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Editorial. Weaving the future of education, innovative pedagogy in a digital, inclusive, and sustainable world

Editoriale. Tessere il futuro dell'istruzione, pedagogia innovativa in un mondo digitale, inclusivo e sostenibile

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As we navigate the complexities of 21st-century education, a clear imperative emerges from recent scholarship: we must move beyond viewing educational technology as a mere tool and instead embrace it as a catalyst for profound pedagogical transformation. The discourse is no longer simply about if we should use technology, but how we can leverage it to create more inclusive, engaging, and critically aware learning environments. The second general issue of 2025 of the Italian Journal of Educational Technology brings together diverse perspectives that reflect the growing richness and complexity of research in educational technologies, both in terms of contexts explored and methodological approaches adopted.

Our journey begins by exploring the transformative power of education in one of society's most challenging contexts: the prison. The explorative case study by Decembrotto and Mari (2025) on the "Giocare Dentro" project powerfully illustrates the universal and foundational need for structured game as an educational practice. By introducing board games into the Italian prison system, the project creates a regulated space where cognitive, emotional, and social skills can be developed. In a setting defined by isolation and rigid control, games offer a counter-narrative of empowerment and personal growth. They become a medium for managing conflict within shared rules, fostering self-reflection, and encouraging communication, reminding us that the core principles of good pedagogy transcend context and serve even the most marginalized learners.

From the structured, physical interactions of board games, we shift our focus to the digital realm, examining the challenges of extending educational opportunities through mobile technology in formal schooling. The systematic literature review by Amalia et al. (2025) on mobile learning in Indonesian primary schools highlights a critical gap between potential and practice. While mobile apps, augmented reality, and e-modules have successfully improved educational outcomes, their implementation is hampered by significant systemic barriers. These include limited infrastructure, inequitable access

to devices, and a pressing need for enhanced teacher skills. This research offers an important reminder that technological innovation cannot thrive in isolation from its social and educational contexts. It requires a supportive ecosystem built on professional development, robust infrastructure, and community engagement to ensure that digital tools become instruments of inclusion rather than exclusion.

If technology is to be integrated effectively and inclusively, then the training of future educators becomes paramount. The phenomenological study by Trevisan and De Rossi (2025) explores how blended learning and flipped classroom models can transform pre-service teacher education. Their findings show that these student-centered approaches are highly effective in fostering higher-order thinking skills, such as analysis and evaluation. By actively engaging pre-service teachers in the very methodologies, they will be expected to use, such programs prepare them to design flexible, technology-permeated learning experiences. This direct experience is crucial for building the professional identity and confidence needed to overcome the challenges of innovative teaching.

The potential for technology to revolutionize teacher training, particularly for inclusive education, is further explored by Filippone et al. (2025). Their research on using 3D virtual worlds and educational escape rooms with special education teachers in training demonstrates remarkable success in enhancing digital competencies. These immersive environments boost motivation and provide a powerful platform for designing personalized activities aligned with Universal Design for Learning (UDL) principles. The study shows a significant improvement in skills related to problem-solving and digital content creation, confirming that hands-on, engaging training can equip teachers with the practical abilities needed to create truly inclusive learning spaces.

Beyond the acquisition of technical skills, however, lies the deeper challenge of fostering a culture of collaborative reflection. The work of Romiti et al. (2025) investigates how Computer-Supported Collaborative Learning (CSCL) can promote "evaluative thinking" among in-service teachers. Their study of an online professional development program reveals that structured collaborative activities encourage teachers to move beyond mere data literacy. Through educational dialogues, participants learn to collectively analyze practices, interpret data within their school's cultural context, and co-construct strategies for improvement. This process of reflective, social inquiry is fundamental for driving meaningful and sustainable school self-evaluation and improvement.

Finally, as we embrace the digital transformation of education, we are called to a new level of critical consciousness regarding its hidden costs. The contribution by Orsenigo et al. (2025) serves as a powerful concluding reflection, urging us to consider the environmental impact of our increasingly digital world. The authors detail the immense footprint of technology, from the "embedded emissions" in device production, which uses over seventy chemical elements, to the "operational emissions" from the energy and water consumed by data centers every time we stream content or use an AI model. This reality necessitates an "environmental education of digital resources", a new pedagogy that fosters digital moderation and a critical understanding of the tangible consequences of our virtual actions.

In conclusion, the papers in this issue collectively argue for an educational future built on thoughtful integration. It begins with the fundamental humanism of play-based learning, extends through the critical and equitable application of technology, is actualized by innovative and reflective teacher education, and is ultimately grounded in a profound sense of responsibility to our planet. The overarching goal is to foster a holistic form of education that prepares citizens to navigate the complexities of the digital era while remaining aware of their ethical obligations within an ecologically interdependent world.

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Board games in prison: An explorative case study

Giochi da tavolo in carcere: uno studio di caso esplorativo

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ABSTRACT This article examines the "Giocare Dentro" project, an Italian initiative that introduced board games into the prison system as an educational practice. Developed by Gabriele Mari and his team, the project aims to use board games to promote cognitive, emotional, and social skills among people in prison. Despite the restrictive and isolating nature of the prison setting, a closed institution marked by marginalisation, over the years board games have proven to promote communication, self-reflection, and conflict management. Where the penitentiary educational approach views education as serving disciplinary purposes, the project offers a different perspective, using play as a form of empowerment and personal growth. Through a structured interview with Mari, this case study highlights the complexities and potential of a board game-based project in prison, providing important insights on how to replicate the experience in other prison contexts.

KEYWORDS Prison; Board Games; Play-Based Education.

SOMMARIO Questo articolo approfondisce il progetto "Giocare Dentro", un'iniziativa italiana che ha introdotto i giochi da tavolo nel sistema carcerario come pratica educativo. Sviluppato da Gabriele Mari e dal suo team, il progetto mira a utilizzare i giochi da tavolo per promuovere le abilità cognitive, emotive e sociali tra le persone detenute. Nonostante la natura restrittiva e isolante del contesto carcerario, un'istituzione chiusa segnata dall'emarginazione, nel corso degli anni i giochi da tavolo hanno dimostrato di poter promuovere la comunicazione, l'auto-riflessione e la gestione dei conflitti. Dove l'approccio educativo penitenziario vede l'educazione come funzionale a scopi disciplinari, il progetto offre una prospettiva diversa, utilizzando il gioco come forma di *empowerment* e crescita personale. Attraverso un'intervista strutturata con Mari, questo studio di caso mette in luce le complessità e le potenzialità di un progetto basato sul gioco da tavolo in carcere, fornendo importanti indicazioni su come replicare l'esperienza in altri contesti carcerari.

PAROLE CHIAVE Carcere; Giochi da Tavolo; Educazione Ludica.

1. Introduction

This article examines a play-based experience developed by Gabriele Mari, an educator, game developer and designer, and his team within the project "Giocare Dentro" (Playing Inside), a board game-based project implemented in prison, which focuses on promoting structured play as an educational practice within this setting. After presenting the theoretical framework concerning the concepts of play, "lifelong playing", and the challenges associated with the prison context, the case study is pre-

sented in a discursive format, employing a structured interview. The article concludes with some considerations based on the critical analysis of this specific experience and the interview.

2. Play, Lifelong learning and Lifelong playing in any context, including prison

According to Johan Huizinga (2002), play is a pre-cultural experience, predating culture. For example, children create their own games and play regardless of the presence of an adult to "teach" them how to play. Moreover, despite often being associated with childhood, play is not exclusive to that stage of life; it plays a fundamental role in the development of the individual and extends throughout a person's life, representing as a sort of "lifelong playing" (Farné, 2005; 2024). There is no age at which one can be considered beyond play experience: at every stage of life there are playful dimensions and experiences. As adults, what we call "play" refers to any activity we choose to engage in freely, for enjoyment and well-being (Farné, 2005; 2024). From this perspective, we can regard sports as a cultural form of play, and likewise, the same concept can certainly be extended to board games, both traditional and modern.

Play is a fundamental element of the process of civilisation (Huizinga, 2002); it contributes to the development of rules and social structures that later become integral to cultural life. Additionally, Gregory Bateson (1996) described play as an important form of social interaction and communication that transcends mere enjoyment, contributing to the development of social and cognitive skills. He introduced the concept of play as "meta-communication", suggesting that, through play, people communicate not only content but also the rules and dynamics of the interactions themselves. This implies that play allows for the establishment and understanding of boundaries defining acceptable behaviour, fostering mutual understanding among participants. Thus, play is a practice in which relationships and meanings are continuously negotiated, explored, and renegotiated.

Roger Caillois (2016) attempted to classify play activities and proposed six characteristics that define play: freedom (play is a voluntary activity, and participants choose to engage freely); separation (play takes place in a time and space distinct from everyday life); uncertainty (the results of play cannot be pre-determined); rules (every game is governed by a set of rules that define how it should be played, establishing the modes of interaction and the conditions for winning or losing); non-productivity (play is an activity that has no productive goal); simulation (play often involves elements of representation, where participants assume roles or scenarios that may differ from reality). While these categories may require revision and expansion today, they offer an interesting perspective on play in its many forms. For example, play creates an "alternative" dimension, enabling an experience that allows us to break free from the present, the "here and now", and everyday roles, thereby facilitating the exploration of new, expected, unknown, or unexpected dynamics. In addition, Caillois (2016) analysed play's structure by introducing the distinction between "paidia" (free, spontaneous play) and "ludus" (regulated, structured play). These concepts represent the two extremes of a spectrum, illustrating the evolution of play from a more unstructured activity to a complex, rule-governed cultural form.

Play is often utilised for purposes that are not necessarily related to enjoyment. For this reason, it is essential to distinguish between "original" playful activities (fun-oriented) and educational activities conducted in the form of play. To clarify these two different ways of understanding play, Aldo Visalberghi (1958) distinguished between "ludic" activities and "game-like" activities. In ludic (or playful) activities, the aim of the game and the end of the game are the same. Participants engage in the game

for fun, without external goals: ludic activities self-define. On the other hand, game-like activities can be viewed as experiences that adopt a ludic form, although the aim of the game does not correspond to that of the activity (enjoyment). In this case, the objective lies outside the game and may include learning outcomes. The objective remains external to the act of playing and is typically determined by others.

The "pedagogy of play" emphasizes the educational value of this experience: it aims to promote playful and sports activities based on an educational intent and concerns the advancement of play culture and its practices within the educational process. Through this experience, players "look at themselves and their world through the category of the possible, typical of play, according to which reality is what it looks like, but it could also be different" (Farné, 2005, p. 180). Through direct experience in play (free, uncertain, simulated), the idea of the possible emerges, along with the potential for change, which is an important pedagogical category. According to Farné (2005), "lifelong playing" could be regarded as a meaningful aspect of education. Could lifelong playing have the same value in prison? And is it possible to develop an (educational) play experience even in prison?

As defined by Erving Goffman (2003), the prison is a closed and total institution[1] characterised by many social barriers, including interpersonal dynamics tainted by prison logics and subcultures, marginalisation and stigma, social isolation, and narrowed, stereotyped social roles. Indeed, often a single role prevails, that of the "prisoner". Persons in prison are forced to live within a problematic social microcosm that is radically different from the one they experienced before entering prison. The very nature of prison as a "total institution" – where individuals are isolated from broader society and subjected to rigid structures – creates significant barriers to fostering environments conducive to meaningful play. The potential of play – for everyone, including adults – is very interesting on an educational level. In such a setting, play might be reimagined not just as a recreational activity, but as an opportunity for emotional relief, self-reflection, and interpersonal relationships, as well as a space for experimenting, all essential in mitigating the effects of isolation and marginalisation that characterise prison life.

Moreover, education in prison is not without its ambiguities (Decembrotto, 2024). Its philosophy, when not limited to a disciplinary function, stands in stark contrast to prison logics (UNESCO, 1995). Indeed, education is most often seen as a tool of incarceration technology, essentially a technology of power, an instrument used to control, organize, and amplify the power of bodies, that Michel Foucault (2008) defined as disciplinary technology. This means that within a prison context, it cannot be assumed that concepts like "education" carry the same meaning as they do outside, as full human development, emancipation, empowerment, and openness to possibilities. However, this should not lead to the conclusion that it is impossible to offer meaningful play experiences in prison; rather, as will be illustrated in the following, these experiences cannot be developed without awareness of the context in which they occur and the associated challenges. In terms of its potential, play can work as a counter-narrative to the dominant prison logic.

One final point. The play experience discussed in this article is limited to board games, both traditional and modern. Traditional board games are typically associated with abstract strategy games (e.g., chess, checkers, backgammon). On the other hand, modern board games are more complex to define (Sousa & Bernardo, 2019). In general terms, a board game is a structured form of play involving rules, objectives, and components, typically (though not necessarily) played on a flat surface. A distinctive fea-

[1] A "total institution" refers to a setting (comprising both a structure and an order, e.g. prison or asylum) where a group of individuals, sharing similar circumstances, is isolated from the rest of society for an extended period and leads a life that is confined and systematically regulated by an authority (Goffman, 2003).

ture of board games is that players are central to the experience (Parlett, 1999). Each game is characterized by specific goals that provide direction for gameplay. Board games can serve as a medium through which players engage in strategic thinking, social interaction, and skill development. As such, they not only entertain but also reinforce essential life skills, reinforcing the idea that play is a vital component of human development. Playing modern board games appears to improve cognitive and executive abilities (Martinez et al., 2023), including logical thinking, problem solving and short-term memory; but also social skills, including relationship and emotional skills. Often board games require players to interact with one another, fostering social dynamics such as cooperation, competition, and negotiation.

3. Context and methodology

"Giocare Dentro" (translatable as "Play Inside") is a board game-based project began in 2015, following the experience of structured play activities with young people with autism who were involved in board games, carried out by a group of educators from the "La Pieve" social cooperative[2]. On that occasion, the team of educators adopted the TEACCH method[3] (Mari, 2018), an educational strategy designed for teaching children with autism. The educators began referring to themselves as "play-based educators", as their educational practice focused on the systematic use of board games as a playful mediator and on their facilitation of play activities. These educational activities are characterized by a strong pedagogical intentionality, which can be briefly described as a commitment to promoting the individual's development and well-being. In the "Giocare Dentro" project, this expertise is transferred and adapted to a radically different context: the prison.

The project is implemented within the Ravenna prison, a medium-security institution that accommodates both convicted individuals and those awaiting sentencing. The prison houses approximately 80 people in total, half Italian and half of non-Italian nationality (sometimes considered as such, even if born in Italy, because they do not have citizenship). This institution is relatively small compared to the average size of prisons in Italy and does not appear to suffer from the problem of prison overcrowding. From July 2015 to February 2023, "Giocare dentro" produced 171 game sessions, amounting to a total of 342 hours of gameplay. During these sessions, 103 board games were introduced and played. A total of 65 individuals aged between 19 and 61 (with an average age of approximately 28 years) participated, all men from various national backgrounds. The average attendance per session was about 9 players out of 12 available places (2015–2019). However, following the COVID-19 pandemic, which caused a prolonged suspension of activities in all Italian prisons, attendance decreased to 6 players out of 8 available places (2020–2023). Currently, the project is on standby, awaiting resumption.

To the best of our knowledge, there is no research on this type of educational approach in a prison context. Consequently, this paper presents the results of a preliminary exploratory research, which highlights the strengths, limitations, and potential of introducing board games into a prison context. One of the key strengths of exploratory research is its inherent flexibility, enabling researchers to adapt methods and objectives as new insights emerge during the study. This adaptability informed the selection of this research methodology.

Nonetheless, exploratory research has well-documented limitations, the most significant of which is its inherent subjectivity. Moreover, it is often characterised by a lack of rigorous methodological stand-

[2] https://cooplapieve.it/

[3] Treatment and Education of Autistic and Related Communication Handicapped Children.

ards. This study employs a structured interview with the founder of this initiative, Gabriele Mari, a play-based educator and game designer. To gain a deeper understanding and analyse the effects as perceived by the participants, further research utilising a mixed-methods approach (both qualitative and quantitative) would be essential. For example, gathering player feedback would be invaluable. However, this is particularly complex in a prison context due to the necessary authorisations for collecting the opinions of individuals deprived of their liberty (Decembrotto & De Rocco, 2023).

Despite these limitations, the exploratory approach offers significant advantages in this context, particularly its capacity to uncover new ideas and perspectives. Its adaptability makes it especially suited to challenging environments like prisons, where logistical, social, and institutional constraints often hinder traditional research methods. The value of this research lies in its ability to illuminate a potentially significant educational and playful experience.

4. "Giocare dentro": the interview

The following text consists of the text of the questions (Q) posed by the interviewer and the answers (A) provided by the respondent, Gabriele Mari. The interview was conducted in written form to enhance the clarity and precision of the content and terminology used.

Q: Ten years ago, in 2015, the experimental project "Giocare dentro" was launched, aimed at introducing board games within the prison of Ravenna. How did the idea of a recreational workshop in prison come about?

A: In 2015, as an educator for the "La Pieve", a social cooperative, I began experimenting with the use of structured games, particularly board and role-playing games, in educational contexts related to disability and autism. This approach was later extended to workshops held in summer recreation centres and school classes: it became evident that the relational dynamics fostered within these groups through games were largely comparable. The activity generated an informal and enjoyable atmosphere, elicited a high level of engagement among the participants, and encouraged communication, interaction, and mutual understanding. When the opportunity arose to propose a new course within the penitentiary institution, it seemed natural to extend our playful approach and test it with a new type of group: people in prison.

Q: In your experience, under what conditions does board gaming represent an educational practice? And why is it also directed at adults?

A: Board games are activities that facilitate the development of cognitive, relational, and ethical skills. Through play, individuals engage in reasoning, evaluate options, and make decisions. Interaction with others occurs through cooperative or competitive means, depending on the game, and players navigate these interactions within a framework of rules that necessitates respect for others and adherence to the game's normative structure. The primary condition that makes board games a particularly fruitful educational practice is the deliberate selection by an educator of specific games whose mechanics and dynamics align with the educational objectives set forth. Board games are also suitable for adults because they serve as a comprehensive form of entertainment that can accompany every stage of life. The misconception that games are solely for children stems from an outdated societal perspective and a limited understanding of the extensive range of game offerings designed specifically for adults, encompassing both complexity and thematic content.

Q: How are the board game sessions structured in prison?

A: The board game sessions for the "Giocare dentro" project are structured as weekly meet-

ings lasting two hours each. Each cycle of sessions typically lasts about three months, with variable breaks between cycles depending on the needs of the prison and the bureaucratic situation related to activating the workshops. Each session accommodates a maximum of 15 people and is conducted by two play-based educators from the "La Pieve" cooperative. To participate, people in prison must apply through course registration forms and wait for approval from the Director. The sessions are held in a room designated for workshops, which is equipped with a few tables and chairs. The selection of games (ranging from 5 to 20 boxes) is brought into the prison each time by the play-based educators, who must subject the materials to standard security checks. Within the room, the two educators can set up and run two separate games in parallel or form a single game group, depending on the number of participants, educational needs, and inmate preferences. During a two-hour session, generally, 2 or 3 different games are played at each table. In addition to explaining the game rules, the educators supervise the group or, upon request from persons in prison, participate actively as players.

Q: Why might a person in prison choose to participate in this activity? And if it happens, how does their motivation change over time?

A: Initially, many people in prison choose this activity out of simple curiosity or to pass time differently. Fundamentally, any offered course is seen as an opportunity to escape boredom. However, for those who remain engaged, motivation evolves into some of the primary forms of enjoyment described by Hunicke, LeBlanc, and Zubek (2004) in "MDA: A formal approach to game design and game research"[4]: some appreciate the fellowship, which involves interaction with others as a moment of mutual understanding; others enjoy the challenge of testing their abilities and demonstrating their worth; and some simply enjoy the escape (submission) – at least virtually – of an activity that allows them to "think about something else" in a relaxed and friendly atmosphere.

Q: How would you describe the context in which this educational and recreational experience takes place? What opportunities and limitations have arisen over the years?

A: The prison of Ravenna is a small institution with a capacity of 83 places (almost all occupied). The building dates back to the early 1900s and has structural limitations and inadequate, cramped and poorly lit spaces, as noted in the Antigone last report (Miravalle & Scandurra, 2023). The room where the game sessions are held is a shared space used for other courses as well, often left in disorder, dirty, and cluttered with other materials. The tables are evidently repurposed from elsewhere and lack sufficient comfort. Chairs are often insufficient in number due to being missing or broken, so people in prison bring stools directly from their cells to sit. The main logistical limitation is the lack of a locked cabinet to store game boxes between sessions. This proposed implementation, seen as an initial step for project development, has never been achieved despite repeated requests.

In terms of human resources, the context is characterized by high turnover: with people in prison awaiting trial and serving sentences of up to 5 years, there is frequent turnover. This means that the group participating in the "Giocare dentro" project lacks the stability needed to establish a long-term gaming path. New members often require the reintroduction of beginner games, while the departure of more experienced participants disrupts the planned progression of game complexity. Additionally, another limitation is the poor communication with the educational department of the facility, with whom initial hopes for direct interaction, particularly in defining objectives and monitoring progress, were not realized.

[4] MDA stands for "Mechanics, Dynamics and Aesthetics"

Q: The prison is marked by a repetitive, alienating routine with few incentives. Recreational activities, when permitted, are often considered merely a pastime. However, this project presents a structured proposal with appropriate times and spaces for board gaming. What compromises have been made to maintain the enjoyment aspect while ensuring that the educational dimension related to experimenting with potentially new situations is not lost?

A: Board games are inherently enjoyable, and this aspect must be preserved both to attract newcomers and to maintain motivation for those already attending the course. The games used in the project are what are known in the Anglo-Saxon world as COTS Games, Commercial Off The Shelf Games, regular board games found in stores, designed primarily for general entertainment rather than educational purposes. The educational value of a game is realized through its use. This is where the skill of the educational facilitator comes into play: having a clear objective and understanding that a particular game, through its mechanics and dynamics, works towards that goal. In this way, players will primarily experience enjoyment during the game, but will also be working, more or less consciously, on the competencies that the chosen game targets.

Q: What types of learning can be facilitated by board games (e.g., socio-relational or cognitive)?

A: Cognitively, board games facilitate the acquisition of knowledge, learning content, and keeping primary functions (from visual perception to language, from reasoning to abstract thinking) and life skills (problem-solving, decision-making, critical thinking, and creative thinking) in practice. Games also stimulate skills related to executive functions: emotional self-regulation, flexibility, planning, attention, response inhibition, and memory.

Emotionally and relationally, gameplay addresses self-awareness, emotional and stress management, empathy, effective communication, and the ability to interact effectively with others and establish functional relationships.

Moreover, the ethical dimension should not be underestimated: games teach respect for oneself and others through adherence to rules, becoming a metaphor for the normative structure that underpins and regulates any community and social interaction. Within a detention context, this aspect gains even greater significance.

Q: Board games also involve challenges and sometimes conflicts. How are these elements addressed and managed when they arise in prison?

A: Conflict is a fundamental element of structured games: conflict between players in competitive games, and conflict between players and the game itself in cooperative games. Competition is highly prevalent in prison life, where individuals often seek to appear strong and superior. This latent competition sometimes leads to friction, conflicts, or even physical altercations. This potential conflict, implicit and latent, can sometimes manifest as a state of perpetual anxiety and discomfort.

In contrast, conflict within board games is explicit, direct, and regulated. When players sit down to a game, they know that the goal is to win by outmanoeuvring others. The shared rules explain how to achieve one's objective and interact directly with other players (or rather, against them). The goal, the rules, and possible actions within the game are clear from the start: players understand that others will attempt to hinder and challenge them according to the rules. Accepting this regulated conflict is both liberating and stimulating: liberating because one can engage in direct conflict with another player for strategic convenience or personal dislike, while still being protected by the rules ("Sorry for attacking you, but it's part of the game!"); stimulating because conflict can showcase abilities that one might not otherwise have the chance to display ("You may be bigger than me, but I'm a better strategist, and you've never beaten me at this game").

Throughout the numerous sessions of the "Giocare dentro" project, it has never happened that a conflict sparked during the game spilled over into real life. Apart from some complaints and numerous jokes, all game conflicts have been resolved within the confines of the rules. In fact, it often happens that game conflicts, even when intense, have diffused previous real-life tensions, allowing players to understand each other better and sublimate their differences and misunderstandings through gameplay. Game conflict can thus serve as a prevention mechanism for actual physical conflict.

Q: Are there metacognitive moments for reflecting on the board game experience? How are they developed?

A: The approach intentionally adopted by the project from the beginning has been one of maximum informality. The main metacognitive moment occurs at the end of each game session when the educational facilitator, assisted by the participants, tidies up the game components to prepare for the next game. During these moments, conversations naturally arise that review the steps of the game and comment on its outcome. Amidst the spontaneous dialogue among players, the facilitator seeks to guide the discussion towards specific points of interest to gain feedback on the inmates' experience. Typically, three themes are addressed: the rules (to ensure understanding), game strategies, and the emotions experienced during the game, giving space to various perspectives.

Even during gameplay, especially in more established groups, players may spontaneously reflect on the group interaction ("If you cheat, it means not only do you disregard the rules but also us, who are trying to follow them. If you keep cheating, you don't deserve to be here with us; you might as well go back to your cell") and the analogies between game situations and external experiences ("I drew a Knife card: you know you shouldn't give me sharp objects, or I'll end up causing trouble...").

Q: An important methodological aspect of this proposal involves expanding accessibility and participation in any educational context, including prisons. Today, the themes of inclusion have a prominent place in discussions about games and the need to create "safe spaces" where everyone can feel welcome. How are these aspects connected to board games, and how can this vision be concretized in prison?

A: Inclusion means first and foremost ensuring that everyone can participate in social activities, in this case, gaming activities. This involves considering the unique characteristics that various people in prison bring to the gaming group: some may have visual impairments, attention issues, language barriers (if they are non-native speakers of Italian or cannot read), or lack experience with structured games. The primary concern is to ensure accessibility by creating a shared environment where everyone feels welcomed and free to express themselves without judgment: simple games that are quick to explain and play, with good interaction between players to stimulate relationships, preferably without text on game components, and based on different skills so that everyone, in rotation, can excel.

The second step is to design a pathway that gradually increases the complexity of the games offered to keep engagement and motivation high, balancing the level of challenge with the participants' skill levels to maintain the group within the "flow" experience described by Mihály Csíkszentmihályi (1990) in "Flow: The Psychology of Optimal Experience".

Q: Throughout this interview, several aspects hint at the role of an educator (play-based educator) in a board game proposal in prison. Could you elaborate on the role and competencies of this professional figure?

A: The role of the play-based educator is a specialization that originated within the La Pieve Cooperative to enhance the use of structured games in educational contexts. Their role involves designing gaming experiences (courses, workshops, events, training) that use board and role-playing

games (both commercial and modified, simplified, or self-produced) to achieve predetermined educational objectives.

The primary competency of the play-based educator is in-depth and practical knowledge of games, including their quantity and intrinsic characteristics (mechanics, dynamics, skills stimulated). Additionally, the play-based educator must be able to conduct and facilitate gaming activities in various group sizes and contexts (schools, disability, autism, specific learning disorders, recreational and social centres, prisons, elderly care).

5. Conclusive remarks

The project challenges the traditional view that sees playful activities as simply time-fillers or pastimes and does so in a context that is itself challenging for its own organisational structure. The board game is proposed as an opportunity for personal and relational development and in prison this assumes particular significance, given the limited or non-existent opportunities available in this setting. Board games – within a framework of enjoyment – can mitigate some of the negative effects of incarceration and Gabriele Mari lists some interesting positive aspects based on his decades of experience.

Autonomy in games is expressed through the players' ability to make decisions, choose their actions, and influence the course of the game, all within a context of voluntary participation, free from external constraints. The play-based educator plays a crucial role in this process by balancing challenge with the necessary skill requirements, thereby promoting active and rewarding participation during the sessions. Within the game context, participants are encouraged to view conflict not as an obstacle, but as an opportunity to exercise their agency. This approach enables them to confront and resolve differences within the game, which not only reduces tension but also facilitates deeper reflection on their emotional responses and behaviour in conflict situations. Moreover, the moments of feedback and informal reflection that follow the games, or that may spontaneously emerge during gameplay, provide players with additional opportunities. In these spaces, they can discuss strategies, emotions, and rules, thus internalizing their gaming experiences. This leads to the independent management of the dynamics of the gaming group, as shown by the example of the reprimand for the cheat, in which an ability to self-regulate the group emerges. These interactions extend beyond the gaming context, potentially transforming into new relational modalities that enrich interpersonal dynamics even outside the gaming sessions. All of this reveals a potential that board games share with other forms of play, such as sports, particularly significant in relation to the dynamics (both relational and power-related) and the logics of the prison system.

Finally, it is important to reflect on the role of the play-based educator, a key figure of a board game-based project: they are not only facilitators of play, but professionals who design play experiences aimed at educational objectives. This role requires specific competencies, such as in-depth knowledge of games, an understanding of group dynamics, and awareness of the needs of various contexts (school, disability, prison, etc.), in addition to the typical skills of an education expert. The educational event is never accidental but is the result of intentionality: even during a play experience (including board games), intentionality is expressed as much at the relational level as it is in that temporal dimension, always oriented towards the future and the possibilities that characterises the educational relationship.

In conclusion, many questions remain unanswered. A board game project in prison highlights the potential for fostering emotional intelligence (perceiving, evaluating, understanding, using and managing emotions) and interpersonal skills among people who have often been denied such opportunities.

What potential transformative power could it have in the context? And what impact might it have on the lives of the participants, particularly regarding their relationships with their families? Is there a risk that it could become yet another instrument of "disciplinary technology" (Foucault, 2008), used for the control and regulation of human behavior, instead of serving as a tool for empowerment? Conversely, how can it create spaces of freedom and opportunities for free experimentation within the realm of play? These are all open questions for further research in the area.

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The implementation of mobile learning in Primary Schools in Indonesia

L'implementazione del mobile learning nelle scuole primarie in Indonesia

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ABSTRACT This research explores the implementation of mobile learning in primary schools in Indonesia through a systematic literature review (SLR). Following the systematic review methodology outlined by Newman and Gough (2020), this research conducted an analysis of selected articles. These articles were retrieved from Google Scholar to ensure a broad and relevant selection of sources. Most articles were published in 2021 and 2022. Mobile learning has become a significant trend in education, with its applications including videos, teaching materials, e-modules, augmented reality apps and applications for gadgets (applications that can be accessed through devices such as smartphones or tablets). Based on the results of this study, mobile learning has been successfully implemented in various subjects, demonstrating its potential to improve educational outcomes. However, significant challenges remain, including limited infrastructure, lack of teacher skills and inequitable access to digital devices. Challenges were also identified, such as teacher preparedness and accessibility for students.

KEYWORDS Mobile Learning; Primary Schools; Indonesia; Literature Review.

SOMMARIO Questa ricerca esplora il tema dell'apprendimento basato sull'uso di dispositivi mobili nelle scuole primarie in Indonesia attraverso una revisione sistematica della letteratura. Seguendo la metodologia di revisione sistematica delineata da Newman e Gough (2020), questa ricerca ha condotto un'analisi degli articoli selezionati. Gli articoli sono stati reperiti tramite Google Scholar per garantire una selezione ampia e pertinente delle fonti. La maggior parte degli articoli è stata pubblicata nel 2021 e nel 2022. L'uso dell'apprendimento basato su dispositivi mobili è diventato una tendenza significativa nel campo dell'istruzione: le tipologie di uso variano dalla fruizione di video, materiali didattici, moduli e-learning, app di realtà aumentata e applicazioni per gadget (applicazioni accessibili tramite dispositivi come smartphone o tablet). Sulla base dei risultati analizzati, il mobile learning è stato implementato con successo in diverse materie, dimostrando il suo potenziale nel migliorare i risultati educativi. Tuttavia, permangono sfide significative, tra cui le infrastrutture limitate, la mancanza di competenze degli insegnanti e le disparità di accesso ai dispositivi digitali. Sono state individuate anche le principali barriere alla diffusione del mobile learning, come la preparazione degli insegnanti e l'accessibilità per gli studenti.

PAROLE CHIAVE Apprendimento Basato su Dispositivi Mobili; Scuole Primarie; Indonesia; Revisione Sistematica della Letteratura.

1. Introduction

The ways of accessing and sharing knowledge have changed significantly with the rapid advancements in information and communication technology in recent years. The need for individuals to have access to information on the go, the need to personalise education, and the ever-increasing use of technology all contribute to the increasing popularity of distance learning, e-learning, and mobile learning (Martha et al., 2018). This demonstrates the critical role of technology in creating new opportunities for more flexible and accessible learning for people from all walks of life. Wireless communication technologies and mobile devices play a major role in the spread of these concepts. Moreover, the continuous development of mobile applications further enhances the potential of mobile learning by providing learners with seamless access to educational resources, making learning more interactive, efficient, and accessible than ever before.

Wireless communication technologies and mobile devices play a major role in the spread of these concepts. With the development of applications, mobile technology has evolved beyond a simple communication tool to offer easy access to unlimited knowledge in the field of education anytime and anywhere (Rosiva et al., 2022). Mobile learning is the outcome of a positive impact of technological advancement that changes the values of education, where learning starts to move out of traditional contexts (Maritasari et al., 2022). This facilitates the use of technology in education and makes it easier for students to interact and access any information. Due to its advantages in the field of education, mobile technology is becoming increasingly important for teachers and students as it is being used more and more (Zengin et al., 2018). Based on this idea, mobile learning is a new approach to learning in the modern education system that has gained recognition in the literature.

Against this backdrop, while some countries, such as Italy, have introduced policies restricting the use of mobile devices in classrooms (Rahali et al., 2024), in Indonesia, the government has initiated various policies aimed at integrating technology into education. The Ministry of Education and Culture has emphasized the importance of digital literacy and the use of technology to support learning processes. For instance, the "Merdeka Belajar" (Freedom to Learn) initiative encourages innovative teaching methods, including the use of mobile devices to facilitate learning inside traditional classroom settings (Rasmitadila et al., 2020). This initiative reflects a broader recognition of the need to adapt educational practices to the demands of the 21st century. In line with this, mobile learning has emerged as a crucial way to enhance accessibility and flexibility in education, allowing students to engage with learning materials beyond the confines of a physical classroom.

ElçiÇek and Bahçeci (2017) define mobile learning as learning through mobile technology, which gives students access to information anytime and anywhere based on their specific needs (Wagner, 2008). Using portable devices such as laptops, tablets, and mobile phones for educational purposes is also known as mobile learning (Niazi, 2007). The term mobile learning also recalls the need for students to control their own learning process according to their own needs and learning styles, not just to access information through mobile devices regardless of time or location.

The centre of attention in this mobile-based online learning environment is the student. The use of mobile learning allows students to have a more personalized learning experience (Cholifah & Nafsi, 2021). Through the internet, one can access teachers, curriculum, and schools. Mobile learning allows access to e-learning content regardless of location thanks to the sophistication of mobile information technology. It can assist traditional learning methods as well as distance learning (Rorita et al., 2018). There are many benefits to integrating mobile learning environments into education. One of the main

benefits that mobile devices offer in terms of learning processes and outcomes is that they are portable, cheaper, and provide opportunities for both social and individualised learning (Chinnery, 2006). Therefore, mobile learning promises to support one's long-term learning process. In addition, mobile learning allows to tailor the learning process to the needs of different students (Corbeil & Corbeil, 2011). Thus, it affects the sociocultural and cognitive aspects of learning (Pachler, 2009). The development of mobile learning is expected to increase students' attention to learning materials, thus creating a more interesting and enjoyable learning experience (Pratama et al., 2018). According to Sari and Pardimin (2024), mobile learning can improve students' critical thinking abilities, making it an effective learning method to support higher cognitive skills.

While there are many advantages in the learning process and outcomes of the widespread use of mobile devices in education, there are also a number of barriers to its use. In general, these issues can be categorised under two main headings. The former is technology-related issues with hardware and software, including issues with internet access and infrastructure, issues with screens and keyboards, and issues with mobile device batteries (Kacetl & Klímová, 2019). The latter regards privacy and security concerns and the high cost of mobile devices (El-Hussein & Cronje, 2010). These issues are expected to diminish as technology advances. Therefore, choosing the best learning strategy for students is a must for educators. To implement learning strategies effectively, educators should consider students' conditions, learning materials, and available learning resources when selecting learning strategies. Consequently, educators should be able to utilise the available learning resources to facilitate students' academic success by implementing learning strategies effectively and efficiently. For example, in primary education, mobile apps can support learning through play in order to make learning easier and more motivating.

The aim of this study is to summarize the results of previous research on mobile learning by focusing specifically on its implementation in primary schools in Indonesia. This study intends to explore the current trends, challenges, and outcomes of research in the field of mobile learning to improve education in primary schools in Indonesia.

2. Methodology

This research employs the Systematic Literature Review (SLR) method. According to Dhamayanti (2022), the systematic literature review is a research design that is used to conduct a synthesis and analysis of evidence provided by earlier studies. The SLR method replenishes the expected contribution of several studies by stating and comparing their outcomes in order to summarize of the information and data collected on a certain study topic. This study uses the SLR methodology as explained by Newman and Gough (2020). According to these authors, in order to conduct a vigorous and balanced assessment of the literature, the stages shown in Figure 1 must be followed.

2.1. Research question

This systematic literature review (SLR) will address the following research questions:

- Question 1 (RQ1): What is the landscape of mobile learning studies in primary education in Indonesia, in terms of distribution in time, types of mobile learning technologies used and subjects taught?
- Question 2 (RQ2): What challenges are faced by teacher and students in the implementation of mobile learning in primary schools in Indonesia? What solutions can be adopted to overcome such challenges?

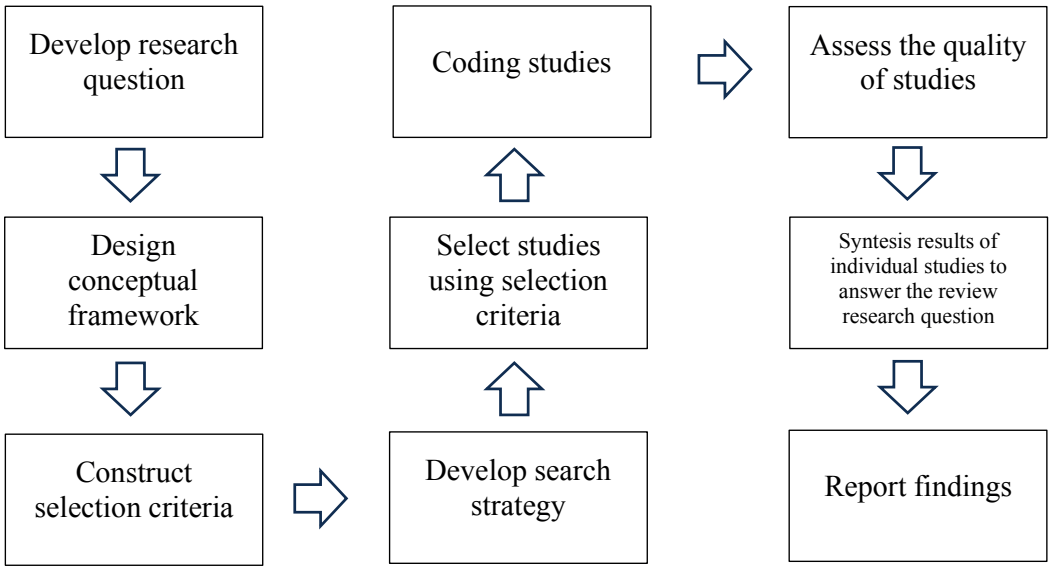

Figure 1. The systematic review process (Newman & Gough, 2020).

2.2. Search strategy

In this Design Conceptual Framework, the researcher chose to use Google Scholar as a search engine. The reason researchers made this choice is because Google Scholar is a search engine for retrieving not only academic documents, but also grey literature and documents in languages other than English (including Indonesian) (Haddaway et al., 2015). Additionally, its use is free. Based on Figure 2, this research consists of several stages, starting with the stage of determining the search engine, creating a search string, carrying out search experiments, refining the search string, and compiling a final list of primary studies that match the search string.

The search string used was "mobile learning", "M-learning", and "sekolah dasar / primary school". The string was adapted to fit the specific requirements of the search engine. These articles were screened based on the inclusion criteria (see Table 1), focusing on studies published between 2024-2019 and specifically addressing mobile learning in primary schools in Indonesia.

Table 1. Search Results on Google Scholar Search Engine.

Keyword String	Total
("mobile learning" OR "M-learning") AND ("sekolah dasar" OR "primary school")	101

The study selection process was carried out systematically to ensure relevance and consistency with the review's objectives. After conducting a search on Google Scholar with the specified keywords, the articles were then selected according to the inclusion criteria, namely focusing on studies published between 2024-2019 and specifically addressing mobile learning in primary schools in Indonesia. This way, 16 articles were obtained. In fact, while mobile learning in general has been investigated in recent

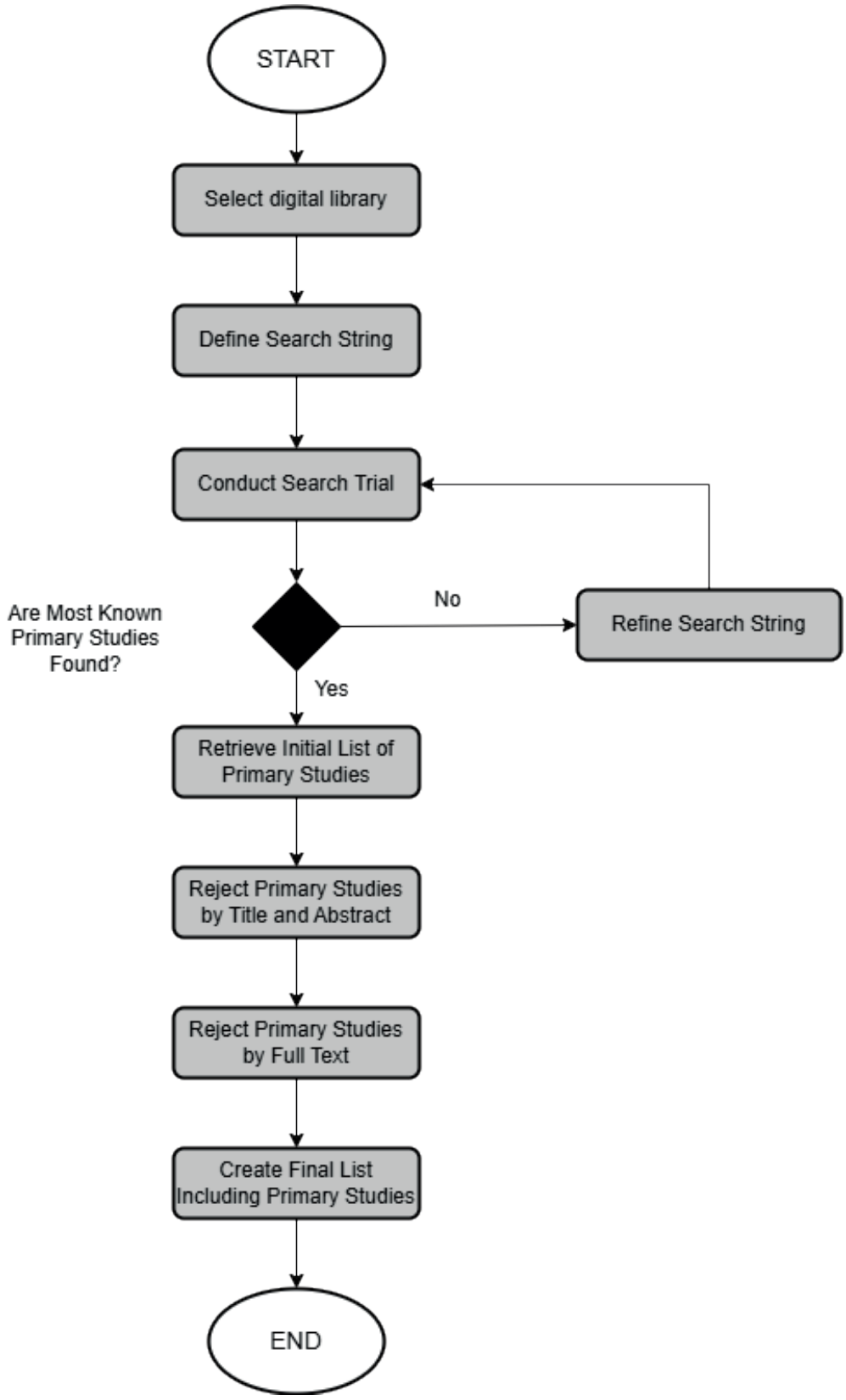

Figure 2. Flowchart of Search Stages.

reviews (Zafrullah & Ramadhani, 2024), Indonesia is a relatively underexplored area in the broader field of educational technology. To study this specific country in depth, this review needs to consider publications not typically included in Scopus or Web of Science, thus providing a more comprehensive understanding of mobile learning in the Indonesian primary education context.

As highlighted by Husain (2019), Google Scholar offers significant advantages for academic research by providing access to a wide range of scholarly articles across various disciplines, including, but not limited to, those covered by traditional databases like Scopus and Scholar. The journals covered include diverse topics, from technology in education to social sciences, ensuring a broad perspective. While databases like Scopus and Web of Science are often preferred for high-impact studies, Google Scholar is a more accessible and inclusive platform, especially for those without institutional access. Husain (2019) also points out that Google Scholar allows researchers to access articles from less conventional or regional sources, which is often relevant for studies such as this that focus on a specific geographical and educational context.

In line with the approach of Tulljanah and Amini (2021), who emphasise the importance of reviewing and selecting studies from accessible and relevant sources for educational research, this study highlights the usefulness of Google Scholar. This search engine provides access to a variety of sources that contribute to the development of educational practices, especially in regions where access to traditional academic databases is limited. This is particularly relevant in the context of mobile learning in Indonesia, where local studies might not always be indexed in high-impact databases. The use of Google Scholar allows researchers to identify research trends in Indonesia more effectively, due to access to a variety of sources that are not always available in Scopus or WoS (Amri et al., 2024).

Therefore, this review supports the use of Google Scholar as an appropriate tool for collecting relevant references on mobile learning in primary schools, particularly as it provides a wider range of articles that may not be available in other academic databases This approach ensures that a more comprehensive set of studies is included in the review, helping to capture trends and insights that might otherwise be overlooked.

However, reliance on Google Scholar as the sole source introduces certain limitations, as it lacks the rigorous indexing standards of databases like Scopus or Web of Science. This may lead to the inclusion of publications with varying quality and impact, potentially limiting the robustness of the review. Nevertheless, Google Scholar remains a more accessible and inclusive platform, especially for those without institutional access.

2.3. Coding phase

The study coding phase is a systematic process used to manage a collection of data into smaller units of analysis by creating categories and concepts derived from the data itself. The coding is carried out by identifying the elements of variables that represent key aspects of the research articles, referred to as quality and relevance variables (Izzaturahmah, 2024). These quality and relevance variables are further explained in Table 2, which outlines how the coding process was applied to assess the implementation of mobile learning in primary schools in Indonesia, as well as its relevance to the local context and the quality of implementation as recorded in the studies analysed.

To identify the key elements, the next step was to read the full text of each article, paying attention to any fragments of text that reflected the elements of the quality and relevance variables. After determining the elements of the quality and relevance variables, a new element was created that is relevant

to this study, where the focus is on articles discussing mobile learning in primary schools in Indonesia.

Table 2. Elements of Quality and Relevance in Research.

Element	Information Captured
Research aim	The aim of each study
Research method	Research method (survey design, statistical analysis methods, etc.)
Research sample	Sample size and demographic data of participants
Research findings	Conclusions, recommendations, and implications presented by the researchers

2.4. Appraising the quality of studies

In a systematic literature review, the data found were evaluated based on quality assessment criteria to gather evidence related to the research question and measure the quality of primary studies. This assessment was conducted using the checklist criteria from Izzaturahmah (2024) which can be seen in Table 3. For the selected articles related to the implementation of mobile learning in primary schools in Indonesia, the quality assessment included three main elements: appropriateness of the research design, quality of method implementation, and relevance to the Indonesian educational context. The research design should reflect the challenges and conditions in Indonesia, while the quality of implementation needs to consider the validity of the data and the application of appropriate mobile learning strategies. This assessment aims to provide a comprehensive picture of the effectiveness and challenges of mobile learning implementation in Indonesian primary schools.

Table 3. Checklist criteria based on Izzaturahmah (Izzaturahmah, 2024).

No	Item	Answer
1.	Is the article cited?	Yes/No
2.	Is the research aim clearly stated?	Yes/No/Partially
3.	Are the research participants or observation units sufficiently described?	Yes/No/Partially
4.	Is data collection carried out thoroughly? For example, is there a discussion of the procedures used for data collection, and how the research setting could affect the data gathered?	Yes/No/Partially
5.	Are potential confounding factors sufficiently controlled in the analysis?	Yes/No/Partially
6.	Is the approach to analysis and the formulation of the analysis presented clearly? For example, is there a description of the raw data forms, reasons for choosing methods/tools/packages?	Yes/No/Partially
7.	Are the findings trustworthy? For example, is the study described methodologically so that we can trust its findings, and do the findings/conclusions resonate with other knowledge and experiences?	Yes/No/Partially

3. Findings

3.1. RQ1 – The landscape of the selected studies

Table 4 shows the 16 studies selected for analysis in this SLR.

Based on the results of the analysis carried out, publications in the field started in 2019 with only 1 article. Figure 3 shows the distribution in time of the other studies. The years 2021 and 2022 saw a significant increase in the number of papers on mobile learning in primary schools in Indonesia. This increase may be attributed to the impact of the COVID-19 pandemic. During the pandemic, the adop-

Table 4. Articles included in the SLR.

No	Author	Research Design Model	Type of Study	Sample	Research Instruments	Mobile Learning Product Results	The Subjects of Mobile Learning Used
1	(D. A. P. Sari & Kiptiyah, 2024)	Borg and Gall Model	Research and Development	30 students in Year 5	Interviews -Media and material Validation Expert Questionnaire -Student Trial Questionnaire	Application for gadgets (articulate storyline-based mobile learning media)	Social studies
2	(Imaduddin & Damayanti, 2024a)	Borg and Gall Model	Research and Development	Year 5 students	-Interviews -Media and material Validation Expert Questionnaire -Student Trial Questionnaire	Application for gadgets (SIMOBILE)	Science
3	(R. V. Sari & Pardimin, 2024)	ADDIE model	Research and Development	10 students in Year 6	-Interviews -Validation sheet for two expert judgements, in this case the principal and teachers who have at least a master's degree – Student response questionnaire.	Application for gadgets (interactive multimedia based on mobile learning)	Mathematics
4	(Anggraini et al., 2023)	Borg and Gall Model	Research and Development	Primary School at West Java, Indonesia	Questionnaires for material feasibility experts, language experts and media experts	Augmented Reality (AR)	Mathematics
5	(Rofi'i & Susilo, 2023)	Borg and Gall Model	Research and Development	Year 5 students	-Interviews, - Questionnaire -Assessments of the Mobile Learning process	Teaching Materials	English language
6	(Suhardi et al., 2022)	ADDIE model	Research and Development	37 students in Year 4	-Interviews -Media and material Validation Expert Questionnaire -Teacher Eligibility Assessment Questionnaire -Student Trial Questionnaire	Application for gadgets (Scientific-based mobile learning application for thematic learning)	Thematic learning
7	(Hardiansyah et al., 2022)	Dick and Carey model	Research and Development	6 Year students	-Interviews – Questionnaires - Tests for students	Application for gadgets (Mobile learning-based learning media)	Science

(Continued).

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Table 4. (Continued).

No	Author	Research Design Model	Type of Study	Sample	Research Instruments	Mobile Learning Product Results	The Subjects of Mobile Learning Used
8	(Zaenal et al., 2022)	ADDIE model	Research and Development	6 Year students	- Interview - Questionnaires for subject matter experts and media experts NuMet assessment sheet instrument - Pretest and post test questions for students	Application for gadgets (Mobile Learning Numeracy "NuMet")	Mathematics
9	(Sakiyah et al., 2021)	DDD-E (Decide, Design, Develeop, and Evaluate) model by Ivers & Barron	Research and Development	35 students in Year 4	-Interviews -Media and material Validation Expert Questionnaire - Pretest and post test questions for students	Application for gadgets (Mobile learning with a Scientific Approach)	Social studies
10	(Ammatulloh et al., 2021)	ADDIE model	Research and Development	Primary school	-Interviews -Media and material Validation Expert Questionnaire -Student Trial Questionnaire	Application for gadgets (Civics Caring Apps)	Pancasila Education
11	(Auliyah & Sari, 2021)	ADDIE model	Research and Development	32 students in Year 3	-Interviews -Media and material Validation Expert Questionnaire -Teacher Eligibility Assessment Questionnaire -Student Trial Questionnaire	Application for gadgets (Appy Pie Android mobile learning application based on creative thinking skills)	Science
12	(Maryono & Budiono, 2021)	Hannafin and Peck model	Research and Development	9 students from each of Year 1, Year 2 and Year 3	- Interviews - Questionnaires for material feasibility experts, language experts and media experts - Teacher Eligibility Assessment Questionnaire - Student Trial Questionnaire	Teaching Materials	Bahasa Indonesia
13	(Utami, 2021)	ADDIE model	Research and Development	18 students in Year 5	- Interviews - Media and material Expert Questionnaire - Student Trial Questionnaire	E-modul	Bahasa Indonesia

(Continued).

Table 4. (Continued).

No	Author	Research Design Model	Type of Study	Sample	Research Instruments	Mobile Learning Product Results	The Subjects of Mobile Learning Used
14	(Firdaus & Hamdu, 2020)	Focus Group Discussion (FGD)	Research and Development	Year 5 students	- Discussions in specific grou	Video	Science, Technology, Engineering and Mathematics (STEM)
15	(Nurhidayat et al., 2020)	Lee, W.W., & Owens, D.L. model	Research and Development	17 students in Year 5	- Interviews - Media and material Expert Questionnaire - Student Trial Questionnaire	Application for gadgets (mobile learning application product that is used in Madura Language)	Non-academic Material
16	(Mabruri et al., 2019)	ADDIE model	Research and Development	64 students in Year 4	- Media Expert Questionnaire- Teacher Eligibility Assessment - Student Trial Questionnaire	Application for gadgets (Science Mobile Learning Media)	Science

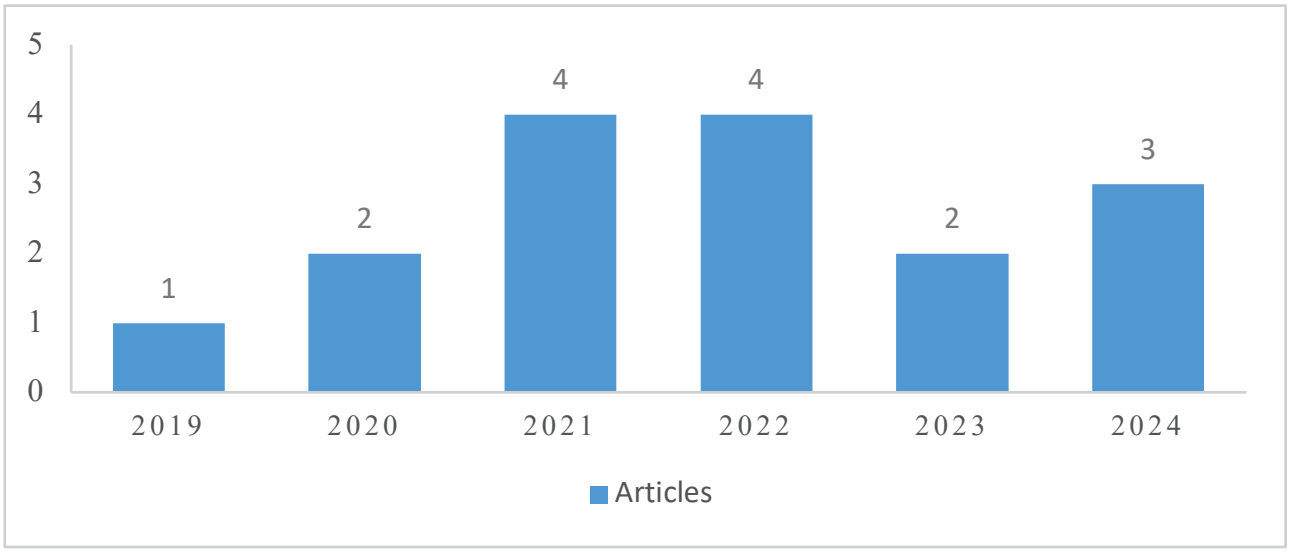

Figure 3. Articles on mobile learning in primary schools in Indonesia by year of publication.

tion of mobile learning surged as schools transitioned to remote learning, leading to a higher reliance on portable devices. However, in 2023 and 2024 the number of studies is lower than during the pandemic. Various factors may have influenced this development, including technical challenges, limited accessibility of devices, as well as lack of adequate training for educators (Mabruri et al., 2019). While the potential of mobile learning to increase flexibility and student engagement remains high, some educational institutions may still face obstacles in overcoming these barriers. Therefore, despite the positive trends in 2021 and 2022, further efforts are needed to ensure that mobile learning can be thoroughly integrated across schools, so that its potential can be truly realised in supporting the education of the future.

Based on the analysis of Figure 4, the devices were used in implementing mobile learning in primary schools in Indonesia to watch videos, access teaching materials, e-modules, applications for gadgets (Android-based applications that can be accessed through devices such as smartphones or tablets), and augmented reality (AR). The use of augmented reality-based mobile learning research is still scarcely investigated (see Figure 4). Even so, augmented reality-based mobile learning research is a subject that should be further investigated and strictly relate to mobile learning research. Through augmented reality, learning is brought to a new dimension as learners can easily visualise what is happening and easily understand complex concepts. The type of mobile technology more frequently used is "Applications for gadgets". These applications serve the purpose of improving students' learning outcomes in various ways. For example, Sari and Kiptiyah (2024) developed articulate storyline-based learning media that showed a significant increase in student learning outcomes in social studies subjects, with an average increase of 56%. Imaduddin and Damayanti (2024) (2024) developed a 'SIMOBILE' application for science lessons that targets increased motivation and learning outcomes. This application received material (89%) and media (88%) expert validation, and was very well received by students (95%). R.V. Sari and Pardimin (2024) used an interactive multimedia approach for Maths, which received an average validation of 92.67%, demonstrating the success of the implementation in supporting learning.

These bespoke apps allow flexible access to learning materials and enhance student interactivity through features such as interactive evaluation, games, and animations.

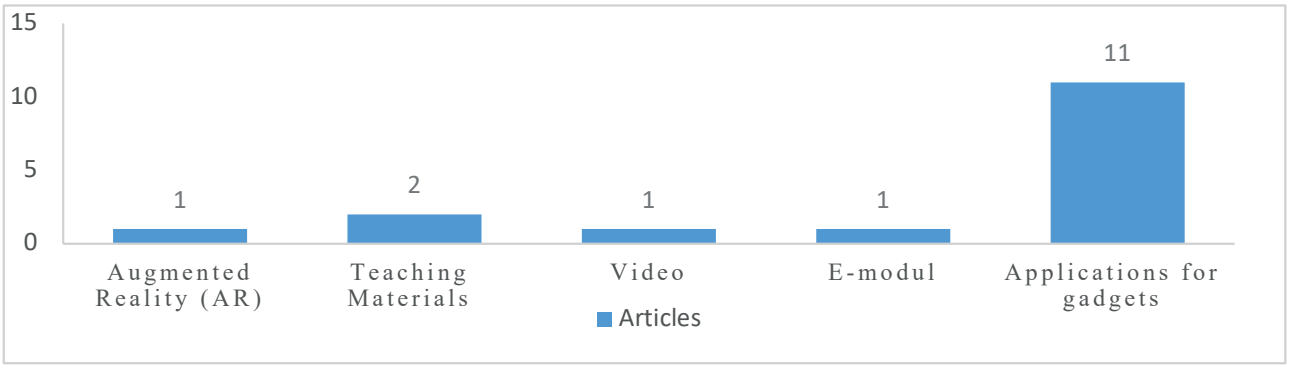

Figure 4. Articles on mobile learning in primary schools in Indonesia by types of mobile learning technology used.

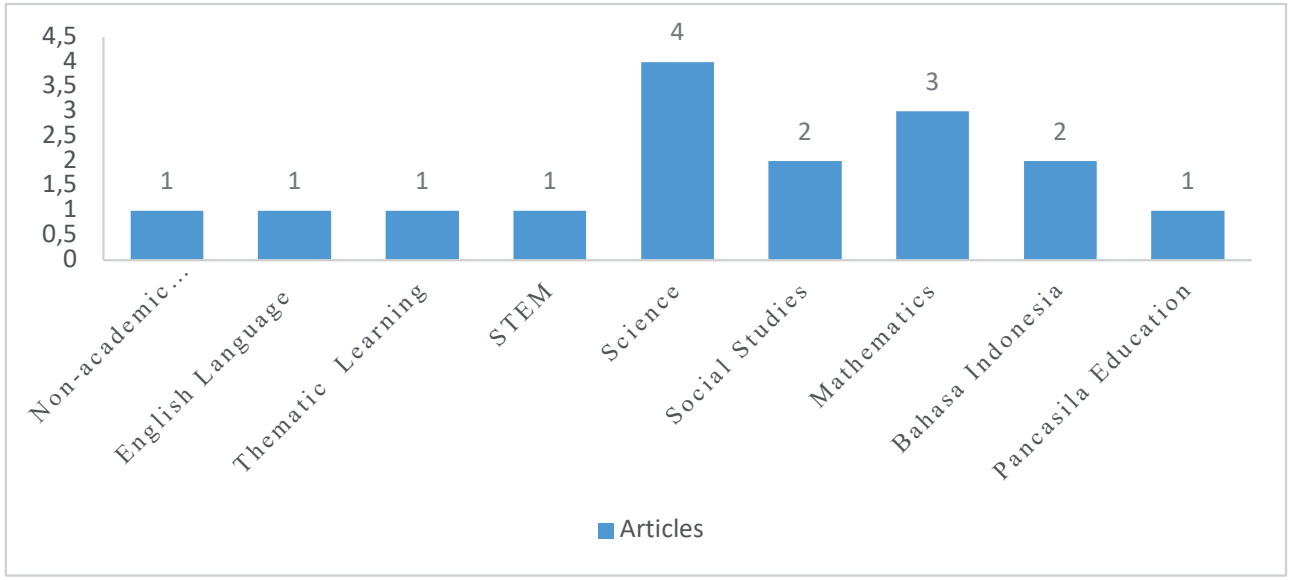

Figure 5. Articles on mobile learning in primary schools in Indonesia by subjects.

Subjects used in primary schools in Indonesia are diverse, such as Indonesian language and Pancasila education, a subject that focuses on Indonesia's national ideology, Pancasila. It aims to instill values of nationalism, ethics, and civic responsibility in students. However, based on Figure 5, mobile learning research mostly uses science subjects. Bahasa Indonesia is a subject used in Indonesia to develop students' language skills in reading, writing, speaking, and listening. It also covers grammar, literature, and text analysis, including various text types such as narrative, exposition, argumentation, and description.

3.2. RQ2 – Challenges in mobile learning implementation

This section addresses research question 2, and is organised according to the classification of study audiences, namely focusing on teachers and students first, and solutions afterwards.

3.2.1. Challenges faced by teacher

One of the key challenges in implementing mobile learning is teacher readiness and competence. Suhardi et al. (2022) highlight the limited capacity of teachers to integrate mobile learning technologies into their teaching practices, especially in rural areas where training opportunities are scarce. Similarly, Hardiansyah et al. (2022) found that many teachers lack the digital literacy skills to effectively use mobile learning tools. Furthermore, teacher-centred studies such as Maryono and Budiono (2021) highlight the need for professional development programmes to increase teachers' understanding of mobile learning. Without adequate training and support, the potential of mobile learning to promote critical thinking and independent learning remains untapped. The lack of user-friendly interfaces in mobile learning tools also adds to the difficulties faced by educators.

3.2.2. Challenges faced by students

Students face various challenges, mainly related to accessibility and engagement. Rofi'i and Susilo (2023) note that while mobile learning materials can significantly increase student motivation, technical barriers such as the requirement for Android-based devices and stable internet connectivity limit access for many students. This problem is exacerbated in regions with inadequate infrastructure, as noted by Zaenal et al. (2022). Motivational challenges also arise when mobile learning materials do not match students' interests and abilities, or are difficult to access. For example, Auliyah and Sari (2021) found that students were less engaged when the mobile application required continuous internet access for educational videos.

3.2.3. Possible solutions

Mobile learning has shown promising results in improving educational outcomes. However, studies such as Hardiansyah et al. (2022) and Suhardi et al. (2022) reveal gaps in teacher preparedness, accessibility for students, and systemic support at the community level. Addressing these gaps requires a multifaceted approach, including:

1) Targeted teacher training: Professional development programmes to increase digital literacy and familiarity with mobile learning platforms.
2) Infrastructure development: Improved access to devices and internet connectivity, especially in underserved areas.
3) Community engagement: Involving parents, stakeholders and policymakers in creating a supportive ecosystem for mobile learning.

By doing so, it is hoped that mobile learning can be integrated more effectively into basic education to support critical thinking, motivation, and collaborative learning.

4. Conclusions

Although this review focuses on a topic that has already been covered by several reviews, it sheds light on a geographic area which, to the best of our knowledge, is not covered by previous reviews. The results show that the number of studies was higher during the pandemic, but remained high after it, the scientific subjects were the most commonly addressed and the technological tools used were quite varied, although bespoke applications were the most frequently used. This systematic review highlights

the implementation of mobile learning in primary schools in Indonesia, demonstrating its effectiveness in improving learning outcomes, critical thinking skills and student motivation across a wide range of subjects, particularly science. However, significant challenges remain, including limited digital literacy among teachers, as noted by Suhardi et al. (2022), and infrastructure issues such as inequitable access to devices and internet connectivity, as noted by Zaenal et al (2022). Furthermore, while culturally relevant tools such as ARBARU (Anggraini et al., 2023) show promise, their scalability remains underexplored, and collaboration between schools and communities is often overlooked (Sakiyah et al., 2021). These findings highlight the importance of addressing systemic barriers through teacher training, infrastructure development, and the creation of culturally relevant and user-friendly mobile learning tools.

However, challenges such as limited teacher preparedness, infrastructure inequalities, and a lack of community involvement hinder mobile learning broader implementation in Indonesia. Addressing these barriers requires focused teacher training programs, equitable infrastructure development, and the creation of mobile learning tools that are both culturally relevant and accessible. By tackling these issues, mobile learning can serve as a transformative educational tool, ensuring equitable and effective learning experiences for all students while supporting the development of Indonesia's educational ecosystem in the digital era.

5. Study limitations and future research trends

This systematic literature review has several limitations. First, the analysis is based solely on articles retrieved from Google Scholar, which may not comprehensively represent all published research on mobile learning in Indonesia, potentially introducing coverage bias. Second, the review found that all included studies were categorised as qualitative research and development projects. While this highlights a focus on innovation and design within Indonesian mobile learning research, it reveals that experimental, quantitative or longitudinal studies evaluating the effectiveness of mobile learning in Indonesian settings remain scarce. As a result, the generalisability of these findings is limited because Research & Development studies typically emphasize prototyping and theoretical validation rather than empirical validation through rigorous methodologies. Future research should prioritise experimental designs, randomised controlled trials and large-scale quantitative studies to objectively assess the implementation of mobile learning and mitigate the confirmation bias inherent in developer-led Research & Development studies. In addition, more focus on inclusivity, enhancing collaboration and exploring innovative pedagogical approaches should ensure that the potential of mobile learning is fully realised.

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ISTITUTO TECNOLOGIE DIDATTICHE

Blending and flipping learning in preservice teacher education: A phenomenological study

Blending e flipping nella formazione iniziale docenti: uno studio di caso

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ABSTRACT This case study explored a large cohort of preservice teachers' perceptions of a blended learning course that integrated flipped classroom elements to promote deep learning about technology integration in education. The course involved face-to-face lessons, online synchronous sessions, team debates, and peer review activities. Data from course evaluations, learning artifacts, and a post-course survey indicated that participants found the blended structure effective for achieving course objectives and fostering higher-order thinking skills like analyzing and evaluating. The flipped approach engaged students in extending their learning through active discussions and relevant activities. Overall, participants perceived coherence between the learning processes activated and the expected outcomes of applying concepts to authentic teaching scenarios. While acknowledging challenges in adapting to the flipped model, preservice teachers valued the opportunities for autonomy, peer modeling, and preparing for technology-integrated instruction. The findings highlight blended learning's potential for transforming even large cohorts of teacher education programs through innovative, student-centered pedagogies.

KEYWORDS Blended Learning; Flipped Classroom; Large Cohort-Preservice Teacher Education; Deep Learning; Technology Integration.

SOMMARIO Questo studio di caso ha esplorato le percezioni di un'ampia coorte di insegnanti in formazione iniziale sulla struttura ed efficacia di un corso blended learning che integrava elementi della classe capovolta per promuovere un apprendimento profondo sull'integrazione della tecnologia nell'istruzione. Il corso prevedeva lezioni in presenza, sessioni sincrone online, gruppi di dibattiti e attività di revisione tra pari. I dati considerano le valutazioni del corpo studentesco, quelle dei prodotti di apprendimento e un questionario post-corso. I risultati hanno indicato che i partecipanti hanno trovato la struttura blended efficace per il raggiungimento degli obiettivi del corso e per promuovere abilità di pensiero di ordine superiore come l'analisi e la valutazione delle tecnologie nell'istruzione. L'approccio capovolto ha coinvolto gli studenti nell'estendere il loro apprendimento attraverso discussioni attive e attività ritenute pertinenti. Nel complesso, i partecipanti hanno percepito coerenza tra i processi di apprendimento attivati e i risultati attesi come l'applicazione dei concetti a scenari didattici autentici. Pur riconoscendo le difficoltà nell'adattarsi al modello capovolto, i partecipanti hanno apprezzato le opportunità di autonomia, modellamento tra pari e preparazione all'istruzione integrata con la tecnologia. I risultati evidenziano il potenziale dell'apprendimento blended e flipped per trasformare anche ampie coorti di formazione primaria attraverso pedagogie innovative e centrate sullo studente.

PAROLE CHIAVE Blended Learning; Flipped Classroom; Scienze della Formazione Primaria; Apprendimento Profondo; Tecnologie per la Didattica.

1. Introduction

For more than a decade now a major challenge for higher education concerns the application of Blended Learning, henceforth BL, teaching modes (Adams Becker et al., 2017). Specifically, the BL approach has attracted much interest as a transformation of teaching in the post COVID 19 period (Kalaichelvi & Sankar 2021). The forced digitization of teaching during the pandemic, while highlighting many critical issues in higher education, presented an opportunity to question and redefine the way higher education develops teaching solutions useful to support innovation, academic quality and curricular standards (Crawford et al., 2020; Trevisan et al., 2020). Upon return to normality, the exclusively face-to-face teaching model tended to be overcome through the integration of digital means towards BL for a number of positive features: more flexible and personalized curricula (Jonker et al., 2018), acknowledgment of student diversity with active methodological approaches (Boelens et al., 2018), student engagement with learning materials (Mestan, 2019).

Other crucial factors have also been investigated for BL implementation, such as institutional transitions (Adekola et al., 2017) and the political influence that organizational, structural and teacher support strategies can have in the transformative action of blended learning (Graham et al., 2013). The instructional design of a BL methodological approach proved crucial to its efficacy (e.g. Mirriahi et al., 2015; Owston & York, 2018) as well as the student-centred methodological perspective (e.g. Vanslambrouck et al., 2018). However, in any process of educational transformation it is the teacher who is the main architect because this process requires much more than simply acquiring new skills or changing pedagogical roles (Bruggerman et al. 2021; Philipsen et al., 2019). It requires action that allows prospective teachers from the initial training onwards to be able to directly experience the integration of digital technologies in education so that they can address their beliefs about the design relationship of technology connected to pedagogy (Gerbic, 2011; Philipsen et al., 2019).

BL is characterized by the fusion of online and face-to-face modes and has been shown to be particularly effective in pre-service teacher education, enhancing flexibility, diversity and engagement (Alammary et al., 2014; De Rossi & Trevisan, 2023; Perry et al., 2021). Active learning fostered by the BL modality emerges as the cornerstone of this educational evolution, focusing on student engagement in knowledge construction and fostering the overcoming of traditional face-to-face only lecture-based approaches (Garcia-Ponce & Mora-Pablo, 2020; Li et al., 2023). This paradigm, within BL solutions, privileges student-centred instruction and integrated formative assessment to promote innovative and meaningful learning practices (Trentin & Bocconi, 2015).

Within the BL approach, the flipped classroom methodology further exemplifies this by reversing traditional teaching methods (Han & Røkenes, 2020) to prioritize active learning and the development of higher order cognitive skills. This factor allows alignment with Bloom's taxonomy (Chandio et al., 2016) for a structured progression of cognitive skills (Li et al., 2023). The flipped classroom methodology not only facilitates student-centred learning, but also integrates technology effectively, preparing pre-service teachers for diverse and technology-infused educational contexts (Perry et al., 2021). However, the fusion of blended active learning with flipped classroom strategies requires university teachers to design initial training teaching experiences that are engaging, coherent and contextually relevant to the students who will be future teachers, harnessing their multiple knowledge to create effective learning environments (De Rossi & Trevisan, 2023; Garcia-Ponce & Mora-Pablo, 2020). This can prepare future teachers to face many challenges when implementing the BL approach, such as new

teaching and technological skills, coping with changing pedagogical roles, or dealing with the critical design and organizational issues of innovative teaching (Vaughan, 2010).

2. Theoretical background

The theoretical context supporting the study proposed in this article is based on three related themes: the definition of BL didactics, the Flipped classroom methodology and deep and active learning processes. Over the last two decades, following the increased implementation of BL didactic approaches, the pedagogical concept of digitally integrated didactics has emerged as the 'new normal' in higher education (Dziuban et al., 2018; Mestan, 2019). The application of BL didactics affects both students and the various institutional systems, attitudes and pedagogical beliefs of teachers (Brown et al., 2024; Garone et al, 2022).

Although the definition of blended learning is still ambiguous (Hrastinski, 2019), the BL pedagogical concept can be understood as the designed combination of online didactics integrated with classroom didactics through active methodological approaches to support learning in a participatory and reflective form (Boelens et al., 2015). The broad meaning of this definition allows for numerous interpretations that make it very relevant to how teachers understand BL didactics and its design (Bruggerman et al., 2021; Ellis et al., 2006). Boelens and colleagues (2017) identified four key characteristics for designing BL didactics: methodological and organizational flexibility, interaction, personalization and an affective learning climate. For example, Han and Ellis' (2019) study highlighted the quality of discussions in BL teaching by emphasizing the importance of integrating online discussions with face-to-face discussions in the classroom.

The role and position of the teacher within the BL implementation process has been the subject of research attention (Brown, 2016). Indeed, teaching consists of more than a combination of skills and pedagogical roles and is considered a 'continuous process of integrating the personal and professional aspects of becoming and being a teacher' (Beijaard, et al., 2004, p. 113). This dynamic process is referred to as 'professional identity' (Beijaard et al., 2004) that can be supported during induction training to help teachers cope with change. Professional identity consists of routines, knowledge, skills, beliefs, and attitudes about one's profession, and it is based on lived experiences (Jonker et al., 2018, pp. 120-121) and for this reason, BL teaching experiences offered during initial training can have an interesting transformative meaning for students to prepare them for the challenges when they will take up their positions as teachers.

A particularly useful methodology in implementing the BL approach is the flipped classroom, which facilitates experiential learning and supports the active construction of knowledge (Awidi & Paynter, 2019; Cecchinato et al., 2019). Another factor in favor of the flipped classroom methodology is that it enhances social learning (Lai & Hwang 2016; Wanner & Palmer, 2015) which promotes the generation and connection of ideas, as well as intellectual convergence. Social learning would support the development of meaningful learning (Jonassen, 2007) by emphasizing the importance of learners' interaction with peers, teachers and others to deepen the meaning of their learning experience (Biggs, 1996). In fact, according to Jonassen's (2007) interpretation, learning is meaningful when it is an intentional, premeditated, active, conscious, constructive practice that includes the reciprocal activity of action and reflection. Accordingly, the learning environment can be defined as a dynamic and open environment that allows subjects to experience active and flexible learning.

A study analyzing the literature on the flipped classroom by Abeysekera and Dawson (2015) highlights multiple factors that promote meaningful learning: the satisfaction of learners' needs for com-

petence, autonomy and relationships and thus increased levels of intrinsic and extrinsic motivation. According to the researchers, the cognitive load of students can be reduced through instructional actions designed according to the students' level of competence. In this way, a sense of competence, autonomy, security and relatedness is likely to positively influence students' engagement in the flipped learning environment.

However, based on Awidi and Paynter's (2019) review of the literature, it is pointed out that the evaluation of the flipped classroom is contingent on ascertaining the motivations and intentions of teachers who design and plan instructional action from a BL perspective. In numerous research (e.g. Abeysekera & Dawson, 2015; Kim et al., 2014; McNally et al., 2017), the complexity of measuring the impact of the flipped classroom in the totality of its aspects with regard to the development of meaningful learning has been highlighted as the variables to be considered are multiple. The variables relate to the characteristics of the proposed teaching activities, which for the purpose of developing meaningful learning should be: active, collaborative, conversational, reflective, intentional, constructive so that the student internalizes a certain methodology that makes him or her autonomous in the cognitive journey (Jonassen, 2007).

From this perspective of analysis, the literature on the innovations of the flipped classroom methodology indicates that the design focus of teachers has been on student engagement and student-centred teaching and learning processes with encouraging results particularly with regard to motivational aspects, active learning and, to some extent, outcomes (Bates, 2015, 2018; Bishop & Verleger, 2013; Lim & Libing, 2016, McNally et al., 2017).

3. The study

This study is grounded in social constructivism for educational research, which positions participants and their processes of meaning-making at the center of understanding a phenomenon (Creswell & Creswell, 2018). From this epistemological stance, the study acknowledges the pivotal role of context in shaping individual interpretations. This necessitates a research design that is methodologically aligned with such assumptions. Accordingly, a case study approach was adopted (Stake, 2006; Yin, 2008), consistent with a constructivist paradigm that seeks to interpret participants' constructions of reality and thereby gain insight into their behaviors within a specific context (Baxter & Jack, 2015). Furthermore, this approach aims to capture the complex dynamic and unfolding interactions of events, human relationships and other factors within each unit of analysis, i.e. case (Cohen, 2017). The specific case at stake was an elective blended course on teaching methodologies and educational technologies offered during the 2023-2024 academic year at a mid-sized European university's initial teacher education program. The course integrated flipped classroom elements into a blended learning environment to foster active learning and engagement with course materials before and during class meetings.

The case study explored the students' perceptions on the following issues:

1) Effectiveness of the course's blended structure in facilitating course objectives.
2) Effectiveness of the course's flipped approach in promoting deep learning.
3) Coherence between the processes activated during the course and the expected outcomes at the end.

The course structure comprised two face-to-face lessons and one synchronous session per week, over 5 weeks (total: 30h). The face-to-face sessions focused on analyzing authentic teaching scenarios through various theoretical frameworks for educational technology, e.g. Technological Pedagogical and

Content Knowledge (TPACK – Koehler & Mishra, 2005); Replacement Amplification Transformation (RAT) and Passive Interactive Creative RAT (PICRAT – Kimmons et al., 2020), Extend Enhance Engage (EEE – Kolb, 2020), Interactive Constructive Active Passive (ICAP – Chi & Wylie, 2014), and Technological Pedagogical Reasoning & Action (Loughran, 2019; Trevisan & Smits, 2023). Collaborations were established with practicing teachers and researchers, who contributed to course delivery. Volunteer in-service primary school teachers provided video scenarios of their classroom practices with technologies, stimulating discussions among preservice teachers. University-affiliated researchers also participated, engaging in discussions on the frameworks and their cross-contextual applications.

Students had the option to form teams and sign up for team-based online debates during the weekly remote session. These teams debated the qualities of teaching scenarios either available online or provided by in-service teachers, based on the week's framework. Teams recorded and uploaded their debates to the course's Learning Management System platform, allowing for peer feedback using a shared rubric. The instructor assessed each debate and peer review using the same rubric, providing formative feedback to individuals and sharing score trends with the entire cohort to demystify and foster learning (Ritchhart, 2015; Ritchhart & Church, 2020). Participation in debates and peer reviews were voluntary, and only the highest score per task would contribute to the overall course grade. Ongoing feedback on processes (e.g., class participation) and products (e.g., debates and peer reviews) aimed to facilitate learning through reasoning (Ritchhart, 2015; Ritchhart & Church, 2020).

3.1. Participants

The participants were the 250 preservice teachers enrolled in the Educational Technology course at the University of Padova during the fall semester of 2023-2024. At the end of the course, they were voluntarily invited to complete an online survey (convenience sampling – Creswell & Creswell, 2018). Their participation and survey responses had no bearing on their course assessment. Participants were fully informed about the aims of the survey.

Nearly all participants (99%) were second-year preservice teachers, aged 20 on average, with 97% being female. While course attendance was elective, 75% of the participants reported attending more than 75% of the sessions, whether face-to-face or remote.

3.2. Data collection and analysis

Given the elective nature of the course, attendance and engagement in tasks were monitored. Grades from the debates and peer reviews were considered evidence of the learning processes activated during the course.

Additionally, a survey was conducted at the end of the course, with 100 volunteer respondents completing it. The structure of this survey is summarized in Table 1. Participation in the research component of the course (i.e., the survey) was voluntary and had no bearing whatsoever on students' assessment or grading for the course itself.

As the instructor of the course, the primary researcher and first author paid particular attention to issues of positionality and potential bias. In line with constructivist case study principles, the researcher is understood as a participant in the construction of meaning, not an objective outsider (Stake, 2006). This perspective aligns with the understanding that complete objectivity is unattainable in qualitative research,

and the researcher's experiences and perspectives inevitably shape the interpretation of data. To safeguard ethical and methodological rigor, several strategies were implemented: survey participation was anonymous, strictly voluntary, and conducted post-course to eliminate any link to students' grades. Additionally, transparency with participants was maintained regarding the research purpose, and data were analyzed with a conscious effort to bracket personal assumptions, in alignment with reflexive qualitative practices (Baxter & Jack, 2015). Finally, regular discussions with external researchers (e.g. second author) not involved in the course were held to challenge assumptions and interpretations.

Table 1. Survey structure.

Area of inquiry	Survey items (type and number)	Survey items (example)
Demographics and background	Six, multiple choice	How often did you attend synchronous online sessions?
Effectiveness blended course structure (Research focus 1)	Five 5-point Likert (1: not at all effective; 5: fully effective)	How effective did you find asynchronous debate peer-reviews (thinking of the course objectives)?
	Bloom's taxonomy, six 5-point Likert items (1: never; 5: always)	How often did you feel engaged in applying ideas and concepts in different contexts?
Effectiveness flipped course structure (Research focus 2)	Five 5-point Likert (1: not at all effective; 5: fully effective)	How effective did you find asynchronous debate peer-reviews (thinking of your learning)? Would you like to elaborate on your answer?
	Triple E checklist (Kolb, 2020): seven items for Engagement; three items for Enrichment and Extension. All items were 3-point Likert (1: not at all; 3: definitely)	Did the suggested activities promote active content-focused discussions between students and/or the teacher? (Engagement)
		Were the contents and activities relevant to your future profession? (Extension)

Coherence among processes and products (research focus 3) was measured considering the paired scores for each of the five items about course objectives, and learning: digital agenda/book of the course; strategies in synchronous face-to-face lessons; online-based debates; online-based debates' peer-review; formative assessment/feedback strategies.

4. Findings

As for course attendance and student engagement, an average of 200 students decided to attend face-to-face lessons every week. A total of 194 students participated in one debate session and 138 to two (a total of three debate rounds were possible overall). A total of 185 students participated in two peer review sessions and 168 in three (the maximum possible), over the five weeks of course.

As for evidence of the learning processes during the course, both the debate and peer review scores increased steadily throughout the weeks, with a steeper trend in the students who engaged in these tasks multiple times. A summary of the results is available in Table 2.

Upon being asked to hypothesize why during one of the classroom discussions, the students pointed out the usefulness of peer modelling through previous videos, reviews and matching feedback on the course platform. The main results of the survey on course structure and quality are summarized in Table 3.

Table 2. Course evaluations.

Evaluation instance		Mean	SD	Mode	Range
Participation in debates	One round (n=194)	25.2	.82	25	25-29
	Two rounds (n=138)	27.8	.76	27	25-29
Participation in peer review	One round (n= 5)	25.8	1.23	26	16-28
	Two rounds (n= 185)	27.3	.97	28	16-29
	Three rounds (n= 168)	28.6	.96	29	16-30
End of course evaluationa	Who engaged in tasks (n=140)	28.95	1.6	30	18-30
	Who did not engage in tasks (n=63)	27.5	2.5	28	19-30

a. Some of the enrolled students did not take the end-of-course evaluation task immediately after the course. Those results were not included in this analysis.

Table 3. Survey scale results (average and mode).

Area of inquiry		Scale range	Scale average	SD	mode	N
Effectiveness Blended course structure	Strategies and activities (course objectives)	1-5	4,35	0,79	5	100
	Bloom-remember	1-5	2,72	1,30	1	100
	Bloom-understand	1-5	3,18	1,41	2	100
	Bloom-apply	1-5	3,88	0,94	3	100
	Bloom-analyze	1-5	4,13	0,78	4	100
	Bloom-evaluate	1-5	4,54	0,61	5	100
	Bloom-create	1-5	2,77	1,40	1	100
Effectiveness flipped learning	Strategies and activities (learning)	1-5	4,30	0,79	5	100
	EEE-Engage	1-3	2,65	0,49	3	100
	EEE-Enhance	1-3	2,83	0,40	3	100
	EEE-Extend	1-3	2,63	0,50	3	100

The data appears to indicate the effectiveness of the blended course structure (research focus 1), as evidenced by the positive evaluation of the *strategies and tasks employed for achieving course objectives* (mean = 4.35, SD = .79). Additionally, the data suggests the recognition of higher-order cognitive levels from Bloom's taxonomy, such as *analyze* and *evaluate*, which were reported to occur frequently (M = 4.13, SD = 0.78; evaluate: M = 4.54, SD = 0.61).

The effectiveness of the flipped learning approach (research focus 2) can be found in the favorable assessment of the strategies and tasks in facilitating a meaningful learning experience (mean = 4.30, SD .79) and the different dimensions of the *EEE* framework (with means above 2.6 for all three dimensions). Within scale 8 (table 3), the lowest score was attributed to the item "*How effective did you find the flipped strategies during face-to-face lessons (for your learning)?*" (*M*= 3.85, *SD*=0.8).

The coherence between the processes activated and the expected products (research focus 3) was examined by comparing the scores for strategies and tasks related to course objectives (1) and meaningful learning experiences (8 – Table 3). As shown in Table 3, participants perceived coherence in this dimension, with nearly identical scores on the two scales in terms of mean, standard deviation, and mode.

5. Discussion and conclusion

The findings from this case study shed light on the participant preservice teachers' perceived benefits of the blended learning course structure and flipped classroom approach in promoting active learning and higher-order thinking. Participants recognized the activation of various cognitive processes throughout the course, with a notable emphasis on the higher levels of Bloom's taxonomy. The flipped approach was perceived as an engaging strategy that enhanced and extended their learning experiences.

Furthermore, the data revealed coherence between students' perceived effectiveness of the processes activated during the course (aimed at fostering meaningful learning), and the accomplishment of expected final products (aligned with the course objectives). This coherence suggests that, from the participants' perspectives, the blended learning course structure and flipped classroom approach of this course supported them in deeply engaging with the content, applying critical thinking skills, and reflecting on their learning processes and future teaching practices.

While these findings underscore preservice teachers' positive perceptions of the innovative pedagogical models in enhancing their learning outcomes, some challenges were also perceived. Notably, participants' unfamiliarity with the flipped approach and their ingrained experiences with traditional teaching methods posed hurdles. The lowest-rated item pertained to the perceived effectiveness of flipped strategies during face-to-face lessons for learning. These results highlight participants' perceptions of the demands of the flipped approach, which requires greater responsibility, organization, autonomy, and self-direction from students (Garcia-Ponce & Mora-Pablo, 2020).

While this study underscores the transformative potential of integrating technology and innovative teaching methods within teacher education programs, the findings also revealed that the transition to these innovative pedagogical models necessitates a gradual acclimation process for learners to develop the required autonomy and organizational skills. Overcoming these perceived challenges may involve implementing a supportive "flipped learning continuum" to progressively familiarize students with this new learning paradigm, thereby enhancing their readiness for the demands of contemporary educational settings (Tomas et al., 2019).

6. Limitations and future directions

This study was limited to a single course context at one university, with a relatively homogenous sample of preservice teachers. Future research should explore BL and flipped approaches across multiple teacher education programs with large cohorts, to enhance transferability. Moreover, a deeper qualitative approach, e.g. through interview studies, could shed light into students' experience of the phenomenon. A longitudinal approach tracking preservice teachers' experiences as they transition into the profession could provide insights into how their training influences classroom implementation of technology-integrated reasoned pedagogies. Additionally, investigating faculty perspectives on redesigning courses and overcoming institutional barriers to BL would complement the student view presented here. Examining specific learning outcomes and achievement data could further substantiate self-reported perceptions of the effectiveness of these innovative models. As BL teacher education evolves, continuous research will remain crucial for refining best practices in preparing future educators for technology-integrated teaching and learning environments.

7. Author contributions

Ottavia Trevisan: abstract, sections 3, 4, 5.
Marina De Rossi: sections 1, 2, 6.

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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.

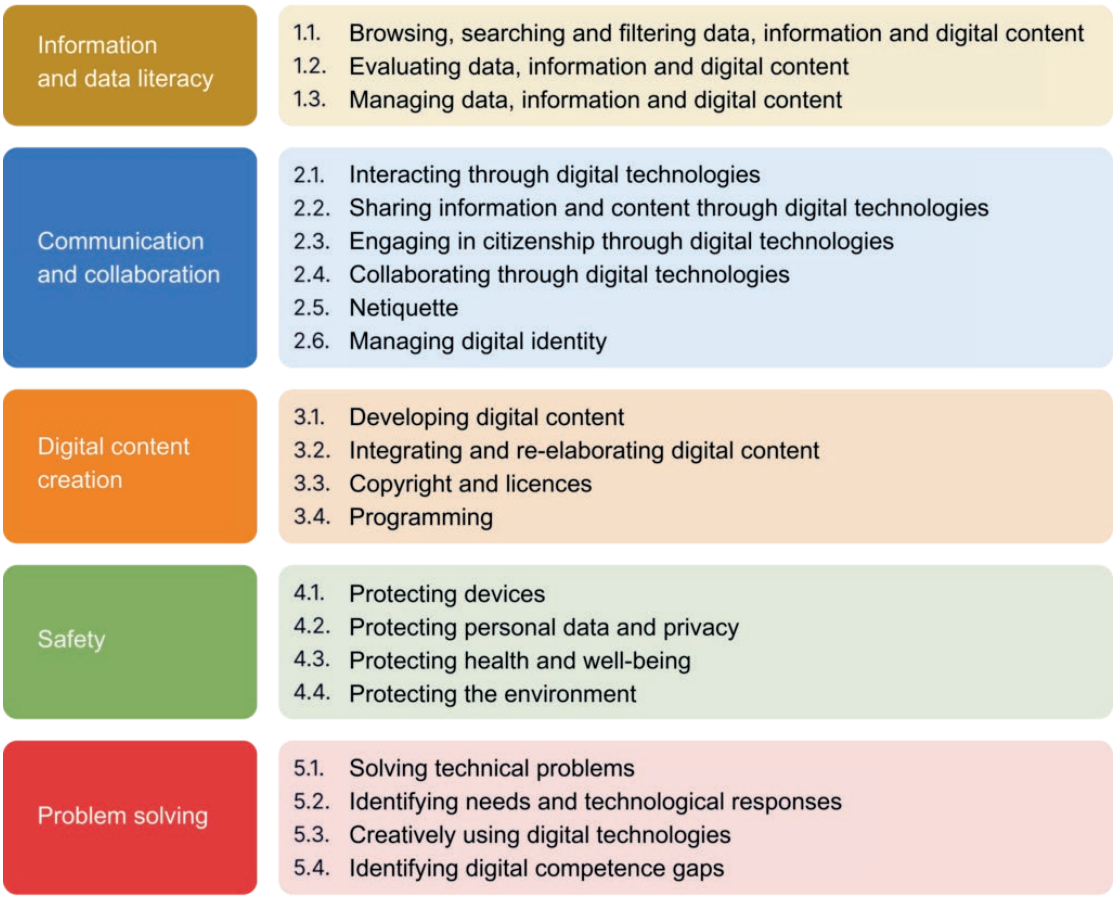

Figure 1. The DigiComp conceptual reference model (Vuorikari et al., 2022).

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

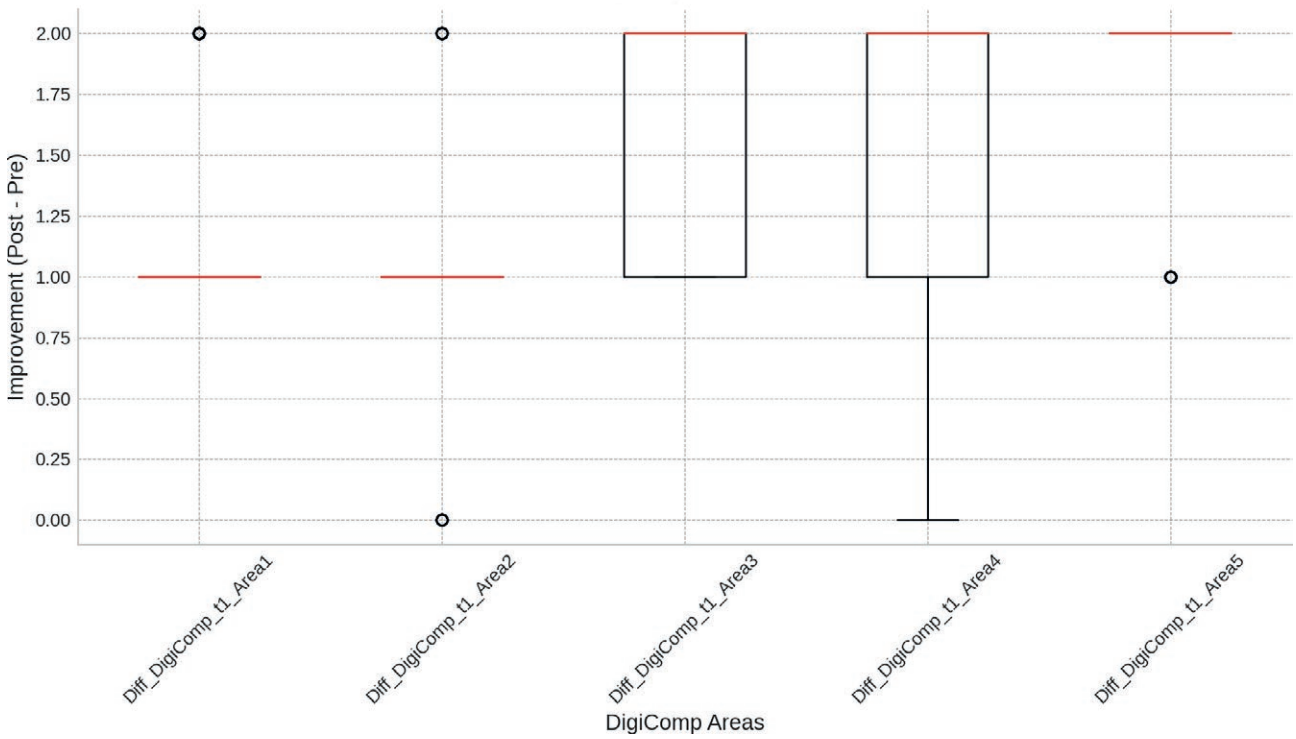

Figure 2. DigiComp Boxplot: displays the mean increases (t1-t0) for each DigiComp area.

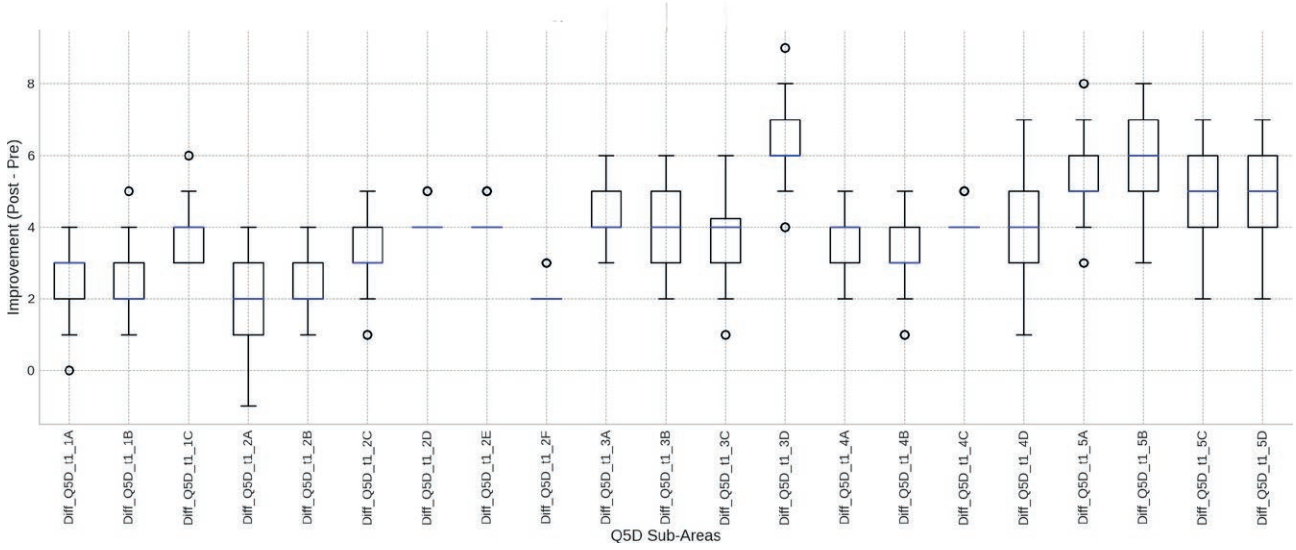

Figure 3. Boxplot Fifth Dimension: visualizes the increases for each sub-area of DigiComp5D.

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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Online collaborative learning to promote teachers' evaluative thinking

Apprendimento collaborativo online per promuovere il pensiero valutativo negli insegnanti

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ABSTRACT The study focuses on how to strengthen teachers' evaluation skills in a social and collaborative dimension. The introduction of collaborative learning modes was tested within an institutional teacher training programme via LMS. Indeed, Computer Supported Collaborative Learning (CSCL) is considered appropriate for developing reflective skills through peer exchange. The article examines the Valu.Elearn programme, aimed at in-service teachers to strengthen their evaluative competence. The study focuses on two collaborative e-activities. A total of 166 teachers and two tutors participated in these activities during the school year 2021-22. The Community of Inquiry was used as a framework for analysing the content of the forums, while the interactions between participants were examined using sociocultural discourse analysis. The findings highlight the potential and limitations of the online environment for promoting collaborative reflection on evaluation issues.

KEYWORDS Computer-Supported Collaborative Learning; Educational Dialogue; Community of Inquiry; Evaluative Thinking; School Self-Evaluation; Teacher Professional Development.

SOMMARIO Lo studio si concentra su come rafforzare la capacità valutativa dei docenti in una dimensione sociale e collaborativa. All'interno di un programma istituzionale di sviluppo professionale docente tramite LMS, è stata testata l'introduzione di forme di apprendimento collaborativo. Infatti, l'apprendimento collaborativo supportato dal computer (CSCL) risulta appropriato quando si vogliano sollecitare capacità di tipo riflessivo tramite il confronto tra pari. L'articolo esamina il programma di formazione Valu.Elearn, rivolto agli insegnanti in servizio per rafforzare le proprie competenze in ambito valutativo. Lo studio si concentra su due e-tivity di tipo collaborativo, che hanno coinvolto complessivamente 166 docenti e due tutor nell'anno scolastico 2021-22. Il Community of Inquiry è stato utilizzato come quadro di riferimento per l'analisi del contenuto dei forum, mentre le interazioni tra i partecipanti sono state esaminate attraverso l'analisi socioculturale del discorso. I risultati evidenziano opportunità e limiti della collaborazione online per la promozione di una riflessione condivisa sui temi valutativi.

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[1] Author contributions: All authors contributed substantially to the development of this article. Specifically, SR was involved in the research design, data analysis, and interpretation, and authored Sections 2.1, 4.1, and 5. FF contributed to the research design, data analysis, and interpretation, and authored Sections 2.2, 3 and 4.2. MR contributed to the research design, critically reviewed the manuscript, and authored Sections 1 and 6.

PAROLE CHIAVE Apprendimento Collaborativo Basato sul Computer; Dialogo Educativo; Comunità di Indagine; Pensiero Valutativo; Autovalutazione di Istituto; Sviluppo Professionale Docente.

1. Introduction

In recent years, increasing attention is being paid to building evaluative capacity for school professionals to drive school improvement (Poliandri et al., 2022).

As a result of national strategies to promote quality assurance and internal evaluation at school level in many education systems, several programs have been developed to improve teachers' evaluation skills as part of their continuing professional development (CPD).

Although evaluative skills are considered strategic for managing educational institutions, their building represents a challenge, given the complexity of the factors involved and the lack of coverage of these topics in pre-service teacher education.

Evaluative skills typically encompass data literacy as their primary focus, along with related components such as setting a purpose, collecting and analysing data, interpreting results, and taking instructional action (Kippers et al., 2018, Poliandri et al., 2022). School-level evaluation also requires skills related to data-based decision-making (van der Scheer et al., 2017). This involves using data analysis to set challenging goals, elaborating strategies for goal accomplishment, and executing the chosen strategy. Finally, evaluating school activities and results requires exercising critical thinking in a social dimension and as part of a school-based evaluation, and thus involves thinking how the data fit into the overall understanding of achievement and culture of the school (Ryan et al., 2007).

In order to fill the gap and reach a wide audience, online and e-learning programmes for teacher professional development (PD) with a focus on evaluation are increasingly delivered in different formats, including synchronous and asynchronous courses and blended learning. However, special attention needs to be paid to the instructional design of these courses so that participants are encouraged to develop high level skills.

Computer-Supported Collaborative Learning (CSCL) is seen as a key tool in educational technology for enhancing cognitive processes and learning through a dialogic approach (Ludvigsen & Mørg, 2010). For this reason, CSCL seems to be a powerful strategy to be adopted for teachers' CPD in the field of school evaluation.

This study discusses the affordances and constraints of an online collaborative environment to support the development of evaluative thinking, that is the ability to think how the data fit into the overall understanding of achievement and culture at school (Ryan et al., 2007).

2. Literature review

2.1. School Self-Evaluation and Evaluative Capacity Building

School self-evaluation (SSE) can be defined as an internal evaluation where the professionals that usually conduct the core-service of the organisation also implement the evaluation of their own school (Scheerens, 2003). SSE is recommended as a means for triggering school improvement and internal learning among school staff (Chapman & Sammons, 2013), although other and divergent purposes are often pursued, including consumer orientation and accountability (Scheerens, 2003; McNamara et al.,

2022). The process underlying SSE implies a reflection on practice, made systematic and transparent, with the aim of improving pupil, professional and organisational learning (McBeath, 1999). This reflective process is linked to the notion of teachers' collaborative inquiry (Chapman, 2018; Godfrey, 2020), as well as that of data-informed decision-making (Schildkamp et al 2019, Young et al, 2018) and evidence-informed practice (Brown & Malin, 2022), as teachers are encouraged to use data and information to improve their practice at an individual and community level.

In recent years, state-mandated SSE have been developed in several European countries, where schools are required to carry it out on a regular basis (European Commission, 2015). Within this scenario, in Italy the National Evaluation System has introduced SSE combining different rationales, such as accountability, improvement and transparency (Mentini & Levantino, 2024).

Given the complexity of the SSE process, a key issue is how to build the evaluation capacity of school professionals.

Approaches to support SSE can be broadly divided into top-down programmes, bottom-up interventions and mixed strategies, promoting collaboration within and between schools. Top-down programmes are promoted at central level through the provision of external evaluation frameworks, indicators enabling schools to compare, guidelines and manuals for carrying on internal evaluation (European Commission, 2015). These types of support are designed to facilitate the local collection of data for mandated self-evaluation systems. As the SSE process is connected to collecting data, interpreting and using them for action, collecting and analysing different kinds of data is crucial to understand school problems and develop a plan for action. However, the top-down approach is often challenging and complex for school staff to manage. In this regard, a main criticality is to move from data analysis to subsequent contextual evaluation and development of action strategies. Thus, data literacy needs to be integrated with other essential aspects of teaching, including general pedagogical knowledge and knowledge of educational contexts (Mandinach & Gummer, 2016), to support decision-making and improvement strategies. Above all, the difficulties faced by teachers in carrying on SSE are connected to a shortage of evaluation literacy, or capacity to "think evaluatively" (Ryan et al, 2007), as well as to engage in forms of reflective inquiry.

Alternative means of support engage teachers in school self-evaluation theory and practice, to develop their own context-sensitive evaluation models (McNamara & O'Hara, 2008). Such programs aim at increasing awareness of self-evaluation techniques, encouraging an exchange of experiences, engaging in practical activities related to self-evaluation (Barzanò, 2002). The experience of data teams – school teams supported by researchers for collecting and analysing data and using them for decision making and improvement – has highlighted that school teams can benefit from partnerships with external agents (researchers, other schools). While the teachers involved appreciate being guided through in this complex process, the question is how to reduce the need for external support and build up internal expertise (Lai & McNaugthon, 2013).

Lastly, programs that provide collaboration within and between schools offer opportunities for professional development and peer learning, combining practitioner knowledge with school-based data and evidence-based knowledge (Godfrey & Brown, 2019). These bottom-up approaches allow schools to reflect on teaching and learning processes and students' results, focusing on specific issues that are perceived as pressing for them, such as students' well-being, students' inclusion, and assessment strategies. Along these lines, school peer reviews are evaluations carried out by school practitioners with other schools in partnerships or networks. Peer reviews can provide feedback, critical friendship, validation of the school's self-evaluation or support other schools' improvement efforts. In this regard, school

peer reviews and collaborative peer inquiry, engaging schools in forms of collaborative action-research, are considered as new frontiers for school evaluation (Godfrey, 2020).

2.2. Framing online collaborative learning

Generally, teachers' collaborative learning is key for school improvement (Brown et al., 2021). Concepts such as reflective professional inquiry and collaborative reflective inquiry concur to define teachers' collaborative learning for school improvement as a reflective inquiry process. However, online collaboration has specific characteristics and online networks of practice (Brown & Duguid, 2001) have loose ties compared to face-to-face communities of practice (Lave & Wenger, 1991). Online participation behaviours can be described as 'lightweight', operating through weak ties to a common purpose, especially when enacted through rule-based contributions, and only in specific contexts as 'heavyweight', operating through strong ties to community members, enacted through internally negotiated, peer-reviewed contributions (Haythornthwaite, 2009).

A variety of approaches have been developed to assess effective collaborative interactions in online courses (Calvani et al., 2010). The Community of Inquiry (CoI) framework – based on the social constructivist paradigm – allows us to understand how people can learn collaboratively in an online environment (Anderson et al., 2001; Garrison et al., 1999; Garrison, 2009). This model represents a reference point for studying online collaborative learning (Khodabandelou et al., 2024). CoI is a process model of online learning which views the online educational experience as arising from the interaction of three presences: cognitive, social and teaching presence. Cognitive presence is a "process of practical inquiry distinguished by discourse and reflection for the purpose of constructing meaning and confirming understanding" (Garrison, 2009, p. 355). Rooted in Dewey's construction of practical inquiry and the critical thinking it seeks to foster (Dewey, 1933), cognitive presence is conceptualised as a cycle of "practical inquiry" resembling an ideal SSE process in which teachers are triggered by a real situation to inquiry systematically and critically their educational practices to improve them. More broadly, the process of practical inquiry values the interplay between experiential and evidence-based knowledge at stake in a situated, reflexive and participatory approach to SSE.

Garrison defines social presence as "the ability of participants to identify with the community (e.g., course of study), communicate purposefully in a trusting environment, and develop interpersonal relationships by way of projecting their individual personalities" (Garrison, 2009, p. 352). The function of social presence is to foster a sense of belonging that supports an environment in which learners can openly communicate with each other to negotiate different perspectives and confirm mutual understandings. Overall, such interpersonal and communicative skills are important also in a SSE process, in which the school staff is asked to discuss internally and with external experts and to communicate their action plan for improvement to the whole school community, including parents. Furthermore, practical inquiry into the SSE is inherently social as it does not take place in a social vacuum but rather in a network of social interactions ranging from peer learning to collaborative inquiry.

Teaching presence refers to "the design, facilitation and direction of cognitive and social processes for the purpose of realising personally meaningful and educationally worthwhile learning outcomes" (Anderson et al., 2001, p. 5). As far as SSE is concerned, teaching presence can be seen as the external support from experts, instructors and tutors to develop the evaluation capacity building of the school staff.

However, critical concerns have been raised about the emphasis placed on the social dimension of the CoI framework. According to Annand (2019), well-structured learning materials and support,

together with opportunities for self-directed and self-paced learning, can provide an important alternative means of achieving deep and meaningful learning for adults. In light of these concerns, online collaboration on asynchronous platforms seems to be a valuable opportunity for adult learners, rather than a necessary means of achieving meaningful learning. The notion of critical thinking spreading from the CoI framework – with special regard to cognitive presence – has also been criticised, with Kaczkó & Ostendorf (2023) highlighting the risks of reducing the complexity of multifaceted educational concerns through modelling and operationalisation.

This study goes beyond the Coi framework by proposing educational dialogue as a heuristic concept to identify relevant modes and functions of discourse patterns in asynchronous online discussions, as well as to evaluate the quality of the dialogues in relation to educational objectives of the PD programme. According to Baker and colleagues (2021) educational dialogue is the process of development of collective thinking in and by dialogue (Baker et al., 2021). In this regard, educational dialogue can be seen as declination of "collaborative learning" because "to engage in dialogue means to make thinking evolve together, which is also, by definition, a form of learning" (Ibidem, p. 587).

Mercer and colleagues (Mercer, 2000; 2004; Johnson & Mercer, 2019) identifies three modes of discourse to evaluate the quality of educational dialogues: disputational, cumulative and exploratory. Disputational mode is mainly characterised by disagreement and individualised decision making. Conversely, the cumulative mode of discourse is potentially more collaborative as control is shared and speakers build on each other's contributions, adding their own information and constructing a body of shared knowledge and understanding although they do not challenge or criticise each other's views. In the exploratory mode participants engage critically but collaboratively with each other's ideas. Exploratory mode is a process of reasoning through 'interthinking' (Littleton & Mercer, 2013) in which statements and suggestions are offered for joint consideration, challenge and elaboration of alternative hypotheses.

A further reading of educational dialogue drawn upon theories of knowledge building (Scardamalia & Bereiter 2014), which describe the creation and improvement of new ideas and adding value to a community by looking at the functions of online collaboration, which are distinguished into knowledge sharing, knowledge construction, and knowledge building/creation (van Aalst, 2009; Fu et al., 2016). Each function embodies a specific learning theory. Knowledge sharing is underpinned by an understanding of learning as the transmission of ideas, for example the peer exchange of good evaluation practices. Knowledge construction is involved in problem solving and construction of knowledge, for example the identification of criticalities in the teaching methods along with possible solutions to improve them. Knowledge building focuses on the online community as source of collegial support, inquiry, pursuit of communal goals and communal advance (Fu et al., 2016).

3. Context and methodology

This study was carried out in the context of a PD program, Valu.Elearn, developed by INVALSI for 500 teachers and school principals serving at primary or secondary schools in Italy during the School Year 2021-2022. The program was aimed at providing participants with knowledge and methodological tools to guide SSE. INVALSI, in collaboration with expert scholars on assessment and school evaluation and two companies delivering ICT services and e-learning, co-designed five online courses structured in 10 learning units each (Romiti et al., 2023a).

The courses were delivered in asynchronous mode through the LMS Moodle. A team of e-tutors guided trainees throughout their educational path and provided them with opportunities for collaboration, specifically in the e-tivities.

The present empirical research concentrates on two e-tivities conducted in a forum moderated by an e-tutor and reflect the pedagogical strategy of problem-based learning (Savery, 2006) as they simulate problem finding and problem-solving operations regarding assessment and evaluation in the school context. However, the e-tivities feature different collaborative design scripts, which prescribe or suggest how participants are expected to collaborate (Kollar et al. 2006).

In the first e-tivity, "Unfair assessments", learners were invited to describe in about 120 words an episode of unfair assessment at school, and to explain how they addressed – or how it could be addressed – the problematic situation and/or comment on the episodes and related solutions outlined by their colleagues. Hence, here collaborative inquiry was presented as an opportunity rather than an obligation to complete the task.

The second e-tivity, "Index for inclusion and evaluation" prescribed collaboration in small groups to complete the task. Teachers were asked to carry out a common evaluation of the quality of the inclusion in their respective schools based on some indicators drawn upon the Index for inclusion (Booth & Ainscow, 2011), with a focus on student assessment practices. To complete the task, participants were invited to post within two weeks their written evaluation in the forum.

Participants were recruited mainly from the schools involved in the PON Valu.E project (Expert School Evaluation/Self-Evaluation). Schools were casually sampled to represent all geographical areas (North, Centre and South) of the Country (stratified random sampling). As for the specific sample of this study, it consists of teachers and e-tutors engaging with the two e-tivities with at least one intervention in the forum. Overall, 146 teachers (130 females and 16 males, average age 52 y.o.) and 2 e-tutors (average age y.o. 44) actively engaged in the two e-tivities: 66 teachers and 1 male e-tutor carried out the first e-tivity and 80 teachers and 1 female e-tutor the second e-tivity. Overall, teachers located in schools across different areas of the Country were involved, specifically 36 from the North (24,7%), 51 from the Center (34,9%), 59 from the South (40,4%). Among them, 16 were serving in kindergarten schools (11,0%), 65 in primary schools (44,5%), 40 in lower secondary schools (27,4%) and 22 in upper secondary schools (15,1%). 3 teachers (2,1%) did not provide any information about their respective schools.

A mixed method to textual analysis including content and discourse analysis was adopted to investigate trainees' participation in the two collaborative e-tivities. In a nutshell, content analysis served the purpose of detecting to what extent the texts in the forum reflected a collaborative inquiry whilst discourse analysis was aimed at exploring how the interactions in the forum actually led to the development of an evaluative thinking through educational dialogues.

Specifically, the content analysis (Krippendorff, 2004) was carried out to answer to the research question "Do teachers inquire collaboratively to evaluate their school/educational practice?".

From this perspective, texts were deductively encoded based on the adaptation of the CoI framework, with the sub-dimensions of cognitive, social and teaching presence (Table 1).

Following the coding approach used in previous studies (Poliandri et al. 2023), the sentence – understood as a single clause/proposition between one full stop and another – was taken as the minimum unit of analysis for the attribution of a code.

To obtain reliability on the coding scheme, two coders (the first and the second authors of this paper) encoded approximately 25% of the total number of interventions (O'Connor & Jaffe, 2020).

Table 1. Codebook for the Community of inquiry.

Category	Code	Code's description
Cognitive presence	Exploration	Exploration of the proposed topic/issue through the retrieval of information and ideas
	Integration	Reflective integration aimed at constructing meaningful interpretations or explanations
	Resolution	Resolution of the question posed through critical reflection
Social presence	Emotional expression	Expression of feelings and emotions
	Open communication	Participation in group discussion and interactions with other participants
	Group cohesion	Commitment to colleagues, group work and group identity
Teaching presence	Instructional design and organisation	Planning and design of the structure, process, interaction and evaluation aspects of the online course
	Facilitation of discourse	Facilitation of participants' discussion to identify areas of agreement and disagreement, as well as to increase critical understanding of the issue/topic

Hence, Krippendorff's Alpha was calculated to measure the extent of agreement between coders with respect to the 8 sub-dimensions. Krippendorff's Alpha tests returned all reliability scores above 0.80, that is fully satisfactory (Krippendorff, 2004). The two coders then refined their shared understanding of the coding schemes by discussing and resolving disagreements. Next, all remaining interventions were coded by one coder (author 1 of this paper). Finally, the Coding Frequencies of the CoI (sub) dimensions were calculated. The entire coding process outlined above as well as the subsequent quantitative analyses were computer-aided with the software QDA Miner.

As mentioned above, also a discourse analysis (Mercer, 2004) of the exchanges in the forums was carried out. In this regard, the analysis was intended to answer the second research question, that is "How do teachers' educational dialogues support evaluative thinking?".

A coding scheme based on the classification of discourse modes by Mercer (2000) into cumulative, disputational and exploratory was employed (see Table 2). The scheme is used to identify the collaborative trajectories of the educational dialogues for school self-evaluation purposes.

Table 2. Codebook for Educational Dialogues.

Category	Code	Code's description
Discourse mode	Cumulative	Focusing on confirmation and repetition, and conflicting ideas being ignored and assimilated
	Disputational	Finding out 'who's right and who's wrong' and what's wrong with your idea
	Exploratory	Critical and constructive engagement with each other's ideas

In this approach, the embracement of the concept of collective thinking in and by dialogue (Baker et al., 2021) led to the consideration of the exchange – rather than the individual turn or message – as the smallest relevant unit of analysis.

Interaction logs were captured exclusively within Moodle (web forums). Although participants occasionally resorted to external channels (e.g. WhatsApp or ad-hoc video calls) for micro-coordina-

tion, ethical and technical constraints prevented us from collecting those exchanges. As a result, the dataset represents on-platform collaboration only. All participants' interventions in the forums along with related information such as ID participant, role (e-tutor or 'student'), number of words and date/time of each post were retrieved from Moodle as two separate Excel documents, one for each forum's e-tivity. The textual corpus for the analysis of the forum "Unfair assessments" consists of 15,760 words for a total number of 88 cases (or posts) examined. As for the forum "Index for Inclusion and evaluation", the corpus corresponds to 34,412 words and 138 cases. The first step in the analysis was to reduce the data by selecting online discussion groups containing at least one thematically related triadic exchange (Baker, 2021). Afterwards, one coder (author 2 of this paper) categorised each exchange according to its discourse modes (Mercer, 2000). Next, the results of coding were discussed and refined by the authors of this paper. This coding process was conducted manually on the Excel spreadsheets containing contextual information on the actors and the dynamics of the educational dialogues, including participant's ID and role (e-tutor or student) and date/time of the post.

4. Results

The results presented in the following sections attempt to answer the two research questions: do teachers inquire collaboratively to evaluate their school/educational practice? (4.1), and how do teachers' educational dialogues support evaluative thinking? (4.2).

4.1. Teachers' inquiry in the online community to evaluate school practices

When applying the CoI framework to e-tivity 1 (Forum "Unfair assessments"), the Cognitive presence was detected to a much higher degree (70%) compared to the other dimensions (Social presence 25%, Teaching presence 5%, see Table 3).

Within the Cognitive presence, we found sentences describing episodes of unfairness in students' assessment (code "Exploration"), sentences offering additional elements and knowledge base to deepen or better understand the cases (code "Integration"), and sentences showing possible ways to overcome or mitigate the problems raised (code "Resolution"). In order to explore the issue, participants recall their personal experiences as students, parents or teachers and present single cases or recurring situations that are perceived as unfair (19% of cases). The description of the case is often followed by an integration, where additional reflections are provided, drawing on general knowledge on educational matters, specific knowledge on student assessment, students' wellbeing and motivation, as in the example below:

> I think there is a very close relationship between the words fair/unfair and the motivation to learn, the enjoyment of going to school. Feeling undervalued by the teacher can have a negative effect on performance and can lead the student to abandon their studies or, worse, to lose faith in themselves.

Examples of Integration were found in the posts commenting on their own experiences as well as those commenting on the experiences of others. The sentences explaining why and how unfair assessment happens, and its consequences on students' learning, are reaching almost a third of the codes assigned (32%).

Finally, sentences expressing possible ways to overcome or reduce an unfair assessment have been coded as "Resolution" (19%). Most of them suggest introducing common criteria, specific tools or grids

for student's assessment. Others recommend enhancing the dialogue with students in the classroom and within the teachers' staff.

To sum up, participants were engaged with a controversial issue – how to deal with an unfair assessment – and conducted an action-oriented practical inquiry, moving from personal experience, through the interpretation and explanation of why it occurs, to suggestions for overcoming the problem. This process can be seen as a small-scale SSE, examining a specific subject.

The Social presence was characterised by forms of social interaction between participants (code "Open communication", 17% of cases), and, to a lesser extent, by the expression of personal feelings and emotions ("Emotional expression" 8%). Communication was open when a genuine interest in engaging others emerged, which included agreeing or disagreeing with others. Furthermore, addressing the topic of unfairness led to the emotional expression of feelings such as irony, anger, or sadness, even using emoticons, exclamation marks and ellipses. We did not find sentences referring to the role of the group for sustaining participation and social interaction (code "Group cohesion"). This is most likely due to the instructional design of the e-tivity, which encouraged discussion between the participants, but without asking them to develop a collaborative project. The social dimension, although not large in number, allowed for mutual exchange and recognition of each other's contributions, an important prerequisite for the implementation of SSE.

The Teaching presence is represented by sentences written by the tutor to introduce the task (code "Instructional design and organisation") and a few messages aimed at stimulating discussion (code "Facilitation of discourse"). To start the dialogue, the tutor has opened the threads with a standard message, explaining how to perform the task.

In five cases (2%), the tutor asked participants to better explain their thoughts or to comment on other's statements, assuming the function of moderator and facilitator of the discourse:

> I would like to relaunch the discussion with all the participants in the group by asking them if they think that the solutions proposed by L. are adequate.

Nevertheless, in three out of five cases, the tutor's request for further reflection remains unanswered. This may be due to the participants' unwillingness to go beyond the task request to complete the e-tivity by engaging in further discussion, as well as to the need to get on with the subsequent tasks and not fall behind in the course.

In e-tvity 2 (Forum "Index for Inclusion and evaluation") the content analysis highlights a more balanced presence of the three components of the CoI framework (Cognitive presence 49%, Social presence 35%, Teaching presence 17%, see Table 4). In addition, almost all the sub-dimensions are present to a similar extent. In this respect, the sub-dimension "Facilitation of discourse" is an exception since it was not detected.

In the Cognitive domain, the sub-dimension "Exploration" (23% of codes) is characterised by texts presenting a thick description of inclusive practices and highlighting strengths and weaknesses in the schools where the teachers work. These texts are often organised in extended periods with several sentences or bullet points.

Although the texts were posted by single participants, in most cases they have been written in a collective form by a group of teachers. Indeed, several sentences refer to "our school" as the result of a collective analysis, while a few texts present individual views.

The sentences coded as "Integration" (13%) are aimed at the interpretation and explanation of school inclusion. Some discuss key concepts related to the topic (such as 'educational design' and 'feed-

back') or offer definitions ('inclusive education'). Others quote well-known educationalists (Hattie, Morin, Bruner, Booth and Ainscow) to move the debate forward or mention laws and regulations that support inclusive education.

Finally, with the code "Resolution" (13%) we coded a wide range of pedagogical practices and strategies to improve the quality of inclusion at school. The classroom practices refer to cooperative learning, self-regulation of learning, observation tools, educational assessment. In addition, strategies at school level are mentioned, such as common criteria for student assessment, PD programs, monitoring the inclusion process.

To sum up, in this e-tivity participants have critically reflected on the adoption of inclusive teaching practices for student assessment. They explored how their schools work on this issue, added explanations from their cultural background, and suggested strategies to improve inclusive practices at school level, reproducing the cycle of SSE.

The Social presence was also relevant, because participants were asked to work together to fulfil a common task. In particular, the sub-dimension "Group cohesion" emerges (18%). Social interactions took place not only in the forum, but also outside it, in online platforms for video meetings or in physical venues if the teachers belonged to the same school:

> Given the impending deadline, I suggest we meet tomorrow afternoon around 17:30 on Meet or another platform.

When coming back to the forum for posting the synthesis of their work, members of the same group posted identical texts, in some cases signing it as a collective work. Social presence is also characterised by the expression of emotions and the sharing of personal information. Some teachers introduce themselves to other members or present aspects of their daily life, others express regret for being late with the task:

> Dear all, I apologise for not being able to participate in the group work within the established times, but December turned out to be a particularly busy period both for school duties and for the issues related to Covid.

Lastly, the sentences that show interaction with others such as expressing agreement, asking questions to colleagues or tutor, thanking, or greeting, were coded in "Open communication" (10%). In brief, the social dimension in this e-tivity emerges as a function for supporting collaborative processes of SSE, with special regard to group cohesion.

The Teaching presence is focused exclusively on introducing the participants to the task. The e-tutor posted the same standard message in each discussion group opened within the forum. The message consists of seven sentences giving some advice, practical information and support for the submission of the assignment. All these sentences were coded as "Instructional design and organisation". I this case, the absence of any attempt to facilitate participants' discussion did not prevent participants from organising themselves and completing autonomously the e-tivity.

The observed values in cognitive, social, and teaching presence between the two e-tivities are highly significant according to chi-squared test (p-value lower than 0,01). Therefore, we can say that the observed differences in the two e-tivities are not due to chance and the results are comparable (see Table 5).

If we compare the Cognitive presence in the two e-tivities, in both participants moved from their personal experiences at school to explore the problem, integrate it with their pedagogical knowledge and suggest ways to solve it.

Social presence in e-tivity 1 occurred when participants went beyond the individual task and expressed interest in others' points of view. Unsurprisingly, when the task did not require working on a common assignment, the group cohesion was absent. On the contrary, in e-tivity 2 group cohesion emerges as an important element for fostering social interaction. Overall, the social dimension was observed to a fair extent in both e-activities.

Finally, comparing the teaching presence, the tutors played their role in two different ways. While both tutors spent effort in introducing the task as a starting point for the development of the discussion, only in e-tivity 1 the tutor intervened to facilitate the debate by commenting on the teachers' contributions. This dimension is, however, weak in both e-tivities.

Table 3. Content analysis results, e-tivity 1.

Category	Code	Count	% Codes	% Codes per category
Cognitive presence	Exploration	45	19,10%	70,00%
	Integration	75	31,80%	
	Resolution	45	19,10%	
Social presence	Emotional expression	18	7,60%	25,00%
	Open communication	41	17,40%	
	Group cohesion	0	-	
Teaching presence	Instructional design and organisation	7	3,00%	5,00%
	Facilitation of discourse	5	2,00%	

Table 4. Content analysis results, e-tivity 2.

Category	Code	Count	% Codes	% Codes per category
Cognitive presence	Exploration	56	22,70%	48,70%
	Integration	33	13,40%	
	Resolution	31	12,60%	
Social presence	Emotional expression	16	6,50%	34,60%
	Open communication	25	10,20%	
	Group cohesion	44	17,90%	
Teaching presence	Instructional design and organisation	41	16,70%	16,70%
	Facilitation of discourse	0	-	

Table 5. Content analysis results, e-tivity 1 and e-tivity 2.

Category	E-tivity 1 Count	E-tivity 2 Count
Cognitive presence	165	120
Social presence	59	85
Teaching presence	12	41

Chi-square test, p-value 0,0000018.

4.2. Teachers' educational dialogues and evaluative thinking

Educational dialogues were identified in both e-tivities. However, the number of dialogues in the e-tivity "Unfair assessments" is double compared to those detected in the e-tivity "Index for Inclusion and evaluation" (see Table 6).

Table 6. Discourse modes in the e-tivities.

	Disputational mode	Cumulative mode	Exploratory mode
E-tivity 1 "Unfair assessments"	1	1	2
E-tivity 2 "Index for Inclusion and evaluation"	0	1	1

The screening of participants' exchanges in the forum dedicated to the e-tivity "Unfair assessments" brought to the identification of four educational dialogues out of nine discussion groups. One dialogue is characterised by a disputational mode, one by a cumulative mode and two by an exploratory mode.

The online dialogue in disputational mode builds upon the discussion between two teachers discussing their conflicting views on interpreting learning outcomes according to the Gaussian curve. Here, one teacher asserts that such distribution indicates the unfairness of the assessment criteria ("*In my view, the forced distribution of results seems the most prevalent evaluation bias*"). Conversely, his/her colleague claims that this very same criterion makes assessment fair ("*I intervene to strike a blow for the bell distribution*"). Despite several exchanges on this topic the mode of the discussion remained highly conflictual, without evolving into the construction of a renewed knowledge. Notably, here the e-tutor did not intervene to moderate the discussion.

Conversely, three dialogues were more oriented towards knowledge construction/building, one in a cumulative and two in the exploratory mode. The dialogue in cumulative mode was identified in a discussion group involving seven teachers. Here, all teachers' interventions focused on the issues raised in the opening post, namely the potential arbitrariness of the oral exams and the importance of dialogue between teachers and students for a fair and meaningful assessment. In this case the mode of discourse is cumulative as all participants motivate their agreement with the first intervention by adding their own confirmative observations.

Online educational dialogues in exploratory mode were detected in two discussion groups involving three and five teachers respectively. Unlike the previous dialogues, the teachers did not limit themselves to motivate their (dis)agreement with others' views. For example, the five teachers engaged critically in the process of co-construction of knowledge, dealing with how to assess an essay and the negative consequences of unfair assessments on students' motivation to learn. The following teachers' exchange well exemplifies the enactment of the exploratory mode of discourse, as to address the problems identified by the opening post (Teacher 1) some strategies (Teacher 2) and a further conceptual framing of the issue at stake (Teacher 4) are suggested.

Teacher 1: "*I heard a student complaining that he got a four for his Italian essay, even though there was no red mark in his paper. [...] What is assessed should always be stated to the students, and then I think it is unfair to enclose an individual's ability to express themselves in a number.*"

Teacher 2: "*I agree with your analysis of the episode. In this regard, the use of an assessment grid*

not only helps the teacher to make an objective assessment of the examinations but also capacitates the children of the assessment given to them."

Teacher 4: "[...] *In pedagogical practice, a form of power is exercised that becomes unfair when, as in this case, the student is alienated from the process and reduced to a passive subject who is subjected to a judgmental action.*".

As for the e-tivity "Index for inclusion and evaluation", only two educational dialogues were detected. However, collaboration appeared not limited to two discussion groups. Indeed, several interactions in the forum show that teachers' discussion often took place outside the e-learning platform in synchronous mode, especially when in service at the same school (see section 4.1). In practice, many teachers choose to employ more immediate and familiar tools of collaboration before posting their collective evaluation report in the forum. Often one member acted as spokesperson of the group by publishing the required report. Consequently, most of the possible educational dialogues among teachers to complete the e-tivity could not be identified in our analysis.

On two occasions, however, educational dialogues were visible in the forum. They developed according to two different modes, cumulative and exploratory respectively.

A cumulative mode was identified in a discussion among five teachers from the same school. In this case, as it can be seen in the exchange below, teachers express their reciprocal agreement by adding some brief observations on the aspects identified by the first teacher.

Teacher 3: "*What do you think? You can download the file and add your reflections.*"

Teacher 4: "*I agree with the critical issues identified, particularly the need to use assessment to promote the development or improvement of self-assessment processes, especially in relation to learning styles and strategies.*[8]"

Finally, the educational dialogue in exploratory mode was identified in a discussion group involving the e-tutor and three teachers from the same school. In this case, the opening intervention by the e-tutor simply recalls the aims and the instruction of the e-tivity. Teacher's reply to the e-tutor is a preliminary analysis of strengths and weaknesses of the state of inclusion in their school. The next post by another teacher agrees on the preliminary analysis and provides further insights. The final post by a third teacher, critically integrates the previous contributions into their final SSE. Overall, in this educational dialogue the reflective and reciprocal engagement with each other's ideas is quite evident and productive of community knowledge advancement.

5. Discussion

In our study we have explored, through the lens of the CoI framework, how participants collaboratively inquire online to examine and evaluate their educational practices.

As emerged with the content analysis, generally in both e-tivities participants have mobilised key cognitive aspects related to the SSE process. Specifically, participants seem to have enacted practical inquiry (Garrison, 2007) projected into real educational settings rather than in abstract or decontextualized terms, in line with a school-based evaluation approach (MacBeath, 1999, Mc Namara & O'Hara, 2008). Thus, online activities helped teachers improve their evaluation skills and support data-based decision-making (van der Scheer et al., 2017), as well as encouraging evaluative thinking (Ryan et al., 2007). In this regard, we have provided evidence that in both e-tivities the main steps of the cycle of practical inquiry underlying the cognitive presence – exploration, integration, and resolution – have been largely developed.

Specifically, in the first e-tivity participants explained how and why unfair assessment occurs. This e-tivity has allowed participants to critically reflect on individual professional practices related to students' assessment. In the second e-tivity participants focused on what is being done at school level to promote inclusion and on highlighting strengths and weaknesses in school organisation. The SSE process has been simulated online, through an accurate description of the school inclusive policies, an integration with theoretical inputs aimed at a better understanding of inclusion, and a search for possible ways to enhance the quality of inclusion in their schools, adopting forms of reflective enquiry to address pressing educational issues (Brown et al., 2021). In this sense, a common strength of the e-tivities offered in asynchronous mode is that, overall, they have stimulated teachers' reflexivity on their educational practices, at individual or collective level, thus providing the foundation for school improvement (Chapman & Sammons, 2013).

Conversely, content analysis detected to a lower extent social and teaching presence, especially in the first e-tivity. As already mentioned, collaboration and dialogue were optional in the first case, while in the second case they were fundamental to achieving the task. From this perspective, the substantial balance between the cognitive and social components in e-tivity 2 seems due to the different instructional design of the e-tivity rather than to participants' higher willingness to collaborate. However, according to the limitations discussed in the CoI framework (Annand 2019), it could be argued that limited interaction between learners did not prevent them from engaging in high level cognitive tasks or achieving meaningful learning.

Regarding the teaching presence, the role of the e-tutor as a facilitator of a reflective community was rather marginal. As communication was asynchronous, e-tutors provided soft tutoring, focusing on the initial instructional design, welcome, and final feedback. They provided learners with long, structured collective feedback, highlighting the strengths and weaknesses that emerged in the assignments (Romiti et al., 2023b). However, this final feedback was provided in a separate forum and is therefore not included in the present analysis. As we know, a strong facilitation role can enhance interaction and evaluative thinking (Calvani et al., 2010).

In the present research this occurred infrequently, and when the e-tutors attempted to encourage reflective thinking, they did not always received response from trainees. This highlights the challenges involved in facilitating discourse in asynchronous settings. Nevertheless, the minimal teaching presence did not prevent the participants' completion of e-tivities. This result is in line with other research findings, showing the absence of the tutor effect across a large number of MOOCs delivered via the EduOpen platform (Sannicandro et at., 2019).

Indeed, Sannicandro et al. (2019) found no significant differences in completion rates between self-paced and tutored courses. Our results confirm that e-tutors often fail to encourage greater participation among trainees in asynchronous courses. However, their minimal presence does not significantly impact the completion of courses designed to promote self-directed learning.

Similar mixed results related to the online learning collaboration are corroborated by the findings from the discourse analysis of educational dialogues. On the one hand, our study confirms that social interactions in formally organised online teacher communities are often limited or superficial, with a minority of participants actively interacting (Lantz-Andersson et al., 2018; Dille & Røkenes, 2021). However, it should be observed that in the second e-tivity several groups preferred to interact synchronously outside the e-learning platform, in an online or face-to-face meeting, as most groups were formed by teachers from the same school.

This finding seems to suggest the constrain of learning collaboratively in asynchronous mode,

especially when the assignment requires working together on a complex task. Dense collaborative interactions naturally thrive on immediate feedback, so it is unsurprising that participants, although they could have relied on the institutional platform's tools, chose instead the applications they knew best.

This drift from the formal learning space has design and research implications that converge on how such "dense collaborative moments" might be captured. From a design perspective, instructors may either ask learners to document off-platform exchanges through concise reports and reflective summaries or restrict collaboration to the institution-approved tools such as wikis and chats.

Alternatively, they can integrate familiar external tools, for example Google Docs, directly into the platform, so that comments and revisions remain visible and attributable. On the research side, our lack of access to message logs and attendance records from channels like WhatsApp or video calls almost certainly means we have underestimated the sheer volume of collaboration.

Despite this, the interaction patterns traced inside the LMS – where activities, assessment and facilitation actually took place – still tell us a great deal about how the instructional design shaped peer engagement. Future inquiries, therefore, should extend LMS analytics with consent-based data extraction from external tools or with participant diaries, creating a richer, more accurate map of the collaboration ecology.

On the other hand, the in-depth analysis of the educational dialogues in the digital forums shed light on their relevance in supporting collaborative processes of school self-evaluation. Specifically, in e-tivity 2 both educational dialogues were knowledge building-oriented as teachers inquired about the inclusiveness of their school and identified strategies to improve the inclusive function of evaluation in their respective contexts. Conversely, functions of educational dialogues in e-tivity 1 are more diverse as foreseen in the design script, thus ranging from knowledge sharing to knowledge construction for a shared evaluation of teachers' practices.

The limitations of the study are related to the qualitative approach adopted. Although a non-representative sample was selected, and the generalisability is limited, we have emphasised the potential transferability of the study (Lincon & Guba, 1985), providing sufficient information for readers to evaluate the relevance of the findings to other contexts.

6. Conclusion

Our study highlighted both affordances and constrains in the educational design of the e-learning platform to support collaborative learning, evaluative thinking and their relationship.

On the one hand, findings related to the cognitive dimension of participants' communication in the online forum can be seen as evidence of the evaluative thinking (Ryan et al., 2007). On the other hand, findings related to the social and teaching presence seem to question the assumption that online collaboration is key to support learning and evaluative thinking. Indeed, according to the content analysis based on CoI's categories, evaluative thinking was evident despite the scarcity of online interactions with peers and e-tutors. From this perspective, the necessity for sustained communication among learners to achieve deep and meaningful learning seems discarded (Annand, 2019).

Furthermore, if we consider the choice of some participants to communicate outside of the LMS, a second relevant issue emerges, that is the limit of the asynchronous communication to collaborate online, in a changing scenario where social media interaction and synchronous meetings are freely available and commonly used.

This suggests both the partial effectiveness of Learning Management Systems to support teachers'

collaboration and the difficulty to detect the processes of collaboration that might take place somewhere else, via social media or offline.

At the same time, the discovery of some exploratory dialogues through which participants constructively engage with each other's ideas shed light also on the opportunity to co-construct evaluative thinking in a Learning Management System.

Overall, our mixed results about the relationship between online collaboration and evaluative thinking suggest the importance of balancing individual learner agency with collaborative scripting (Wise & Schwartz, 2017) and attuning the needs and social media habits of the teachers with the needs of the collaborative endeavour of school self-evaluation. In this regard, future research could examine both the role of informal digital communication in online teacher training and the impact of structured tutor facilitation on teachers' engagement and evaluative thinking.

A follow-up investigation on these issues could be conducted by comparing the asynchronous online programme Valu.Elearn with a hybrid educational model that has already been tested by INVALSI to strengthen teachers' evaluative thinking (Giampietro et al., 2023).

The implications of the findings for teacher CPD on evaluation unfold on multiple levels.

For instructional designers, the evidence gathered indicates that the learning environment must become permeable to users' existing communicative practices. For example, LMSs should be integrated with the social tools most familiar to teachers – for instance the ability to open and comment on Google Docs directly inside the virtual classroom – so that they are not forced to migrate elsewhere for intense, decision-oriented exchanges. On this foundation a light collaborative script can then be layered, one that balances individual autonomy with micro-constraints such as reminders, shared rubrics and rotating synthesis roles, keeping the collective construction of evaluative thinking alive without smothering personal initiative.

For trainers, this translates into reinforcing a mediating role that goes beyond initial design and becomes metacognitive accompaniment: monitoring interactions, detecting any drift toward external channels, prompting short logs or real-time reflections and reintegrating them into the course's public space. Such type of tutorship keeps the learning trajectory visible, re-engages those on the fringes and turns tutor input into opportunities to make evaluation criteria explicit, preventing dialogue from dispersing in micro-chats inaccessible to the community.

For policy makers, finally, the lesson concerns the need to invest in flexible platforms – open to interoperability with third-party apps yet equipped with analytics that respect privacy through informed consent – and to fund CPD programmes that include collaborative design and online facilitation to build evaluation capacity.

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The environmental impact of the digital universe and the role of education

L'impatto ambientale dell'universo digitale e il ruolo dell'educazione

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ABSTRACT The environmental impact of the digital universe is one of the critical challenges humanity faces today. This impact manifests primarily through two forms of emissions: *embedded emissions*, resulting from the processes involved in transporting, processing, and assembling over seventy components, and *operational emissions*, generated by the active use of digital services, such as sending messages or sharing content. This paper examines the educational potential of an emerging discipline named *environmental education of digital resources*. Rooted in a philosophy of education articulated in the final section, this discipline is proposed as a central tool for dissemination and knowledge production within the context of cloud computing. The paper concludes with reflections on the limitations of this contribution and suggests a trajectory toward a new *paideia*, aiming to regenerate thought and redefine our relationship with the digital realm.

KEYWORDS Digital; Environmental Impact; Emissions; Philosophy of Education; Relation.

SOMMARIO L'impatto ambientale del digitale rappresenta una sfida cruciale per l'umanità, articolandosi principalmente in due forme di emissioni: quelle incorporate, derivanti dai processi di trasporto, lavorazione e assemblaggio di oltre settanta componenti, e quelle operative, generate dall'utilizzo attivo dei servizi digitali, come l'invio di messaggi o la condivisione di contenuti. Questo contributo analizza il potenziale educativo di una disciplina emergente, definita "educazione ambientale delle risorse digitali", fondata su una filosofia dell'educazione descritta nell'ultima parte del testo. Tale educazione si propone come strumento centrale per la divulgazione e la costruzione di conoscenze nel contesto del *Cloud computing*. Concludiamo con alcune riflessioni sui limiti del lavoro e sulla necessità di sviluppare una nuova *paideia*, capace di orientare verso una rigenerazione del pensiero e nuove modalità di relazione con l'universo digitale.

PAROLE CHIAVE Digitale; Impatto Ambientale; Emissioni; Filosofia dell'Educazione; Relazione.

1. Introduction to the problem

The issue of the environmental impact of the digital universe (Sissa, 2024) has gained prominence in recent years compared to previous decades. This does not imply that the issue was non-existent or irrelevant in the past; on the contrary, it was already present. However, the attention of policymakers, economists, media, and citizens was not sufficiently focused on it. During the last three decades of the 20th century, public interest on environmental issues was largely directed toward the chemical industry and several significant post-World War II events, such as the banning of the dangerous pesticide DDT in 1972, the toxic cloud in Seveso in 1976, the Bhopal disaster in India in 1984, and the partial explosion at the Chernobyl nuclear power plant.

In the early 1990s, the IT sector, particularly the Internet, experienced rapid acceleration with the advent of the World Wide Web, spearheaded by Tim Berners-Lee. From that point onward, the digital revolution assumed an increasingly global dimension, engaging a growing number of disciplines. Nonetheless, despite the enthusiasm for innovation and its rapid development, discussions surrounding the environmental impact of the seemingly intangible web remained absent. Yet, even then – dating back to the very inception of the internet – it was well understood that its operation required physical infrastructures: cables, circuits, powerful computers, memory systems, and various equipment. These all had to be produced, transported, powered, and, within an increasingly short timeframe, disposed of (Sissa, 2024).

With the dawn of the new millennium, climate change began to draw public attention, particularly with the Kyoto Protocol in 2005. During this period, however, only a few researchers explicitly addressed the environmental impact of the digital universe; the broader context was not yet conducive to its full consideration. In the 2010s, the digital revolution underwent further transformation with the rise of major telecommunications operators and leading ICT multinationals (Wu, 2023), collectively known by the acronym GAFAM (Google, Amazon, Facebook, Apple, Microsoft), later referred to as the Big 5 (Google, Amazon, Apple, Meta, Microsoft). In this context, the 2015 Paris Agreement on climate change was adopted, establishing a roadmap for emissions reductions (UNCCC, 2016).

Since then, studies on carbon footprints have intensified to identify their causes, quantify their impact, and develop reduction strategies. States are now required to account for their carbon emissions through periodic reports – a responsibility increasingly shared by corporations as well (Freitag et al., 2021).

Currently, an annual increase in human presence on the web has been observed, accompanied by growing engagement in new activities and the use of social platforms. As early as 2007, some authors, notably Edward Castronova, referred to the 21st century as the era of the great mass migration to the digital universe (2007). However, the miniaturization of personal devices, the invisibility of digital operations, and users' lack of awareness regarding the infrastructure underlying cloud computing – such as data centers and the entire chain supporting their operation (Pitron & Jacobsohn, 2023) – remain underexplored issues among the general public.

Unlike in previous decades, scientific research has progressively unveiled a range of data concerning the environmental impact of digital technologies. These analyses have addressed the use of personal devices as well as the implications of telecommunication infrastructures and large data centers (Lucivero, 2020; Pitron, 2022; Luccioni, Jernite & Strubell, 2023).

As highlighted in the scientific literature currently available, these data remain partial, difficult to access, and subject to rapid changes. Such fluctuations arise from the evolving patterns of digital tech-

nology usage, the energy sources powering the digital infrastructure, and corporate decisions – particularly those of ICT multinationals – regarding their role in the sector (Sissa, 2024). Despite these limitations, the data available call for a broader reflection that also involves the humanities. These disciplines are tasked with foregrounding the issue of the environmental impact of digital technologies, fostering practices aimed at raising awareness of the problem and building a new relationship between humans and machines. This relationship must necessarily account for interspecies conviviality and the sustainability of this dynamic (Pouydebat, 2021; Becker, 2023).

The second section of this contribution delves into the meaning of the two primary sources of emissions in the digital universe: embedded emissions and operational emissions, distinguishing the moments and phases in which each comes into play. The third section, on the other hand, explores the role of education, presenting and juxtaposing some of the leading theoretical perspectives on the subject. These perspectives aim to directly influence daily educational practices, offering a new interpretive framework for analysing the relationship between humans and machines. This approach seeks to promote an awareness that is less artificial and more mineral, less invisible and more tangible, in relation to personal digital devices.

The contribution concludes with a series of final reflections that highlight the various stages of the journey undertaken, while also indicating some constructive pathways for addressing the topic as a challenge oriented toward sustainability.

2. Embodied emissions, operational emissions

The definition of sustainable development formulated by the Brundtland Commission in 1987, established by the United Nations and chaired by Gro Harlem Brundtland, describes sustainable development as development that meets the needs of the present without compromising the ability of future generations to meet their own. This concept emphasizes the principles of intergenerational equity, highlighting the importance of treating the planet as a borrowed resource that must be preserved through responsible management of its assets.

In relation to the above mentioned definition of sustainable development, embodied and operational emissions can be introduced taking into consideration:

- Environmental/ecological externalities: demand for electricity and water for the proper functioning of technologies such as data centres, streaming content, generative artificial intelligence and related carbon footprints. The life cycle of technological tools and increases in demand for goods and services available "in one click". On the other hand, digital technologies allow greater efficiency in the organization and delivery of goods and services;
- Externalities at economic level: reduction of time and costs of operations of repetitive nature and/or manual and simultaneous decrease in the dynamics of exploitation of disadvantaged geographical areas. At the same time, such automations certainly lead to a loss of jobs from the more mechanical ones up to specialized ones;
- Externalities at the social level, certainly one of the themes here is access to digital technologies meant as access in itself, capacity for use – digital divide, and benefits or results that arise from the use of technologies.

Every product and service is associated with emissions generated throughout its lifecycle, which can be divided into two main categories: embedded emissions and operational emissions. Embedded emissions include those linked to the use of primary energy during production, transportation, and

disposal processes, while operational emissions stem from energy consumption during the usage phase. In essence, the former pertains to pre- or post-use stages of the product, whereas the latter concerns energy consumption during its use (Sissa, 2024).

Primary energy is defined as any form of energy present in nature that has not undergone artificial transformation. It can be classified as non-renewable (such as coal or oil) or renewable (such as solar or wind energy). Secondary energy, by contrast, results from the conversion of primary energy, with electricity being a typical example, derived from both renewable and non-renewable sources of primary energy.

Embedded emissions represent the total primary energy consumed in the production and disposal of a product, regardless of its actual usage. This calculation considers energy consumed at every stage, from the extraction of raw materials to their transport to processing sites, from production and assembly to the final product. Additionally, reverse processes, such as disassembly, deconstruction, recycling, and final disposal, are included.

The environmental impact of a digital device begins with the extraction of raw materials, progressively increasing along the production chain. This process extends geographically and technologically, involving laboratories, factories, and intercontinental transport. Raw material extraction demands substantial primary energy consumption, which is further compounded by the significant energy required for component manufacturing. These components are subsequently transported to assembly sites, where they form the final digital devices. The overall logistics, including the transportation of production materials, assembled components, finished products, and waste for disposal, further contributes to energy consumption (Berreby, 2024).

Devices such as computers, laptops, and smartphones are complex systems composed of numerous components: batteries, displays, touchscreens, casings, microphones, speakers, cameras, and sensors. They also incorporate advanced technological elements such as central processing units (CPUs), graphics processing units (GPUs), network and wireless processors, voltage regulators, memory systems, and machine learning units. The creation and operation of these devices require approximately 70 chemical elements from the periodic table, which comprises 83 elements excluding radioactive ones.

The functional core of every digital device is the microchip, integrated circuits designed to handle digital information processing and memory. These microchips represent the technological heart of modern electronic devices.

> Microchips and many other high-tech goods are forms of highly organized matter. Since they are manufactured using raw materials with relatively high "entropy" – the natural disorder toward which matter tends – it is natural to expect that a substantial investment of energy and processing materials is necessary for their transformation into an organized form. The embodied and operational emissions are defined (...) for each product or unit of service. The more complex and technologically advanced a product is, the higher the percentage of embodied emissions relative to the total (Sissa, 2024, pp. 42-43, the translation is provided by the authors).

Operational emissions refer to the energy consumption generated during the active use of a device by a user to access a service via an application. Common examples include online shopping, posting on social media, sending messages via WhatsApp, accessing banking services, streaming TV series, conducting Google searches, or interacting with language models. These services, delivered via the internet, involve the processing of user requests by specific computers located in data centers, which generate the corresponding responses (International Energy Agency, 2023; Roundy, 2023).

Although many household digital devices, such as smartphones, tablets, and laptops, have relatively low direct electricity consumption (excluding high-energy appliances like refrigerators), they are almost

always connected to the internet. This constant connectivity necessitates the continuous operation of data networks, resulting in additional energy consumption that is often imperceptible to the user (Andreu, Delgado & Torrubia Torralba, 2022; Pasqualetti, 2024).

This energy consumption encompasses not only the power required to operate personal devices but also the energy needed to keep data centers, network infrastructures, and equipment supporting data transmission functional. This "invisible" contribution to operational emissions constitutes a significant component of the overall environmental impact of digital services. «When we are connected to the Internet, every digital activity corresponds to a service request, which in turn requires processing performed elsewhere. In addition to the end digital devices, the Internet and data centers – where the digital services we use through our devices are created and managed – also require electrical energy. These electricity consumptions are neither known nor visible to the end user» (Sissa, 2024, p. 50, the translation is provided by the authors).

Considering concrete examples, the creation of a post containing a photograph involves the transfer of data over the internet from the user's device to the server managing the account. This process encompasses several operations: uploading the image, processing the request by the service, assigning viewing permissions (e.g., restricted to friends or public), and storing the file in the user's allocated space.

The request generated by the digital device travels through the network to the server hosting the service. There, the request is processed, and the result – the publication of the post with the desired parameters – is sent back via the internet to the user's device and to others authorized to view it. Each step of this process, from transmission to the server, to processing, and to delivering the response, contributes to energy consumption and the operational emissions associated with the digital service (International Energy Agency, 2023). «When devices are connected to the Internet, every service request involves transmitting data, generating traffic, and requiring processing: all of which consume electrical energy and thus cause carbon emissions» (Sissa, 2024, p. 47, the translation is provided by the authors).

Finally, regarding the operational maintenance of data centers, it is crucial to highlight the role of freshwater in cooling systems for these processing hubs. As Pengfei Li, Jianyi Yang, Mohammad A. Islam, and Shaolei Ren (2023) note, technology companies provide limited information about the environmental impact of their digital technologies, particularly their AI systems. Based on data concerning the water needs for cooling Microsoft systems, this research group estimates that a person asking 10–15 questions to GPT-3 consumes approximately half a liter of water (Berreby, 2024). This figure, however, varies by region and could be higher for digital technologies requiring more computing power and larger artificial intelligence models. In 2022, Google's data centers consumed nearly 20 billion liters of water for cooling – an increase of 20% from the previous year – while Microsoft reported a 34% increase over the same period (Li et al., 2023).

As Berreby (2024) observes, generative artificial intelligence demands vast amounts of energy for computation and data storage, as well as millions of liters of water to cool equipment in data centers. Regulatory and oversight authorities in the United States and the European Union are beginning to demand greater transparency. Meanwhile, technology companies integrating AI across fields – from writing and surgery to climate modelling – emphasize the potential for artificial intelligence to reduce humanity's ecological footprint. However, increasing calls for clarity, particularly from environmental activists, highlight the concern that promised or achieved benefits may be overshadowed by growing negative effects.

The lack of standards and regulations complicates the collection of accurate data. Estimates indicate that data center cooling consumes potable water, and nearby communities face challenges in monitoring these practices (Li et al., 2023). For instance, in Oregon, where Google operates three data centers, a lawsuit was filed to prevent the disclosure of water usage, creating tensions with local farmers and communities. Similar issues have arisen in Chile and Uruguay, where data center projects have been contested for their impact on local water resources.

A cultural shift is needed in the development of digital technologies and artificial intelligence. In this context, the humanities, particularly education, should play a more active role in raising awareness of the issue and fostering a broader understanding of when and how these technologies should be deployed to serve humanity. This approach must align with a planetary context where all living and non-living entities actively interact.

3. What is the role of education?

This new objective integrates into the field of environmental education but is characterized by a transdisciplinary approach that weaves together the sociology of knowledge, critical pedagogy, and the philosophy of education. From this perspective, it proposes an "environmental education of digital resources", a concept emphasizing the need to manage our relationship with digital resources following principles of external and internal sustainability.

The term *external sustainability* refers to the conscious and respectful use of digital devices, aimed at minimizing environmental impact and preserving life habitats – both human and non-human (Pouydebat, 2021; Ceruti & Bellusci, 2023). In line with the thinking of Ceruti and Bellusci, this perspective calls for a move beyond anthropocentrism, acknowledging that ecological and digital crises can no longer be addressed solely in terms of human survival. Instead, external sustainability points to the Earth as a complex and interdependent system, where all forms of life are entangled in a dynamic web of relationships.

This conception strongly resonates with Bruno Latour's *Actor-Network Theory* (2022), which posits that the actors shaping our world – whether human, animal, plant, technological, or geological – are all active participants in the construction of earthly dynamics. Latour challenges rigid hierarchies between subjects and objects, emphasizing that each element within the network holds agency and contributes to reciprocal influences across the system. From this viewpoint, sustainability is no longer a unilateral human project imposed upon the world, but rather a co-constructed process in which the living and the non-living constantly interact, shaping ecological, cultural, and technological equilibriums.

To adopt a genuinely sustainable outlook, then, means recognizing and respecting this intricate network of interdependencies, and developing an ethics of care that extends beyond the human to encompass the entire fabric of the living and the non-living.

Internal sustainability, on the other hand, refers to an approach to education that goes beyond the mere acquisition of skills, emphasizing self-exploration and attention to "technologies of the self". These are internal tools that can guide patterns of reflection and action. This concept closely resonates with Gert Biesta's notions of *agency* and *transaction* (2014a; 2014b; Priestley et al., 2015) within the philosophy of education.

For Biesta, *agency* is not simply the capacity to make autonomous choices, but rather the ability of individuals to act meaningfully within educational and social contexts. Education, in this view, should support the emergence of the subject as the author of their own actions, rather than reducing them

to passive recipients of knowledge. The concept of *transaction*, on the other hand, highlights the relational and situated nature of learning: not as a mere transfer of knowledge, but as a dynamic process involving interaction between the individual and their environment.

Within this framework, internal sustainability can be understood as a space where education fosters conscious and reflective action, encouraging the development of the subject in relation to the self, to others, and to the world.

In a context defined by unprecedented technological and social acceleration (Rosa, 2015; 2023) and driven by automated and alienating flows (Hannerz, 1998; Appadurai, 1996; Stiegler, 2024), the pursuit of staying updated with continuous innovations proves unrealistic. The pace of innovation is too rapid for full assimilation. Therefore, it becomes crucial to invest in the development and maintenance of reflective and actionable patterns that function as timeless structures (Bertin, 1977). These are meta-historical frameworks capable of providing critical anchorage in the face of change. The legacy of established models for problem management must be regarded as reserves of discarded options and opportunities, always available for "reuse" in an exaptive sense (Jullien, 2021; Rossi, Borghini, 2024; Gallese, Morelli, 2024).

To introduce what we define as the "environmental education of digital resources", it is necessary to clarify that its primary goal is to disseminate knowledge about the environmental and digital dynamics outlined in previous sections. However, its scope extends beyond these themes to include issues such as electronic waste (e-waste) management and data colonialism. While relevant, these topics fall outside the focus of this contribution for reasons of thematic coherence.

The implementation of such education demands an approach that transcends mere content transmission, a method critiqued in numerous national and international studies. Instead, we propose a philosophical perspective on education, one that is not an alternative to practice or theoretical abstraction but rather a theory directly influencing the relationship between body, force, and action (Edwards, 2012; Barone et al., 2024).

In this framework, theory becomes a care for thought and a reflection on patterns of action and reflectivity. Gert J.J. Biesta's philosophy of education (2022) is particularly suited to providing a generative theoretical framework, one capable of guiding educational approaches to managing the environmental impact of digital resource use and digital participation. Biesta's framework offers guiding meanings useful for directing future empirical research, laying a solid theoretical foundation to address the challenges of this field.

Before delving deeper into this theory and explaining its selection, it is worth questioning why a transmissive approach falls short. A brief excursus, enriched by a literary metaphor, may prove indispensable to further support the adoption of such a perspective.

There is a significant difference between a genuine cognitive process and the mere retention of informational content. Storing information does not necessarily imply cognitive internalization, as true understanding, processing, and recall involve not only intellectual acts but also the engagement of the entire realm of sensitivity. Sensitivity plays a vital role in attributing meaning, a semantic operation requiring extensive participation that encompasses subjective sensibilities and interpersonal dynamics, making the information itself more meaningful. While utilitarian, fact-based learning connected to specialized, situated functioning exists, it is not the focus of this discussion.

A literary example can help elucidate what it means to retain information without truly "feeling" it – without understanding it intrinsically and in its broader context. Every cognitive process gains meaning only in correlation with a socialized world of meanings, as revealed through language (Wittgenstein, 2009).

The example comes from *Ficciones* (1986) by Jorge Luis Borges. In the story *Funes, the Memorious* (*Funes el memorioso*), first published on June 7, 1942, in the Argentine newspaper *La Nación*, Ireneo Funes, a farmer, suffers a traumatic brain injury after a fall. This incident changes his memory, granting him the extraordinary ability to remember everything: «*All the branches and clusters of a pergola, the shape of the southern clouds at dawn on April 30, 1882, the trail of foam that an oar lifted from the Rio Negro on the eve of the Quebracho expedition*» (Borges, 1986, p. 25, the translation is provided by the authors).

As Giuseppe O. Longo (2018) observes, Funes is doomed to remember everything without feeling anything. He accumulates details without the systemic thinking or filtering mechanisms that allow one to discern what is worth preserving and what is not, what is crucial to remember for the future and what is not. Consequently, Funes is maladapted, unable to comprehend the internal and external events of his life: he is condemned to recite information.

He has lost the social function of memory and the sense of preserving it in a narrative that works for himself and others (the world).

In our contemporary context, accumulating cutting-edge information is entirely insufficient for several reasons. The rapid obsolescence of knowledge, cyclical changes in labor markets and professions, and the uncertainty about the future triggered by the pandemic have foregrounded the challenge of this decade: cultivating resources in students that can act as safeguards for facing both predictable and unpredictable scenarios. Creative, individual, and collective exploration of problem-solving hypotheses is needed.

We must, ultimately, "reconstruct" the value of formal environments like classrooms, reimagining them not as mere spaces for passive listening and information intake over a schedule-dictated timeframe. Instead, classrooms should be envisioned and lived as places where the future is already taking shape, where individual reflections are active actions that stimulate and structure credible alternative futures (Orsenigo & Valentini, 2024). They should become spaces where care for thought is practiced, and reciprocity in attention and support is cultivated.

This care extends beyond the immediate educational context, projecting into and influencing broader life domains.

In this sense, the present proposal aligns with studies on educational materiality, which, starting with the work of Riccardo Massa, consider teachers, students, educational materials, technologies, physical spaces, objects, artifacts, time, and rhythms as co-authorial nodes in a network that actively participates in the educational experience's realization.

> Human and non-human actors relate to each other, "associate," forming a set of dynamic networks that in turn produce effects. For example, a teacher using interactive technology in the classroom – think of a smart board or a projector – is not just a user of the technology but becomes part of a network where the technology, students, and other human and non-human actors (cables, internet connection, digital skills, bandwidth capacity, arrangement of bodies in space, technical support, blackout curtains, remote control device, subjects taught, etc.) mutually influence the learning dynamics. The heterogeneous actors, aggregates, or assemblages that make up sociomaterial networks also contribute to the construction of meanings, emotions, moral orders, and power (Barone et al., 2024, p. 78, the translation is provided by the authors).

This represents, therefore, a rethinking of the "materiality of the educational universe".

The issue of technological mediation – namely, the use of material resources as a "third educator" – was already foregrounded in the *Reggio Emilia Approach*, beginning with the reflections of Loris

Malaguzzi. However, this notion had already assumed an essential role in early childhood education through the work of Maria Montessori.

Today, it takes on renewed significance in light of Tim Ingold's *ecology of culture* (2001). In his work, Ingold intersects with the thoughts of Massa and Barone, questioning the taken-for-granted relationship between thinking and doing, between abstract concepts and physical objects. He reminds us that materials "think" within us and that we think through them. This is an ongoing effort, characterized by imbalances and subsequent attempts at rebalancing, to establish relationships among things, objects, the organization of space and materials, and actions guided by abstract intentions.

Central to this discourse is a distinction made by Ingold himself between the concepts of *building* and *dwelling*, describing the transition from the *Building Perspective* to the *Dwelling Perspective*. «From the perspective of dwelling, it is precisely the very act of being in a space that makes it possible to build it. To dwell is not only to occupy a space but means to feel at home, to appropriate it» (Barone et al., 2024, p. 122, the translation is provided by the authors).

In the educational context, fostering the appropriation of space clearly involves negotiating meanings and trajectories of sense. To some extent, it entails repeatedly adjusting the "fusion of horizons", collectively seeking and re-seeking new connections of ideas, meanings, and interpretations, while knowing and recognizing, composing and recomposing the educational space.

This space, on the one hand, consists of networks of matter; on the other hand, it comprises "other matters", such as ideas, documents, rules, and norms. Gert J.J. Biesta's philosophy of education does not propose ideas merely to reflect upon but rather *ideas to think with* (2022, pp. 4-5). For Biesta, to exist as subjects means to be in a continuous "state of dialogue", where the production of subjectivity does not arise internally – from intentions or desires – but is deeply connected to the ways in which one relates to and is called into engagement by the aforementioned materials and "other matters".

Furthermore, Biesta asserts, «the educational task consists in igniting in another human being the desire to exist in and with the world in an adult way, that is, as a subject» (2022, p. 15, the translation is provided by the authors).

In a world marked by automated flows, visible and invisible environmental impacts, and educational spaces whose configurations shift with each passing decade, what does it mean to want to exist in an adult way?

> What distinguishes an adult way of existing from a non-adult one is that in the first case, one is able to recognize the otherness and integrity of that which and who is other than oneself, while in the second case, the otherness is not even considered. In other words, an adult subject recognizes that the world "out there" is truly "out there" and is neither a world we have constructed ourselves nor simply a world at our disposal, of which we can freely do whatever we want. The term "World" here refers both to the natural world and the social world, both to the world of things and to the world of living beings. It refers both to our planet and everything that exists on it, as well as to the other human beings we encounter. It refers, with an interesting term proposed by Alphonso Lingis, both to planet Earth and to the earthlings who inhabit it. Recognizing the otherness and integrity of this world is not an act of generosity on my part that allows the existence of that which and who is other than me. It is not up to me to decide whether the world exists or not. Rather, it is up to me to decide whether to grant (or not grant) otherness and the integrity of the world a place in my life (Biesta, 2022, p. 16, the translation is provided by the authors).

When teaching addresses and directs itself to the other as a subject, it operates in a radically different manner compared to when it relies on a temporal logic (the concept of teaching as the promotion of development or growth) or as the establishment of specific abilities or competences for a generic "after". Here, Biesta intersects with the thought of Jacques Rancière, particularly in the concept of "dis-

sensus". This concept should not be understood as the absence of consensus or conflict, but following Rancière (2007; 2022), it should be understood as the irruption of an "incommensurable element" into a state of affairs, in a specific "partition of the sensible". Dissensus is not «The opposition of interests or opinions [but] the production within a determined and sensible world of something that is heterogeneous to it» (Biesta, 2022, p. 109, the translation is provided by the authors).

An environmental education of digital resources, supported by such a philosophy of education, thus distances itself from the idea of learning that is embedded in a relationship of comprehension that centers the self as the transformer of the world into an object for the self. This approach radically limits other forms of existence that are more decentralized between the self and the world, where it is the world that calls the self into question, and not vice versa. Therefore, it also departs from constructivist theories that emphasize the action of constructing meaning and the effect of control; here, however, the builder is not at the center of the world being understood: «From a different perspective, one can instead assume that it is the "reception" that shapes the subject-world relationship» (Biesta, 2022, p. 133, the translation is provided by the authors).

The encounter with the resistances of the world, represented by what opposes the subject's initiatives, is a fundamental experience. It reveals that the world is not merely a projection of our mind or our desires, but has its own integrity and autonomy. An emblematic example is the environmental impact of digital actions, which, as highlighted, operates both visibly and invisibly, amplifying the perception of the world as a force resistant to the subject's interpretations and projects (Ceruti & Bellusci, 2023).

In this context, an education aimed at disseminating such themes creates a breach capable of revealing a sensitive state or condition that permeates experience, while often remaining hidden. This education acts as an opening toward proximate resistances, those that are evident but poorly perceived, stimulating a critical awareness. The object of inquiry, therefore, is dual: on one hand, technologically equipped educational environments, such as classrooms, and on the other, wearable or portable technological devices that have profoundly shaped everyday life for the past decade.

We know the operational potential of these objects – the ability to perform meaningful actions with a simple click – but we less often consider the resistances that they "embody" and "emanate". These resistances, independent of our will, continue to propagate and manifest, especially through the environmental impact of digital technologies, which today must be treated as a super wicked problem. In this sense, to address this complexity, education must take on multiple functions: from an analytical rationality that studies the relationship between a single digital action and its impact, to a reinterpretation of the classroom as a formal space capable of generating future and credible alternative meanings; to an education as a practice of subjectivation, through which subjects perceive themselves as active agents in the construction of the curves of visibility, the curves of enunciation, and the forms of interaction that determine contemporary scenarios (Agamben, 2006; Deleuze, 2007, 2018).

4. Concluding notes: a new paideia

This contribution originated from the urgency to reflect on the contemporary meaning of sustainability, a concept that emphasizes the principles of intergenerational equity, highlighting the importance of considering the planet as a borrowed resource – an idea we have sought to extend to the choices and uses of digital technologies and artificial intelligences. Despite the significant progress established by the Kyoto and Paris agreements, these have not been sufficient to raise awareness among populations about

the need for a new balance between technological progress and the safeguarding of our habitat. Today, with automated flows and the interconnection between political, financial, and technological choices, the impact involves not only human beings but also the habitats of other living species. Responsibility has become global, yet the understanding of this complexity remains still insufficiently widespread.

In the second chapter, we focused the attention of the educational world on two main forms of emissions related to the digital: embedded emissions and operational emissions. However, for reasons of consistency and space, we did not delve into the topic of embedded emissions, which would require an extensive analysis of the extraction and production supply chain of materials, intertwining issues of human rights and illegality. Another limitation of this contribution is the insufficient treatment of the cloud computing chain, which would necessitate a detailed study of the CO_2 emissions produced at each stage of the process. Despite these limitations, we believe this reflection can serve as a starting point for future developments, laying the groundwork for an emerging discipline that we have defined as "environmental education of digital resources".

In the third paragraph, we emphasized the need for this discipline to be grounded in a philosophy of education that transcends mere information transmission. Teaching should be conceived as a zone of knowledge, a reception from the world, and a decentralization of the self, where the subject is addressed by the world itself. The classroom must become a laboratory space for co-creating credible futures, through the interaction between students, teachers, and objects, within a collaborative framework that recalls Bruno Latour's Actor-Network Theory (2022). Even objects, indeed, actively participate in the construction of new knowledge, contributing to redefine relationships with the digital and fostering a more balanced use of technologies.

In other words, the educational process must regain its center in a zone governed by relationality, designed to decenter the role often idealistically assigned to subjects, understood as the sole bearers of constructive agency. Devices, incorporated into the relationship, acquire educational value only within a context where the friction provoked by the objective world (both living and non-living) determines the various criteria for assimilation, through which its salience is meaningfully recognized and evokes the beginning of a "questioning". Thus, objects actively participate in every interpretative process.

Therefore, it is a matter of promoting a new paideia, oriented towards the regeneration of thought. This regeneration opposes the tendency of scientific and technical progress to fragment knowledge, risking its entrenchment in automatic and mechanical processes, devoid of genuine critical and creative depth.

> A Paideia that helps to understand that knowing means entering into the movement of things, into the play of constraints and possibilities that generate and transform them [...]. A Paideia consistent with the vision of the cosmo-anthropological relationship in which man is not separable from nature, but recognized as an integral part of a complex process of co-evolution. A Paideia that provides the adequate awareness to conceive science and technology not as "Promethean" tools for merely quantitative progress, but as tools to build an alliance with nature, within nature, and to promote the sustainable and equitable improvement of the human condition. A Paideia that acknowledges that the pursuit of a co-evolutionary relationship with all actors of the world, living and non-living, is the precondition for our very survival and for the possibility of outlining a livable and fertile future. A Paideia that recognizes the indivisibility of human life, to be understood, at the same time, as earthly, biological, psychic, social, cultural, and spiritual. Finally, a Paideia that recognizes both the indivisibility and, at the same time, the plurality of humanity (Ceruti, 2024, the translation is provided by the authors).

In this sense, a new paideia proposes a significant expansion of the concept of relationship, where the focus is no longer solely on the relationship between humans and technological devices, but, in a

more radical perspective – to use a term from Richard Grusin that Michele Cometa reflects on – the relationship between the human and the non-human, between living and non-living entities, the dense «entanglement of bíos, zoe, and téchne» (2023, p. 35).

In the field of philosophy of education, it is essential to broaden the concept of medium, shifting from the traditional understanding centered on human-made technological artifacts to embracing an ecological vision. This perspective includes «a series of complex devices, both organic and non-organic» (Cometa, 2023, p. 28), recognizing that media are not merely tools but elements that structure and mediate relationships between the living, the non-living, and even the "quasi-living", such as technologies that exhibit a form of agency (Cimatti, Maiello, 2024). This vision allows for the placement of technological and communicative transformations within a broader horizon, one that accounts for deep ecological interactions. Education, in this view, as previously stated, is not a linear process of knowledge transmission but a dialogical and relational experience, where the educator is not simply a transmitter or facilitator but a mediator of meaningful relationships with the world.

5. Authors' contributions

According to CRediT System: Enrico Orsenigo – Conceptualization, Resources, Writing original draft; Cecilia Pellizzari – Writing Review & Editing; Michela Bongiorno – Writing Review & Editing; Maria Valentini – Writing Review & Editing; Lino Rossi – Project Administration, Supervision, Writing Review & Editing.

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