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Tangible digital storytelling and phygital reality: benefits for inclusion and cooperation in young children

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Abstract

Modern technology progresses at an incredibly fast pace. With personal computers, mobile phones, tablets, and the Internet, technology is used in all spheres, affecting our daily lives greatly. Educational games are also taking advantage of the technological process, for example, many useful apps are available for children. Gaming and educational opportunities have expanded because of the development of tablets and smartphones. Teachers have the opportunity to combine physical and electronic objects when creating education materials, so they are not confined to the use of traditional physical objects. Storytelling remains one of the oldest teaching methods for children: the development of technology has given impetus to the creation of tangible digital storytelling, which combines programs with physical objects, creating a single field for learning. Creating stories in which a child can interact with his/her peers has also provided new opportunities for inclusion and cooperation in young children. Indeed, the increased use of speakers, videos, pictures, and other tools that can help to quickly create and easily adapt objects for children with various backgrounds has fostered inclusive teaching. This paper will consider the evolution of the storytelling practice, focusing specifically on tangible digital storytelling and its benefits in young children.

Keywords: *tangible digital storytelling; inclusion; cooperation; children.*

1. Storytelling in the educational setting

The act of storytelling is a cultural practice based on the act of sharing a story, and it has been a way of communicating information and teaching since ancient times (Roig et al., 2018). The stories told by our ancestors go back 30,000 years, appearing as drawings in caves. The Native American Choctaw, like the Greeks, used animals to create stories (Society, 2020). In later years, storytelling has continued to be an essential part of the human experience from an educational and entertainment perspective. Throughout history, all populations have shared stories to get to know each other and to pass on values to feel part of the same community.

Moreover, this practice has been a learning facilitator within schools since it allows sharing ideas and values, and it also represents an artistic expression, which supports the creation of emotional and emotional bonds promoting empathy (De Vecchi et al., 2016; Gladwin, 2020; Catala et. al., 2023). A narrative is still a simple and effective way of introducing children to a complex world (Bruner, 1990). Furthermore, they are more likely to pay attention, listen attentively, and be more engaged than with any other method of learning (Bietti et al., 2019). Storytelling has also been found to be useful in improving literacy skills (Melzi et.al. 2023) and writing skills (Tanrıkulu, 2022).

At the same time, storytelling offers the possibility for children to invent stories in groups by promoting the co-construction of knowledge (through the sharing of different imaginaries) and positive interdependence by offering the possibility for each student to propose their own personal contribution to the creation of the story.

This form of collaborative and cooperative learning (Gillies & Ashman, 2003; Johnson. & Johnson, 2009) favors the encounter between different imaginaries and active listening, representing a methodology that can be used to promote inclusion because "narrative is an essential form through which children describe their own experiences and communicate their views of the world" (Ahn & Filipenko, 2007; p. 279).

2. Digital storytelling

Even today, people continue to tell stories through new digital media tools. Over the past decades, digital cameras, editing tools, interactive whiteboards, and other electronic media have prompted teachers to use many more approaches than ever before to help children in building their own knowledge and ideas (Armstrong, 2003).

One such powerful approach to multimedia production is digital storytelling (DST) (Sadik, 2008). DST has been defined as "the art of telling stories with a variety of digital multimedia, such as images, audio, and video" (Robin, 2006; p. 1). Since children are involved in the use of technology from a young age, this way of telling stories has become a natural way of learning. Indeed, a digital story can be considered as a hybrid between traditional storytelling and multimedia technology (Normann, 2011). In this context, technology not only promotes meaningful learning, "but also increases motivation to learn, encourages collaboration, and helps develop critical thinking and problem solving strategies" (Pitler, 2006; p. 1).

The use of DST as a pedagogical tool has been proven to have a variety of benefits (e.g., Di Blas et al., 2012; Lisenbee & Ford, 2018; Maureen et al., 2018; Yuksel et al., 2010; for a review, see Robin, 2016). For example, sound design and pacing can be tailored to make the story more personalized (Robin, 2016). Through the medium of technology, students can construct their knowledge and share their own ideas and experiences, allowing for the creation of digital stories with great ease (Armstrong, 2003). In this regard, Standley (2003) specified: "No matter what technology is used, the real power of DST comes when students understand how to shape information and ideas to best present them to any audience in the world. The real power behind digital storytelling is the knowledge and ability to use new tools to teach the old tradition of storytelling" (p. 18).

DST proves to be an invaluable asset in the classroom, catering to various educational purposes such as recounting personal experiences, narrating historical events, and serving as an effective learning tool for specific subjects. This powerful method of storytelling incorporates a unique perspective, a dramatic question, and an emotional content to create a personal connection to the story (Maureen et al., 2021). In other words, DST enables students to draw connections between their own experiences and the academic content they learn in classes (Kim & Li, 2021, Li & Deng, 2022). Furthermore, Hwang and collaborators (2016) have found that creating stories using a web-based multimedia system enhances learning motivation, provides more opportunities for language practice, and yields superior learning outcomes compared to traditional storytelling methods involving pen and paper. This approach can also be applied to learning within the domains of science, technology, engineering, and mathematics (Henriksen et. al. 2021).

Moreover, DST combines research, creation, analysis, and fusion of visuals with written text, which improves and accelerates learners' comprehension (Cherry, 2017). In addition, DST has been described as a medium to teach digital literacy skills (Karakoyun & Kuzu, 2016; Schrock, 2013). Due to the built-in instructions, such devices can often be used without a teacher, which is not the case with traditional storytelling methods. Also, digital tools can be used outside of school and other educational institutions, for example, at home (Di Blas & Paolini, 2013).

Previous studies have also highlighted the importance of DST as an approach for collaborative knowledge building and as an effective promotor of interaction among peers in and out of school (Hung et al., 2012; Jenkins & Lonsdale, 2007; Sadik, 2008; Theune et al., 2013). Through DST, students worked together to improve sorties and co-create stories. As a result, they became better at communicating their ideas and listening to different views and perspectives from other students (Del-Moral-Pérez et al., 2019; Wu & Chen, 2020). It has been found that such a process improves students' social skills (Ribeiro, 2016; Schmoelz, 2018). Furthermore, the use of DST in cooperative learning contexts for inclusive education is particularly useful for the development of expressive and social–relational skills in children with Special Educational Needs (SEN) (Garzotto & Bordogna, 2010; Parola et al., 2022), who often experience difficulties in communicating with adults and peers, both in the area of language and in that of self-awareness and self-expression. For example, Smeda and colleagues' (2014) study showed that DST can assist students with SEN within the school curriculum by enhancing students' confidence and contributing to better social and psychological skills.

DST also proves beneficial in first language settings, contributing to literacy development (Liu et al., 2014, 2018; Ohler, 2013; Sarıca, & Usluel, 2016), motivating and assisting struggling writers (Sylvester & Greenidge, 2009), and promoting oral interaction in early childhood education (Papadimitriou, Kapaniaris & Zisiadis, 2013), among other applications. Moreover, there is growing evidence of its value as a tool to foster communicative skills in second language teaching and learning (Abderrahim, & Navarro González, 2020; Hwang et al., 2016; Yang et al., 2022). The versatility of DST makes it a powerful resource that spans across various language learning and teaching contexts, facilitating language acquisition and fostering creativity and expressive skills (Chen et al., 2023).

Finally, DST activities have been related to increased engagement and motivation in learning (Choi, 2018; Hung et al., 2012; Ivala et al., 2013; Smeda et al., 2014), technical skills (Anderson et al., 2018; Ciancarini et al., 2023; Sadik, 2008, Saritepeci, 2021), public speaking (Zhussupova & Shadiev, 2023), development of critical thinking (Yang & Wu, 2012), computational thinking (Yang et al., 2023), and more in general, improvements in overall academic performance (Hung et al., 2012; Nam, 2017; Yang & Wu, 2012; Yang et al., 2022). See Fig.1 for an example of DST tool.

Fig. 1. Toontastic: a digital storytelling tool

This creative storytelling app empowers kids to organize ideas, transforming them into entertaining short stories, animated cartoons, or even book or science reports for school. It is a user-friendly tool that applies the principles of scaffolding to assist learners in producing DST.

3. Tangible User Interfaces (TUIs)

The introduction of multi-touch technologies into the learning process has sparked a natural evolution of DST. This evolution is supported by a growing body of evidence demonstrating the usefulness of tangible tools in various educational activities, spanning geometry activities (Bonnard et al., 2012), science teaching (Shaer et al., 2014), computer programming (Horn & Bers, 2019), and fostering computational thinking (Funk et al., 2021). Indeed, Piaget's developmental theory suggests that manipulating and handling concrete objects can improve a child's spatial and thinking skills (Wadsworth, 1996). Using tactile interactions has proven easy enough for even the smallest child (Gray & Lewis, 2009), clearly making learning more intuitive by the "hands-on" approach. Among the numerous advantages that TUIs provide, recent evidence suggests a causal link with the development of motor and cognitive skills through physical activity (Cerezo et al., 2020; Novak & Loy, 2017). Tangible devices tend to be portable and encourage physical activity that is important for children's development (Marshall, 2007), while computer work often prevents children from moving, which could have a negative impact on health and learning outcomes (Fang et al., 2019; Marshall, 2007). In addition, the existing body of research on tangible devices also proposes that they can foster interest and motivation of students (Mateu et al., 2013) since a playful learning environment can be created with physical objects interacting with virtual environments (Shaer et al., 2014). Even more importantly – given the focus of this work – it supports the development of collaborative and social skills both in typically developing (Garcia-Sanjuan et al., 2018; Schneider et al., 2010) and SEN children (Al Mahmud & Soysa, 2020; Alessandrini et al., 2016; Farr et al., 2010; Hourcade et al., 2012).

Below, we will focus on a brief overview of the benefits of TUIs for cooperation and inclusion.

3.1 Cooperation and TDST

The significance of classroom collaboration as a powerful learning tool has prompted extensive research by psychologists and educators. Numerous studies have demonstrated the effectiveness of collaborative learning (Johnson & Johnson, 1989; Laal & Ghodsi, 2012; Stanton et al., 2001), leading to its recognition as a fundamental 21st-century skill now incorporated into the curriculum of most educational systems (Schul, 2011). In collaborative settings, children engage in educational conversations with their peers, assigning, discussing, and teaching various skills, such as literacy. This process offers participants the opportunity to articulate and clarify their ideas, understand differing viewpoints, and learn how to resolve social challenges that may arise.

TUIs play a crucial role in facilitating face-to-face collaboration, allowing users to interact with the system and each other simultaneously (Marshall, 2007). By employing tangible interfaces, TUIs promote social learning by providing a shared representation of the problem, reducing the cognitive load, and facilitating interaction (Chandrasekera & Yoon, 2015). For instance, Stanton et al. (2001) developed a TUI for collaborative storytelling, where children gathered around a vertical screen to view story drawings, navigating between them on a "magic carpet." This approach encouraged collaboration by slowing down the pace of interaction, leading to more discussions and exchanges of ideas. Similarly, research conducted with Tangible Multitouch Tabletops revealed that these devices foster more visible and open interactions (Leversund et al., 2014). The large tabletop size required children to assist each other in accessing objects that were out of reach, promoting cooperative problem-solving.

Furthermore, the design of a tangible multi-tablet gamified quiz system, known as "Quizbot," has provided an effective tool for organizing interaction and collaboration (Garcia-Sanjuan et al., 2018). The study showed that compared to the tactile version, the tangible platform was more successful in encouraging children to reach consensus after discussions, divide and parallelize their work, and treat each other with respect.

With TUIs fostering face-to-face collaboration, reducing cognitive barriers, and encouraging active engagement, the potential for enhancing the learning experience and nurturing essential 21st-century skills has never been greater. As educators continue to explore innovative ways to leverage TDST and collaborative learning, students can benefit from a more enriching and inclusive educational journey.

Collaboration and cooperation share intricate ties with positive interdependence (Li et al., 2022), encompassing the utilization of tangible and digital tools and the joint creation of narratives. Within this pedagogical framework, students are granted the agency to make individual contributions, tapping into their creativity and employing an array of visual, tactile, and auditory cues. This not only bolsters their motivation to participate, but also acquaints them with varied learning styles, a facet known to nurture divergent thinking (Addone et al., 2022).

3.2 Inclusion and TDST

Cottini (2017) proposes a multidimensional view of inclusion that emphasizes considering individual student profiles in the planning and implementation of classroom tasks. Inclusive practices have long focused on individualization and personalization (Ianes, 1999) to cater to diverse learners (Ianes & Tortello, 1999; Baldacci, 2005; Ianes & Canevaro, 2015).

Storytelling, based on collaborative learning and peer-to-peer tutoring, emerges as a valuable tool to promote inclusion by starting from students' life experiences (Cornoldi et al., 2018). Key elements such as positive interdependence and co-construction of knowledge play a vital role in fostering inclusion (Gillies & Ashman, 2003; Johnson & Johnson, 2009). Through continuous exchange and co-construction of meaning and content, learners assume different roles and are exposed to multiple learning styles.

New technologies have the potential to break down barriers to learning, and the use of TUIs has been found beneficial in promoting the inclusion of students with SEN (Barrett, 2006; Porter, 2004). TUIs encourage communication and active listening (Faver & Alanis, 2012), supporting students' speech, language, and communication skills, as demonstrated in Jadan-Guerrero et al.'s study (2015) that aimed to strengthen literacy skills in children with Down syndrome.

Incorporating multisensory elements in technology design for children with mixed abilities can facilitate collaboration and group discussion, leading to more engaging experiences for primary-aged learners (Cullen & Metatla, 2019). This interaction with the world through their senses helps children learn new skills and can facilitate different types of learning, including literacy (Neumann et al., 2012).

Numerous studies highlight the potential of tangible technologies in aiding individuals with intellectual disabilities, fostering the development of cognitive, sensorimotor, social, and behavioral skills (Antle & Wise, 2013; Falcão, 2017; Gelsomini et al., 2021; Beccaluva et. al., 2022). As technology continues to evolve, tangible DST offers promising avenues to promote inclusivity and support the diverse needs of learners in educational settings.

As previously mentioned, the Universal Design for Learning (UDL) embodies an approach that seeks to provide diverse modes of representation during educational teaching activities. It advocates for the establishment of an environment that nurtures a multisensory dimension (Evans, 2022) to cater to the needs of all students and facilitate meaningful learning. According to this perspective, restructuring the physical learning space to strategize and implement experiences where students can foster their potential based on varying learning styles is entirely feasible (Khurana, 2022). As a result, contemplating the utilization of TDST emerges as a viable strategy to advance a universal teaching methodology.

4. Tangible Digital Storytelling: the fruitful combination of different dimensions

The combination of physical reality and digital reality in Tangible Digital Storytelling (TDST) activities offers students the opportunity to work within different dimensions: the screen and its scenarios combine dramatization with manipulation of objects. This combination allows students to move from one dimension to another and live multiple experiences in different settings.

Tools that integrate both physical and digital experiences fall into the categories of phygital products (fusion of physical and digital; Goretti et al. 2020). Phygital interfaces, as introduced by Beaudouin-Lafon (2000), seamlessly blend digital and physical elements, ensuring a clear distinction between the display of digital information (e.g., on a screen) and the physical manipulation of objects by users. These interfaces leverage physical objects to serve a dual purpose: enabling user interaction to control digital elements, while also representing digital content through direct semantic mapping (Gelsomini et al., 2021).

Theoretical perspectives recognize learning as a dynamic interplay of both intellectual and physical dimensions, wherein embodiment plays a pivotal role. Embodiment refers to an organism's ability to effectively engage its sensorimotor capacities to interact with the physical environment. This interactive process significantly shapes the development of cognitive skills, such as mental imagery, memory, reasoning, and problem-solving (Wilson, 2002). By integrating physical engagement into the learning process, various aspects of cognitive functioning can be enriched and enhanced (Gelsomini et al., 2020).

In the educational context, the concept of phygital reality offers a novel approach to learning, acknowledging younger learners' adeptness at seamlessly transitioning between physical and digital realms. To leverage this potential, the deliberate and conscious use of technological tools becomes essential to ensure that the virtual dimension does not replace the real world, but rather complements it, enriching meanings through digital stimuli (Jurgenson, 2011).

Within this framework, TDST could be a particularly useful methodology for digital natives (Prensky, 2001) who experience from the very early stages of their development two different realms, the physical and the virtual one. Furthermore, the possibility to move from one dimension to the other can have a positive impact on students with special needs as illustrated by the UDL theory (Center for Applied Special Technology [CAST], 2018). UDL is based on three fundamental elements: the employment of multiple tools to involve students, the diversification of representation (Zancanaro et al., 2007), and multiple forms of output (physical, facial, textual, iconic; Rose, 2000; Murawski & Scott, 2021). In line with UDL, the digital reality can either precede or follow the physical one interchangeably. For instance, a storyboard can serve as a foundation for creating a script for dramatization, while an improvisational performance can be transformed into a captivating digital story. The fluidity between these realms allows for dynamic and inclusive learning experiences, catering to diverse learning styles and preferences.

Within the framework of the INCLUDED project, we delved into the impact of collaborative storytelling methodologies on group interactions and story quality among primary school students, both with and without special needs. The INCLUDED project, titled "Inclusive childhood education supported by multimedia and digital storytelling," is an initiative supported by the European Commission (Erasmus+), involving several institutions and educational centers from Italy, Spain, and Finland. The project's primary objective is to enhance social skills, including collaboration, active listening, empathy, and positive interdependence, alongside narrative competence encompassing syntax, vocabulary, cohesion, and coherence. This is achieved through collaborative activities encompassing three storytelling approaches: Traditional Storytelling with paper and pencil materials (TST), DST utilizing Toontastic (see Fig. 1), and TDST utilizing i-Theatre (see Fig. 2). Toontastic (DST) presents a user-friendly interface and a diverse set of features, making it easy to craft captivating digital stories. Among the various methodologies, i-Theatre stands out as a phygital tool, providing a distinctive connection between the multisensory aspects of drawing, storytelling, and digital tools in classroom experiences. It seamlessly combines digital and tangible interfaces, effectively serving as a TDST tool, boasting an integrated multi-touch screen and a scanner-drawer.

Preliminary findings from Spanish and Italian teachers involved in the project indicate that i-Theatre has garnered high interest among educators, as they observed positive outcomes regarding collaboration and student engagement, irrespective of special needs status, from the very first session (Filosofi et al., 2021). The study (Filosofi et al., under review) sought to explore three hypotheses: (1) TDST promotes more inclusive and prosocial group interactions compared to DST, (2) collaborative stories produced through different methodologies exhibit higher formal and content quality than individual stories, and (3) the level of collaboration influences story quality, regardless of the methodology used. To address these hypotheses, the study employed an experimental, cross-sectional design, incorporating various assessments such as cognitive competence, narrative skills, and verbal fluency. The findings revealed significant differences in group interactions and story characteristics across the different storytelling methodologies, with TDST showing advantages over other approaches.

In addition, the research involved 14 Spanish students with mild to moderate intellectual disability and other neurodevelopmental comorbid disorders, actively participating in collaborative storytelling sessions within the classroom setting (Alonso-Campuzano et al., under review). The study comprised three individual assessments of narrative skills and eight collaborative storytelling sessions, utilizing different storytelling methodologies. Video recordings of both individual and collaborative stories were transcribed verbatim and thoroughly analyzed for formal and content characteristics. Behaviors and interactions during the collaborative storytelling sessions were closely examined for each group and session. The results highlighted a positive effect of collaboration on students' stories, indicating improved performance compared to individual efforts, regardless of the methodology used. Encouragingly, the participants demonstrated ease in handling technological devices and engaging in shared storytelling, with no barriers encountered.

Overall, the findings suggest that collaborative storytelling, particularly in the context of TDST, offers significant benefits for students, including those with special needs. The INCLUDED project provides valuable insights and approaches to foster inclusive education through innovative and accessible storytelling methods, opening the avenues for enhancing group interactions, narrative skills, and story quality for all learners. In this light, TDST emerges as a valuable tool to promote nondigital literacy. It bridges the gap between different dimensions, acting as an agent that enriches perceptions and meanings, where one dimension complements the other rather than overshadowing it. By embracing TDST, educators can create an immersive and holistic learning experience that fosters a balanced integration of physical and digital realms, empowering learners to navigate and excel in the ever-evolving landscape of modern education.

Fig. 2. i-Theatre: an interactive integrated system for Tangible Digital Storytelling.
i-Theatre, inspired by the "theatre of objects," is a playful tool for TDST, providing educators with new possibilities to promote the sharing of knowledge and relationships in young children (4–10 years old). The system is both educational and ecologic, reconciling nature and digital technology: it features a tangible interface (with digital-based objects) that suits the way children naturally experience the world and reproduce the fun related to brick-building games.

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