offer a bridge between traditional and innovative learning, creating hybrid environments that combine the best of both worlds. As noted by Filippone et al. (2023/a), the potential of virtual worlds extends far beyond STEM education, encompassing the humanities and language education through methodologies such as CLIL (Content and Language Integrated Learning).

The experiences described indicate that virtual worlds can become a central element in future educational strategies, fostering inclusion and personalization in the learning journey of every student. In this context, teachers play a crucial role in guiding students toward the conscious and productive use of these technologies (Gesthuizen et al., 2025).

This exploratory study fits into this context, aiming to explore the impact of escape rooms in virtual worlds on learning and digital skills, in order to evaluate the degree of effectiveness that this teaching tool can have in enhancing digital skills in the perspective of inclusive teaching.

Using the DigiComp 2.2 framework and the FrameVR.io platform, a sample of 840 pre-service teachers attending the Specialization Course for Teaching Support for students with disabilities in lower and upper secondary schools at the University of Foggia designed and implemented immersive educational experiences, culminating in the creation of an educational escape room used during their internship. This work aims to evaluate how such experiences contribute to enhancing digital skills and teacher motivation while highlighting the usability and accessibility of the digital tools employed.

2. Material and methods

2.1. Partecipants and procedures

This study is part of a broader research project aimed at analyzing the effectiveness of using 3D Learning Virtual Worlds in Education and their impact on increasing study motivation, improving learning outcomes, and enhancing new digital skills and life skills.

The study was conducted on a total sample of 840 pre-service special education teachers attending the Specialization Course for Teaching Support for Students with Disabilities – VIII cycle (360 for Lower Secondary School and 480 for Upper Secondary School) at the University of Foggia. The study was carried out within the laboratory course "Special Education: Codes of Logical and Mathematical Language."

The experimentation was structured into nine phases, summarized in Table 1.

Table 1. Work protocol.

Phases of the Experimentation	Description of the phases
Step n. 1	*Administration of an Anamnestic Questionnaire*
Step n. 2	*Administration of the DigiComp 2.2 Questionnaire*
Step n. 3	*Theoretical Lesson on the Digital Competencies Defined by DigiComp 2.2*
Step n. 4	*Administration of the Quantitative Evaluation Grid for Digital Competencies Defined by DigiComp 2.2*
Step n. 5	*Theoretical Lesson on Escape Rooms in Education*
Step n. 6	*Presentation of 3D Learning Virtual Worlds*
Step n. 7	*Theoretical and Practical Training for Building Virtual Worlds*
Step n. 8	*Practical Implementation of Virtual Worlds and Creation of an Escape Room*
Step n. 9	*Administration of the Quantitative Evaluation Grid for Digital Competencies Defined by DigiComp 2.2*
Step n. 10	*Administration of the Usability Questionnaire for 3D Learning Virtual Worlds*
Step n. 11	*Focus Group*

2.2. Anamnestic questionnaire

Before initiating the educational activities outlined in the laboratory where this study was conducted, all participating pre-service special education teachers were administered an anamnestic questionnaire and a self-assessment questionnaire on digital competencies: the DigiComp 2.2 (The Digital Competence Framework for Citizens, also known as DigiComp) (Table 1, Steps 1 and 2).

The anamnestic questionnaire collected sociodemographic and professional data, which allowed for a comprehensive profiling of the sample. Among the 840 participants, 76.2% identified as female and 23.8% as male. In terms of age distribution, 12.5% were under 24 years old, 41.7% were between 24 and 30, 28.6% between 31 and 40, 12.4% between 41 and 50, and the remaining 4.8% were over 50 years old. Regarding educational qualifications, 18.1% held a bachelor's degree, 52.3% a master's degree, 22.9% a postgraduate specialization or second-level master's degree, and 6.7% held a Ph.D. or postdoctoral qualification.

Participants came from diverse academic backgrounds: 36.4% had degrees in education, psychology, or social sciences; 23.7% in humanities and literature; 16.5% in linguistic disciplines; 11.9% in scientific or mathematical fields; and the remaining 11.5% in law, economics, or healthcare. Most participants (71.4%) had previous teaching experience, though with variation in years of service, ranging from newly qualified teachers to those with over ten years of professional practice across different school levels.

In addition to sociodemographic data, the questionnaire also included two self-assessment items regarding the perceived importance of digital tools in education and the extent to which participants considered themselves digitally competent teachers. On a five-point Likert scale (1 = not at all, 5 = extremely), the average rating for the importance of digital tools was 4.15 (SD = 0.82), while the average perceived level of digital competence was 3.28 (SD = 0.97). These self-perceptions served as a preliminary indicator of digital awareness and confidence within the sample.

2.3. Digital competencies assessment

The DigiComp framework was designed to identify and describe, using a common language, the areas of digital competence. It is a tool developed by the European Union to improve citizens' skills, aiding policymakers in formulating policies aimed at supporting, creating, and planning new digital skills, especially in the field of education and training, to enhance the digital competence of specific target groups (Carretero et al., 2017).

Ala-Mutka et al. (2008) describe digital competence as one of the key competences for lifelong learning. The European Digital Framework (DigiComp) was developed by the Joint Research Centre of the European Commission in 2013 to identify and unequivocally define digital competence, making it unique and relevant for all citizens living and working in Europe (Clifford et al., 2020).

In 2022, the DigiComp framework was updated to version 2.2, incorporating recent discoveries and developments in the fields of technology and digital transformation, particularly concerning artificial intelligence, virtual reality, and augmented reality. In this way, DigiComp 2.2 has become a scientifically significant tool in the field of learning (Vuorikari et al., 2022).

The participants were asked to complete the Italian version of DigiComp 2.2 on the MyDigiSkills platform (https://mydigiskills.eu/it/). They received a .pdf file with their results via email. The results provided participants with the total scores they achieved for each competence and in each aggregate area.

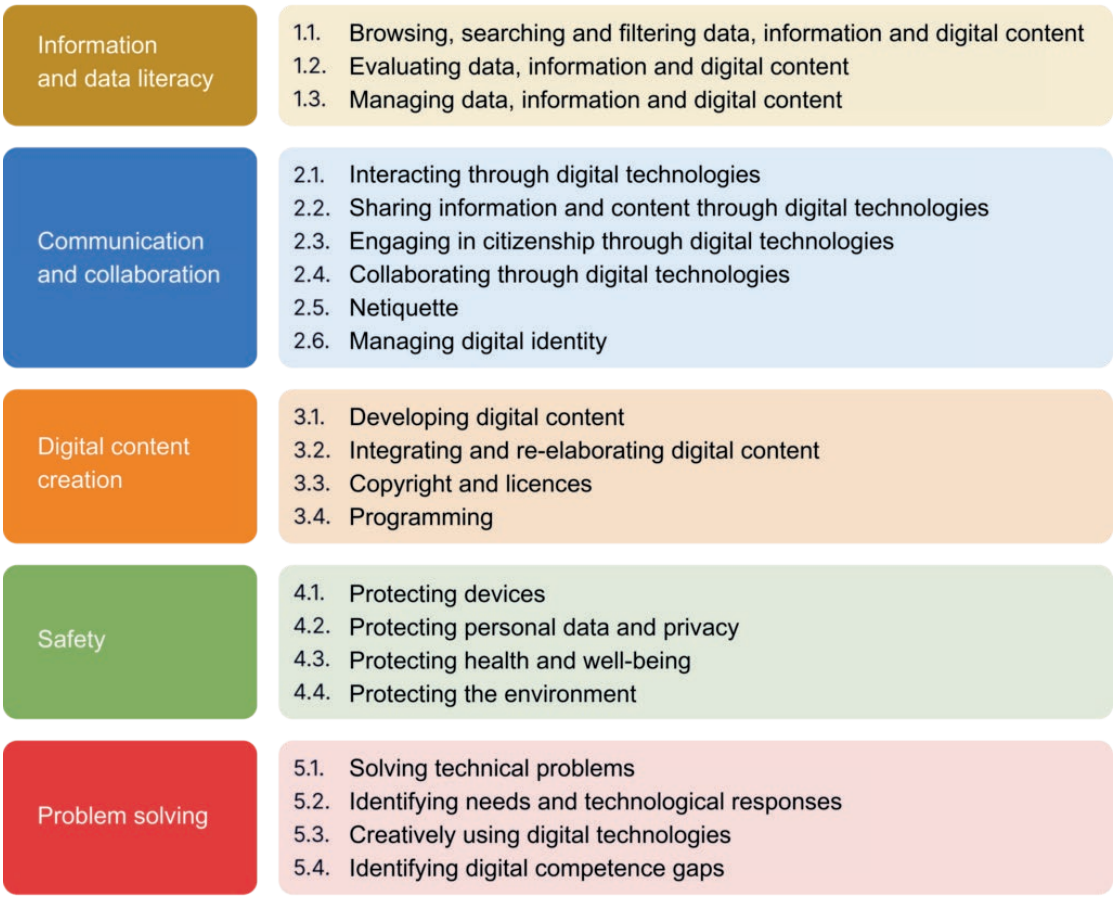

Figure 1. The DigiComp conceptual reference model (Vuorikari et al., 2022).

Following an introductory theoretical lesson (Table 1, Step 3) aimed at helping special education teachers in training understand the objectives of DigiComp 2.2 and the importance of developing skills in the field of Digital Transformation in Education, each trainee was asked to complete an observation grid. This grid allowed for a more detailed quantitative self-assessment of the five digital competences described in DigiComp 2.2 (Table 1, Step 4).

Figure 1 shows the conceptual reference model of DigiComp, where the 21 competences (dimension 2) are grouped into five competence areas (dimension 1).

Each of the 21 skills were evaluated by each special education teacher in training using a graduated observation grid with a score from 1 to 10 (Filippone & Bevilacqua, 2024), which represented in quantitative terms the value expressed by themselves, using the learning scenario as a descriptor (dimension 5) which depicts the link between the use case and its proficiency level (Vuorikari et al., 2022).

The quantitative evaluation grid adopted in the study by Filippone & Bevilacqua (2024) represents a crucial tool for systematically and reliably measuring the 21 digital competences outlined in the DigComp 2.2 framework. This approach allows for the evaluation of participants' progress through a graduated system that assigns a score from 1 to 10 for each competence. In this study, the methodology does not rely on direct observation by tutors but instead on the critical self-assessment of pre-service teachers. They use specific learning scenarios as descriptors to contextualize their mastery levels in each competence area.

This grid not only standardizes the evaluation process but also allows for a detailed analysis of how educational activities contribute to the development of digital competences such as digital content creation, information management, and problem-solving. This demonstrates the effectiveness of an innovative and multidimensional teaching approach.

The importance of this grid also lies in its ability to identify students' strengths and weaknesses, providing a solid foundation for targeted educational interventions. This is particularly relevant in the context of inclusive education, where the personalization of learning activities is essential to support students with Special Educational Needs (SEN). The results obtained not only validate the effectiveness of the educational program but also highlight how technology can act as a catalyst to promote fundamental digital competences and foster inclusion.

Finally, the use of the quantitative grid provides a data-driven approach to monitor individual and collective progress over time, enabling comparative evaluation among different student groups. Thus, this tool becomes an essential component for ensuring the effectiveness and replicability of innovative educational approaches aimed at enhancing digital competences in line with the requirements of DigComp 2.2.

The same observation grid was administered during the final class (Table 1, Step 9) to compare participants' results and determine whether there were any changes in their perceived levels of digital competences.

2.4. 3D learning virtual worlds

After these preliminary investigations, 20 hours of theoretical lessons and practical laboratory activities were conducted (Table 1, Step 5). During these sessions, participants were trained on the use of virtual worlds in education and the practical construction of virtual worlds to be utilized in ordinary teaching practices. This aimed to align with the new digital educational scenario that has emerged in recent years.

For the construction of virtual worlds, the platform framevr.io (https://framevr.io), henceforth referred to as "Frame," was introduced (Step 6).

Frame can be considered the easiest way to create a personal corner of the metaverse. It works on desktops, mobile devices, and VR headsets as it runs directly from a web browser. Frame was initially created to facilitate meetings, events, and seminars in corporate environments because it allows users to easily create spatial, multi-user sites.

The use of Frame assumes that the web browser serves as the metaverse, signaling the onset of a new era of spatial computing where traditional websites, apps, and services coexist with the spatial web alongside the 2D interfaces we are accustomed to today.

In the proposed activities, Frame was tested as an educational tool for creating virtual environments (3D Learning Virtual Worlds). These environments were designed to facilitate innovative lessons centered on group work, cooperative learning, and a novel approach to transmitting and, most importantly, sharing knowledge (Filippone et al., 2023/a).

Participants, organized into cooperative workgroups, created a 3D Learning Virtual World as the final project of the laboratory course. They later utilized this project during the teaching activities conducted in their direct internship, as outlined in the curriculum for the Specialization Course on Teaching Support (Table 1, Step 7).

2.5. System usability scale

At the conclusion of the laboratory course and all its associated activities, each participant was administered a usability questionnaire (Table 3), adapted to virtual worlds (Table 1, Step 10). The scale used in this experiment is detailed in Table 3.

Table 3. System Usability Scale (SUS) Adapted for Virtual Worlds and Used in This Experiment.

Fasi della sperimentazione	Descrizione delle fasi
SUS_A	*I believe that the escape room created with virtual worlds is a valuable tool to be frequently used with students.*
SUS_B	*I believe that creating an escape room with virtual worlds is quite simple.*
SUS_C	*I believe that an escape room created with virtual worlds is easy for me to use with students.*
SUS_D	*I believe that an escape room created with virtual worlds is easy for students to use.*
SUS_E	*I found that the types of digital activities that can be integrated into the escape room are highly engaging.*
SUS_F	*I believe that the escape room created with virtual worlds does not have an educational impact.*
SUS_G	*I believe that teachers could easily use this educational tool.*
SUS_H	*I found that using the escape room created with virtual worlds is not convenient to use with all devices.*
SUS_I	*I felt capable of managing the use of this educational product.*
SUS_L	*I felt able of creating this educational product..*
SUS_M	*I needed to undergo thorough training to use the tools required for building the escape room with virtual worlds.*
SUS_N	*I believe I need technical support to independently build an escape room with virtual worlds.*

The System Usability Scale (SUS) is a standardized questionnaire consisting of 10 statements designed to evaluate the perceived usability of a system or product. Developed by John Brooke in 1986, the SUS is widely used to quickly gather feedback on the effectiveness, efficiency, and user satisfaction of various systems, including software, websites, and hardware devices (Lewis, J. R., 2018).

In the scientific field, the SUS is employed to assess usability by providing a quantitative score that reflects users' perceived ease of use, facilitating comparisons between different systems or product versions. Additionally, it is used to identify design issues; user responses can highlight critical areas requiring improvement, guiding iterations in the development process. Finally, the SUS is highly valuable for comparing user groups, enabling the analysis of differences in usability perceptions among various demographic or competence groups.

Recently, studies have been conducted to deepen the understanding of the application and effectiveness of the SUS (Lewis, J. R., 2018; Suria, O., 2024). These studies underline its importance and versatility as a tool for usability evaluation in various contexts and with diverse user types.

2.6. Focus group

Alongside the quantitative analysis, a qualitative phase was planned through the creation of 84 focus groups within the existing laboratory subgroups. The focus groups were conducted by each group referent teacher, using a semi-structured outline validated by the research team. The composition of the groups reflected the internal organization: 200 and 160 students for the first grade school, divided into units of 10, and 220 and 260 for the second grade school, also divided into groups of 10. The internal homogeneity of the groups was maintained to ensure experiential coherence.

The discussions, verbalized in a synthetic form and returned through verbatim and qualitative observation grids, were analyzed through the thematic analysis approach proposed by Braun and Clarke (2006). Two independent researchers coded the data and compared the emerging categories to validate the interpretation of the contents. The reflections that emerged concerned perceived motivation, digital self-efficacy, sense of active participation and the perception of the inclusive efficacy of virtual environments.

2.7. Data analysis

The data from the DigiComp 2.2 questionnaire (Step 1) were collected using the MyDigiSkills platform within the Beta Tutor section.

A descriptive statistical analysis (mean, standard deviation, median, minimum, and maximum) was conducted on the dataset for the entire sample. This analysis focused on the DigiComp scores (t0 and t1), the scores derived from the evaluation grid designed using the learning scenario of the fifth dimension (hereafter referred to as DigiComp Fifth Dimension, DigiComp5D) as a descriptor (t0 and t1), and the usability scores (SUS).

Additionally, the overall usability score (SUS Score) was calculated on a scale of 0 to 100 as follows:

$$SUS\ score = (sum\ of\ items - minimum\ value) \times \frac{100}{(5 \times 12)}$$

The Shapiro-Wilk test was subsequently applied to verify whether the data followed a normal distribution.

A paired t-test was conducted to compare pre- and post-experimentation scores for the results obtained in the five DigiComp areas, while the Wilcoxon test was used for the results obtained from the quantitative analysis of the 21 digital competences (DigiComp5D).

Additionally, Spearman's correlation analysis was performed to examine the relationship between the improvement in digital competences and individual SUS values, initial knowledge of virtual worlds, and the increase in digital competences.

Finally, to evaluate the effect of school grade, SUS scores, and initial knowledge of virtual worlds, a multiple linear regression analysis was carried out.

Finally, the Kruskal-Wallis Test was conducted to reveale significant differences in SUS scores between competence levels (Basic, Intermediate, Advanced).

3. Results and discussion

3.1. Perception of usability and the importance of digital tools in schools

The perception of usability of innovative digital products is fundamental for the success of digital transformation in the educational context. Tools perceived as intuitive and useful foster the adoption of technologies, enhancing teaching effectiveness and promoting a more engaging and inclusive learning experience.

Digital transformation today offers significant opportunities for educational inclusion by enabling personalized learning and supporting students with diverse needs. The use of assistive technologies and digital platforms facilitates access to educational content, contributing to the reduction of learning barriers.

Educational escape rooms, in particular, represent an innovative approach to engaging students in problem-solving and collaborative learning activities. By integrating elements of play and challenge, these activities stimulate critical thinking and creativity. The use of 3D virtual worlds further amplifies the experience, offering immersive environments where students can interact and learn dynamically.

The data analysis from this experiment strongly supports this new pedagogical direction, as it revealed a mean SUS (System Usability Scale) score of 65.43 out of 100, with values ranging from 55.00 to 73.33. This result indicates a generally positive perception of the usability of virtual worlds, albeit with room for improvement. These findings align with recent research emphasizing the importance of designing user-friendly digital environments to encourage the adoption of immersive technologies in education (Vlachogianni & Tselios, 2022; Mondragon Bernal et al., 2022).

The importance attributed to digital tools in schools was further assessed with a mean score of 4.15 out of 5, suggesting a widespread awareness of the central role of digital technologies in contemporary education. However, participants' self-assessment of their digital skills scored lower, with a mean of 3.28 out of 5. This gap highlights the need for targeted training programs to strengthen teachers' confidence in their digital capabilities (Ala-Mutka et al., 2008). Therefore, it is essential to continue investing in the development of digital skills and user-friendly educational technologies to address the challenges of 21st-century education.

In Italy, the National Digital School Plan (PNSD) serves as a key strategy to promote digital innovation in schools. The PNSD aims to:

Train teachers and students on digital competencies, providing professional development opportunities.

Introduce curricula that integrate digital education while improving technological infrastructure to ensure access to adequate devices and internet connectivity in all educational institutions.

Promote innovative teaching methodologies, encouraging the use of technologies to support active and collaborative learning (Gremigni, E., 2019).

3.2. 3D learning virtual worlds, escape room and digital skills

The statistical analyses conducted revealed significant improvements across all DigiComp areas. Paired t-tests on the DigiComp areas showed significant improvements in all areas, with p-values < 0.001. This indicates that the differences observed between pre-test (t0) and post-test (t1) scores are statistically significant (Table 4).

Table 4. Results of Paired t-Tests on DigiComp Areas.

DigiComp Area	t-statistic	p-value
Area 1	t = − 93.29	p < 0.001
Area 2	t = − 140.84	p < 0.001
Area 3	t = −100.20	p < 0.001
Area 4	t = −80.65	p < 0.001
Area 5	t = −176.30	p < 0.001

All areas showed statistically significant improvements ($p < 0.001$), with high t-values indicating marked differences.

In particular, Area 5 (Problem Solving) recorded the largest increase, suggesting that training in virtual worlds significantly enhanced participants' abilities to identify and solve technological problems.

Similarly, Area 3 (Digital Content Creation) demonstrated a significant improvement, indicating that participants acquired practical skills in creating innovative teaching resources.

This result is supported by the mean increases observed between pre- and post-experimentation scores, represented in Figure 2. The figure highlights that Areas 3 and 5 exhibited the highest increases with greater variability, while Areas 1 and 2 showed moderate increases with more compact distributions.

This pattern suggests that training in virtual worlds is particularly effective for practical skills such as problem-solving and digital content creation. In contrast, areas related to communication and information benefited to a lesser extent, likely due to their less hands-on nature.

These results are consistent with studies demonstrating the effectiveness of immersive technologies in enhancing technical and practical skills (Gárate et al., 2021).

Significant increases were also observed in the DigiComp5D sub-areas, as highlighted in Figure 3.3.

The sub-areas 3D (3.4 Collaboration) and 5B (5.2 Problem Solving) exhibited the largest increases, with the former showing the highest increase and the latter a significant improvement.

Some sub-areas, such as 2D (2.4 Digital Communication), recorded more modest increases.

It is evident that the sub-areas with the greatest improvements are closely tied to collaboration and problem-solving, highlighting that the training methodology based on virtual worlds was successfully

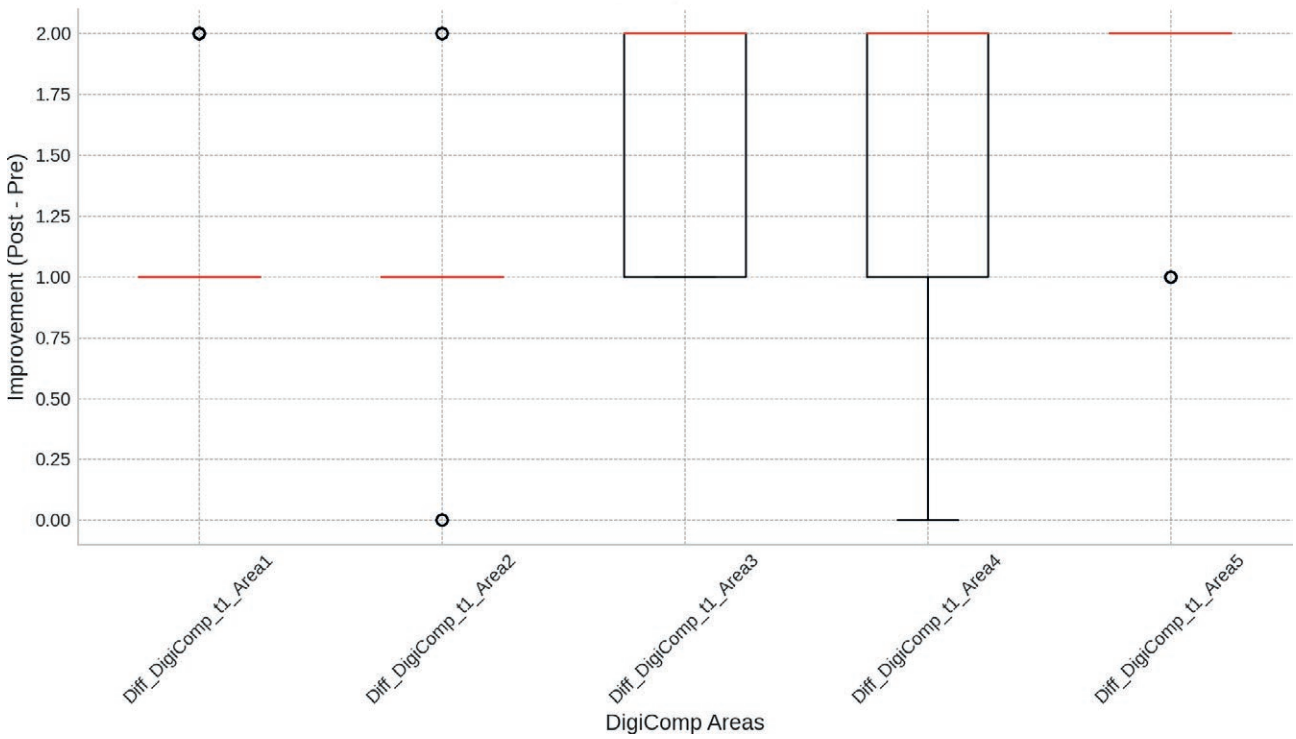

Figure 2. DigiComp Boxplot: displays the mean increases (t1-t0) for each DigiComp area.

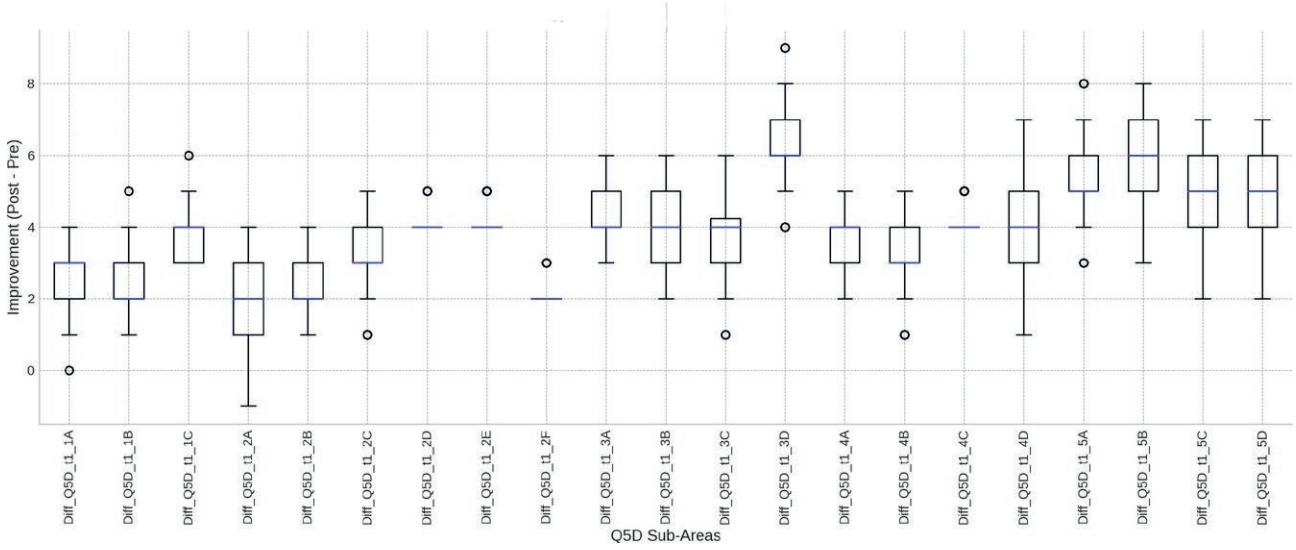

Figure 3. Boxplot Fifth Dimension: visualizes the increases for each sub-area of DigiComp5D.

designed to develop these key competences. This indicates a significant enhancement of skills in these specific sub-areas.

3.3. Qualitative reflections from focus groups: perceptions on the effectiveness of virtual escape rooms

To integrate the results of the quantitative analysis and deepen the understanding of the experiences lived by the participants, a broad qualitative survey was conducted through focus groups, created within the laboratory structure already active in the training path. The entire reference sample, composed of 840 students of the TFA support – VIII cycle at the University of Foggia, took part in this reflective phase. The participants, divided into 360 for the first grade secondary school and 480 for the second grade secondary school, were already organized into operational subgroups – respectively of 200 and 160 for the first grade and 220 and 260 for the second grade – in which focus groups composed of ten units each were activated. Each focus group was conducted by the teacher in charge of the working group, who had already accompanied the students in the previous theoretical and laboratory phases.

The method adopted guaranteed a strong coherence between the concrete experience lived in the laboratory and the qualitative reflection connected to it, enhancing the climate of trust and collaboration already established. The conversations were guided by a semi-structured track that oriented the dialogue towards the dimensions of motivation, development of skills and inclusive perception of virtual environments. The synthetic verbatim were subsequently coded and analyzed by thematic analysis according to the model of Braun and Clarke (2006), with a procedure of independent double coding and inter-judge comparison to ensure internal validity.

The analyses reveal significant reflections that enrich the reading of the numerical data. Numerous participants underlined the key role of motivation generated by the use of digital escape rooms in 3D environments. A support teacher from a lower secondary school stated: "*I really participated with enthusiasm in this experience. I felt more involved than ever before in an educational simulation. It was as if the theory came to life*". This perception of immersive presence and agency facilitated active participation even by students with low familiarity with digital tools, in line with what was observed by Parong and Mayer (2018), who highlight how virtual environments can enhance cognitive and affective involvement in training contexts.

A second recurring area in the focus groups concerns awareness of professional development and digital self-efficacy. Some students stated that they initially experienced a sense of technological inadequacy, which was then overcome thanks to the laboratory approach: "*I never thought I would be able to design an escape room. Now I feel more confident in using digital tools even in the classroom*". These testimonies confirm the potential of immersive environments in promoting situated learning, oriented towards competence and the resolution of complex problems, as highlighted by Radianti et al. (2020) and Makransky et al. (2019).

Particularly relevant are also the reflections on the inclusive value of virtual worlds. Several students reported having designed activities with students with disabilities or special educational needs in mind. A significant example comes from a student in secondary school, who designed a virtual room with audio-narrative paths for students with dyslexia and simplified visual buttons: "*I thought about how to make the activity accessible for a student who has difficulty reading or is easily distracted. The virtual world has given me tools that are often lacking in the real classroom*". The use of immersive technologies is therefore configured as a powerful tool for teaching differentiation, in line with the indications of the *Universal Design for Learning* model (Meyer et al., 2014), which promotes flexible, customizable and accessible educational environments for all.

The collected narratives show how the experience of creating escape rooms in virtual worlds was not perceived only as a technical exercise, but as a transformative experience on a professional and emotional level. The comparison within the groups favored an authentic reflective process, oriented towards the re-elaboration of the teacher identity and the consolidation of an educational approach based on creativity, participation and inclusion. In this sense, the methodological triangulation between quantitative and qualitative data proved crucial to strengthen the solidity and depth of the study, confirming that educational innovation based on immersive technologies can significantly impact educational practices, the motivation of teachers in training and the quality of school inclusion.

4. Conclusions, perspectives, and educational implications

The results of this study demonstrate the effectiveness of virtual worlds and digital escape rooms as innovative educational tools for enhancing digital competencies and promoting active and inclusive learning (Kang, 2021; Kang et al., 2024). The participating special education teachers showed significant improvements across all areas of the DigiComp 2.2 framework, with particularly notable impacts in the dimensions of problem-solving and digital content creation. These findings confirm that immersive and cooperative training activities can facilitate the acquisition of practical skills essential for addressing the challenges of contemporary education.

A key element of the study's success was the adoption of the quantitative DigiComp scale based on the learning scenario of Dimension 5, developed by Filippone & Bevilacqua (2024). This tool enabled the systematic and reliable evaluation of participants' progress, providing a detailed measurement of the 21 digital competences outlined in the framework. By contextualizing competence levels through specific learning scenarios, the scale made it possible to precisely identify areas of strength and weakness, providing a solid foundation for targeted educational interventions. This approach highlighted how immersive technologies can be used not only to develop digital skills but also to support personalized learning and educational inclusion.

The analysis of the System Usability Scale (SUS) further validated the effectiveness of virtual worlds, revealing a positive perception of usability, though with some room for improvement. These findings align with studies emphasizing the importance of designing intuitive and accessible environments capable of meeting the needs of a wide range of users, including students with Special Educational Needs (SEN) (Vlachogianni & Tselios, 2022; Mondragon Bernal et al., 2022).

The qualitative reflections from the 84 focus groups provided additional insight into participants' lived experiences. Many participants reported a strong motivational component linked to the use of virtual escape rooms, highlighting how these environments fostered engagement, self-efficacy and inclusive thinking. These outcomes are in line with the literature on immersive technologies and their role in enhancing cognitive and affective involvement in learning (Parong & Mayer, 2018; Radianti et al., 2020; Makransky et al., 2019). Moreover, the design of inclusive learning paths, often aimed at students with disabilities, shows alignment with the principles of the Universal Design for Learning (Meyer et al., 2014), confirming the transformative potential of digital environments in promoting equity and accessibility.

However, the discrepancy between usability perception and improvements in certain competencies highlights the need to optimize the design of virtual environments to ensure a more uniform impact (Rivera, 2021). While digital escape rooms proved to be effective in motivating learners and strengthening their autonomy, future research should continue to investigate how to enhance their impact across all competence domains.

This explorative study outlines the potential of immersive technologies not only as technical support but also as catalysts for pedagogical innovation. Nonetheless, further research is needed to explore the dynamics between usability, self-efficacy, and learning outcomes, as well as to conduct longitudinal studies to monitor the long-term impact of immersive technologies.

5. Limitations and future research directions

This study has several limitations that should be acknowledged. First, the measurement of digital competences was based on self-assessment tools, which, while valid and widely adopted (Carretero et al., 2017; Vuorikari et al., 2022), may introduce subjective bias. Second, although the sample size was robust, the study was conducted in a single institutional context and within a single training cycle, which may limit the generalizability of results. Third, the focus group analysis, though systematically conducted, relied on reported perceptions and was not triangulated with direct observations or external evaluations.

Future studies should aim to incorporate mixed methods that include performance-based assessments and longitudinal tracking of skill retention and application in real educational settings. Further research could also explore the integration of artificial intelligence within virtual learning environments to support adaptive feedback and individualized progression. Additionally, a comparative analysis across different teacher education programs or national contexts could strengthen the external validity of the findings.

In conclusion, the adoption of virtual worlds and digital escape rooms, combined with advanced evaluation tools like the DigiComp scale based on learning scenarios, represents a promising pathway to making education more inclusive, personalized, and responsive to the needs of a constantly evolving society.

6. Author contributions

All the authors contributed to the writing. Alfonso Filippone, in particular, contributed to the study conception and design. Data preparation were performed by Alfonso Filippone and Umberto Barbieri. The first draft of the manuscript was written by Alfonso Filippone except for the conclusion, written by Emanuele Marsico; and all authors commented and wrote on previosu versions of the manuscript. All the authors read and approved the final manuscript.

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