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“APPRENDIMENTO POTENZIATO DALLA TECNOLOGIA: UNO STUDIO SUI FATTORI CHE INCIDONO SULL'ESPERIENZA DEGLI STUDENTI NELL'USO DELLA REALTÀ VIRTUALE E MISTA”

“TECHNOLOGY ENHANCED LEARNING: A STUDY ON FACTORS IMPACTING ON STUDENTS’ EXPERIENCE USING VIRTUAL AND MIXED REALITY”

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Introduction

It is largely acknowledged that the implementation of ICT in education offers the opportunity to introduce novel approaches to learning, while preparing students for the information society. It is expected, that the incorporation of technology-based assessment prototypes, tutoring systems, and instructional models, into the educational curriculum design, will consolidate innovative teaching practices, and enrich the learning experiences. Certainly, technologies support some fundamental dimensions, such as connectivity (access to globally available information), flexibility (learning occurring at any time and in any place), and interactivity (active exchange with peers and mentors and real-time evaluation of autonomous learning), but which are the technologies so far investigated in the context of education, and from with point of view? Chapter one explores the interdisciplinary studies focusing on technology enhanced learning, in order to draw a state of the art related to the use of technology based tools for educational purposes, while capturing the most relevant findings regarding the impact they are proved to have on learning.

The impact of ICTs on learning is only recently attracting the debates involving psychologists and learning scientists. In chapter two, this study outlines the most significant theoretical frameworks underpinning the analysis so far conducted to investigate the numerous factors implied. While chapter three will particularly focus on the key constructs, and their relationships with learners' perceived impact on learning, identifying the model to ground the empirical study presented in chapter four and five. Chapter four, provides details about the theoretical frameworks that initiated the conceptualization of embodied knowing underpinning the development and use, in the context of higher education, of a game based application called EULALIA. It supports the deployment of an embodied and experiential approach to learning, and it has been designed to operate in both virtual (VR), and Mixed Reality modality (MR); this latter, characterized by the embodiment of knowledge within physical objects (Smart Objects or Tangible User Interfaces – TUIs) that mediate the interaction between the learner and the digital interface, to extend the learning experience, connecting it to manipulable physical elements associated with real life contexts. The design methodology of the prototype used in the empirical study is also described, as well as the co-design approaches used to develop the Open Educational Resource (OER) in form of game based scenarios. These are in fact the playground of the study presented in chapter five, that aims to explore students perceived impact on learning of Virtual and Mixed Reality, and the differences between the two interaction modalities. The study findings, are discussed in the attempt to contribute to a still recently explored field of technology enhanced leaning, that related to the use of virtual and mixed reality, as well as of Tangible User Interfaces (TUIs), considered among the most innovative, while not fully explored in educational context.

Chapter 1

Technology enhanced learning: a state of the art of major accomplishments, key issues of dispute, and research directions

1.1 Defining technology enhanced learning, challenges, and perspectives

Digitisation is progressing throughout all spheres of our present-day society, and the development and use of digital technologies, are associated with a transformation process that impacts all aspect of daily life, including education and training. This, presents both challenges and many opportunities, that accompany educational practitioners' adoption of experiential, situated, and inquiry-based instructional methods (Bandura 1994; Beetham and Sharp 2013; Bell 2010; Bridges et al. 2016; Brown et al. 1989; Johnson 2016; Kolb et. al. 1975; Lave & Wenger 1991; Lu et al. 2014) that can enhance personalisation of learning strategies and allow learners to direct and regulate their own pathways, in some cases expanding the boundaries of educational institutions and strengthening collaboration among peers.

In addition, the role of education is critical in equipping youth with skills to meet the labour market demand, and the competencies they need to address societal challenges. Technologies can be useful to advantage learners dealing with the current and future needs of the society that require transversal life skills and technical competencies that match the job market needs (Sharples et. al., 2016; Tynjälä et. al., 2006), such as problem-solving (Haydon et al., 2012; Volk et al., 2017), communication skills (Liao, 2022; Kagohara et. al., 2013; Manca, 2013), creative thinking skills (Atwood-Blaine et. al., 2019; Middelton, 2005), collaborative engagement (Martin et. al. 2027; Sedaghatjou & Rodney, 2018). However, technological advances have not yet been exploited in the education and training context at the same pace as in the industry. A vast spectrum of technologies is available and applicable in the educational context, but not jet explored with attention regarding the implications on the learning outcomes (Atwood-Blaine et. al. 2019).

As defined by the UNESCO International Bureau of Education and adapted from Seel (2012), Technology-Enhanced Learning (TEL) refers to "the use of information and communication technologies as tools to support student learning"[1]. It encompasses a wide range of applications, such as computer and web-based applications, virtual classrooms and learning environments,

[1] International Bureau of Education definition of TEL http://www.ibe.unesco.org/en/glossary-curriculum-terminology/t/technology-enhanced-learning

digital collaboration tools, social networks, serious games, artificial intelligence systems, virtual and augmented reality, etc., that support access, delivery, and implementation of content in novel and diverse modalities, and enable sharing, and creation of student-centered resources. It is expected that the incorporation of technology-based assessment prototypes, tutoring systems, and instructional models into curriculum design will support the development of innovative teaching practices, and the deployment of more effective learning experiences. Certainly, technologies support some fundamental dimensions such as connectivity (access to globally available information), flexibility (learning can occur at any time and in any future), and interactivity (interaction with peers and mentors and real-time evaluation of autonomous learning).

Nevertheless, the integration of digital technologies into the learning practice is concurrently reported as a complicated organizational process, and as an experience with a positive impact on learning (Fokides & Kefallinou 2020), motivating students thanks to more engaging, interactive, and fun learning environments. Numerous studies have established a connection between the employ of digital technologies and student engagement, motivation, and positive learning outcomes (Fokides & Kefallinou, 2020; Heindl & Nader, 2018). Educational practitioners frequently report that technology-enabled assessments can help reduce the time, resources, workload management, and cognitive load in learning, but annotate that if digitalization is not built into a curriculum transformation and rooted in a pedagogical shift, it can fail to positively transform the practice, not favoring students' learning outcomes. To achieve a successful digital technology adoption, and integration, educational practitioners need sufficient support and professional development, as the main barriers to the effective use of technology in the classrooms include lack of time, technological assistance, training about how to implement technology in a practical routine (Fransson et. al., 2020).

With relation to academic research, a considerable number of disciplines started investigating the areas related to technology-enhanced learning, and highly-ranked journals published special issues on related topics, while several non-profit organisations, companies, and industrial research labs are focusing their community-grounded experimentations in this domain. However, there is no systematic review of the existing literature that supports a clear overview of the major accomplishments in this field, the key issues of dispute, and the most pressing research gaps. The following sections are an attempt to highlight which areas the research have addressed so far, to map the road for future work, particularly in connection with the topics that have a point of contact with the present study and a certain degree of attention on the impact of the integration of technology on learning outcomes.

Despite the growing demand for data on ICT in education, the best-known international sources of statistics do not present sets of indicators, and comprehensive data, regarding the processes and outcomes of ICT integration in education and training that include all three components of inputs, processes, and outcomes. OECD's Programme for International Student Assessment (PISA) dataset remains one of the most reliable sources of information on access and use of ICT in the education domain, despite its limitations regarding the reporting of the current classroom practices (OECD, 2021). In particular, setting comparable key indicators and collecting statistics on the impact of ICT on learning remains challenging.

Available data report that educational practitioners' use of ICT for teaching is mostly related to planning teaching sessions, assessing students' performance, and taking part in supportive communication and collaboration activities with colleagues, parents, and students (OECD. 2020). Educational practitioners face specific challenges when planning to integrate ICT into the pedagogy, mostly related to their lack of confidence in the use of devices, and some researches show, that without sufficient planning and training, using ICT may result in a lack of focus among students and lower overall performance (Ghavifekr, 2016; Trucano, 2005). Integrating ICT in the learning environment affects the instruction time and the curriculum to which students are exposed (e.g. setting clear goals, asking questions to verify understanding), as well as the way learners perceive the learning experience. These factors have been documented as important predictors of student achievement across various subjects (Schmidt et. al., 2015). PISA highlights three dimensions correlated with students' cognitive achievement that can be transformed meaningfully by integrating ICT: structure and classroom management; student orientation (including scaffolding, students' collaboration techniques, and feedback and assessment mechanisms); and cognitive activation (e.g. giving problems, that require students to apply to new contexts what they have learned, and/or giving tasks that can be solved in several different ways) (OECD, 2017a). For example, the literature emphasizes that computer-assisted learning, based on tutoring systems or educational software, is more likely to advance students' cognitive outcomes (Escueta et. al., 2017; Bulman & Fairlie, 2016), in particular when such systems support personalisation, offering content and activities tailored to student's learning needs. Some evidences suggest that digital learning resources affect students' engagement with, and motivation toward, learning activities (Faber et. al., 2017; Lazowski & Hulleman, 2015). In general, the use of technology based tools and resources for educational purposes (tools for searching bibliographical references, translation software, forums and chats, multimedia materials, etc.) stimulates learners involvement in their studies, and results in improved skills and performance (Dahmani & Ragni, 2009).

1.2 A deeper exploration of the use of technologies in relation to the learning contexts and subjects' domains

As part of temporary trials associated with research studies, educators started adapting their teaching practices to accommodate the integration of technology. Karami and Attarn (2013) for instance, found that the integration of ICT problem-based learning were very effective in enhancing teachers' content knowledge and teaching skills. These results, stimulated teachers feeling confident in the use of technology, and triggered a change in the pedagogical models; while did not encourage those educators lacking the self-efficacy necessary to apply technology in the daily practice (Martin, 2020).

It should be mentioned, however, that most of the studies available focus the investigation on the access to connection and devices, and eventually on their use for accessing various subject-related contents. A substantial part of the works analyses from a quantitative point of view the variables that influence the integration of a particular tool within the curricular teaching, such as teacher training and organisational and cultural models. How educators perceive technology in education differs by subject area, and their perception of the integration of technology is not clearly understood, because each subject has a different set of learning outcomes (Howard, 2015). The research conducted across multiple subject areas to investigate the implications of ICT use on math, science, technology, and special education, focus mainly on teachers' feelings towards the use of technology, examining the impact of teachers' attitudes and beliefs the on use and adoption of ICT (Eickelmann & Vennemann, 2017; Levin & Wadmany, 2006; Teo, 2011; Salleh, 2016; Sánchez et. al., 2012). In general, it can be stated that digital skills influence the intensity of ICT use, and vice versa. Some studies show that ICT practice is more congruent with certain subjects, and that educational practitioners are in some cases hesitant to accept a technology as perceiving it incompatible with the focus of their lessons (Hennessy et.al., 2005; Jo, 2013), suggesting that subject culture shapes' the perception of ICT integration and attitudes about ICT in education. This is for instance the case of humanistic subjects, where teachers seem to feel more reluctant to use technology, then those teaching science subjects (Ghavifekr & Rosdy, 2015). Even students who did not have positive feelings towards the computer science lessons experienced feelings of neutrality (Tran, 2019).

It would be interesting to reflect about the use of ICT in correlation with educational domains or broader educational fields (e.g. social studies, art, technological studies; as described in Goodson and Mangan (1995), and if possible in connection with specific skills outcomes in a particular subject.

Learning contexts can be differentiated in a number of ways (formal, and non-formal, as well as undergraduate, postgraduate and continuing or vocational etc., but on-line/off-line), and when experimenting or introducing a technology the attention should be kept on the setting requirements, and needs of the specific educational contexts, but most of all on the specification of intended learning outcomes (Bullock & De Jong, 2013). Regarding secondary and higher education, the literature mainly examines why an increase in performance (in particular, higher examination marks) might be attributable to the use of ICTs. Several works report about how schools and universities investments in ICT have a positive impact on student performance (Banerjee et.al, 2007; Castillo-Merino & Serradell-López, 2014; Power et. al, 2020).

Generally speaking, the research reports that the implementation of ICT in education **improves the learning outcomes and the skills** of students and prepares them for the information society (Assar et. al., 2010), however, technology is still marginally integrated into education at all levels and the impact of ICTs on the academic performance of students is only recently attracting the interest of psychologists and learning scientists. Science related subjects has been associated with new technologies for a long time and remains one of the first subjects in which technology is successfully integrated (Zubkovic et. al., 2017) Positive learning outcomes associated with the use of computer technology in education are greater in mathematics than in any other discipline (Aydın, 2005). Mathematics, in particular, seems one of the subjects most open to ICT's transformative possibilities (Balanskat et. al., 2007; John & Baggott la Velle, 2004). Most probably as mathematical literacy is associated with the technology characteristics of abstraction and symbolic representation, logical process and the capacity to formulate, and it employs and interprets logic processes to solve problems in a variety of real-world contexts. Similar results in fact can be noticed in relation with other sciences and disciplines like psychology, sociology, philosophy, epistemology, pedagogy, which are directly and indirectly based on mathematics (Joshi, 2017). The pedagogical shift engenders new teaching approaches that expand students' conceptual understanding, procedural fluency and strategic competence (Safder et. al., 2011;). ICT assisted teaching is promising in mathematics for achieving arithmetical and logical skills, as it advantages the critical thinking and analyzing skills (Fitzallen, 2005), particularly as it seems beneficial on performance related anxiety (Anthony & Walshaw, 2009). Furthermore, supporting dynamic graphical, numerical and visual technological applications, it provides new opportunities for teachers and students to interact, represent, and explore mathematical concepts (Anthony & Walshaw, 2009), supporting self- efficiency and self-learning (Joshi, 2021).

Balanskat et. al. (2007) cite Eurobarometer survey when reporting that teaching science, mathematics, and computer science educational practitioners are the most intensive ICT users (more than 50% of their lesson), compared to literature and language teachers (who use it only 5% of their lessons), humanities and social science teachers (13%), physical and artist/crafts teachers (16%). Several research studies also indicate that technology, internet and some computer games, can offer an important and effective support to learning a language, if used correctly. On this, Gee, (1996) comments that a socio-cognitive approach contributes to provide language learners a mean to interact in an authentic social context. Pensky, (2002) suggests that online games provide support to improve various vocabulary fields and can be effectively used to give valuable feedback within language learning paths. Young, (2013) highlights that games help students raise their language awareness and encourage successful language learning. Introducing technology into the learning process can rise students' engagement levels and enhance self-directed and autonomous strategies (Lai et.al., 2013).

1.3 Technologies in use and learning approaches

Although available statistics about the implementation of technologies in the education context mostly report about the availability and use of connectivity and devises, such as PC and mobile devises, the literature concentrate on the use and impact of a specific technology of interest, largely acknowledging the technologies potential to support learning. Several research findings, in fact, report that the use of ICT in educational context can affect subject-specific teaching strategies with impact on students' motivation, engagement, concentration on, efforts in, and attitudes towards the subject.

PISA 2021 ICT Framework indicates that the types of ICT resources for learning can be classified as: **digital content for learning**, which includes online courses, digital books and multimedia resources (for the most part, it fits into "semantic learning material" Bundsgaard & Hansen's (2011); **communication and tracking tools**, which facilitate communication among schools, parents and students (and as such could be considered as "functional learning materials"); **virtual learning environment and intelligent tutoring systems** aimed to help students practicing particular skills, thanks to more "didacticised learning materials" Bundsgaard & Hansen (2011). Creating and applying digital contents is considered meaningful in relation with the impact on students learning, but the success is mostly dependent on teachers' digital literacy skills (European Commission, 2020). Nevertheless, evidences from TALIS indicate that the use of ICT for teaching was infrequently included in the education and training of instructors and educators. On average in the EU, fewer than half of all teachers (49.1%) report that ICT was part of their formal education or training. Considering teachers who recently completed their training, a higher percentage is registered, but ICT skills for teaching remains one of the area where teachers say they need more training: 18% of teachers in the EU reported a 'high level of need' for ICT training, surpassed only by strategies of 'teaching students with special needs'. On average in the EU, only 46.9% of teachers report that they frequently or always let their pupils use ICT for projects or class work (European Commission, 2020).

1.3.1 Flexible, ubiquitous, and personalised learning applying blended technologies, mobile applications and blogs

E-learning technologies are currently widely used in higher education, and as a result of recent COVID 19 constraints associated with distance education, they have also entered primary and secondary education with alternatives such as web platforms, video conferencing, e-books, MOOCs, online simulations, text messaging apps, wikis, podcasts, blogs, and social networking tools (Silverstone et. al., 2009). Certainly, the degree to which information is obtained in an e-learning environment influences student learning (Fernandez-Luna et. al., 2008, Willis, 2007). The challenges and benefits of e-learning are discussed in many articles (Altuna & Lareki 2015; Bouhnik & Marcus 2006; Liaw et. al., 2007; Shah & Barkas, 2018), and a common thread runs through the research: the main benefit of e-learning technologies is to rise student engagement, as a positively perceived learning experience increases motivation and engagement (Hewitt & Stubbs, 2017; Shah & Barkas 2018;). In addition, engaged students perform better (Trowler, 2010). Students who are able to find their own meaning of using e-learning technology, can benefit the most (Yusuf & Al-Banawi 2013), as it provides a good opportunity to develop materials, self-determine the learning process, and interact effectively with peers and tutors by receiving instructions and feedback within a learner-centred teaching style (Fhiter et. al., 2017).

The large diffusion and prevalence of mobile devices in education, led the research on **mobile learning** rapidly increasing (Hung & Zhang, 2012; Hwang & Tsai, 2011; Wu et al., 2012) and reviewed (Alsharida, et. al. 2021; Cheung & Hew, 2009; Liu et. al. 2014; Mannheimer Zydney & Warner, 2016; Qureshi et. al. 2020; Wu et. al. 2012;). Cheon et. al. (2012), identified three types of pedagogical approaches using mobile devices, namely individualized learning, situated learning and collaborative learning. Individualized learning enables the learners to practice at their individual pace and customizing the learning objectives; situated learning focuses on the usage of mobile devices to connect the learning paths to an authentic context; and collaborative learning stresses how mobile learning assists the learners to maintain an interaction with peers (Cheon et. al., 2012). Some reviews focus on specific aspects of mobile learning, such as **blogs** (Chawinga, 2017), **mobile learning games** (Avouris & Yiannoutsou, 2012; Schmitz, Klemke, & Specht, 2012), mobile computer- supported collaborative learning platforms (Hsu & Ching, 2013), or **mobile apps** (Jeng, Wu, Huang, Tan, & Yang, 2010) demonstrating how the introduction of such tools stimulates positive feelings towards learning and impacts positively on students motivation (Hsu et. al. 2013; Lin et. al. 2014; Klimova, 2019; Preston, 2015; Schmitz et. al., 2012). Of course a higher attention should be paid on the contents used, as to date, little empirical findings support the proposition that technology itself, rather than the content, bring improved educational outcomes (Biancarosa & Griffiths, 2012).

Tablets and handheld devices support flexible, ubiquitous, and individualized learning opportunities that upkeep literacy development, and support achievements in mathematics, social sciences, etc. (Banister, 2010) and are numerous the software applications available. Several studies report in what way mobile devises can be successfully used to enhance numeracy skills (Jowett et. al., 2012), or communication skills of learners with developmental disabilities. Kagohara et al. (2013) and others report how such technologies successfully reduce challenging behaviors (Neely et. al., 2013), but mobile technology and mobile learning (or m-learning) are attracting a considerable attention in particular in the field of L2 instruction (Chinnery, 2006; Kukulska-Hulme, 2009; Kukulska Hulme & Shield, 2007; Nuraeni, 2021; Qureshi et. al., 2020; Polakova & Klimova, 2022; Saran Seferoğlu, 2010; Stockwell, 2010, Sung et. al., 2015;). Mobile Assisted Language Learning (MALL) has been widely recognized as providing "portability", "social interactivity", "context sensitivity", "connectivity" and "individuality" for language learners (Godwin-Jones, 2011; Miangah & Nezarat, 2012), nevertheless many questions regarding the appropriateness of the content and pedagogical approaches of some apps remain open (e.g., Philip & Garcia, 2014). Regarding the pedagogical assets that mobile devices can bring into education, most research focused on apps as content-delivery tools, (Yao et. at., 2016) while some explored the mobile devices role reinforcing motivation and strengthening leaning engagement, and others, to a lesser extent, investigated the impact on learning outcomes specifically considering the relevant factors influencing the learning process. Certainty, the contents interactivity, the dynamics of representation, the synchronous interaction, that apps and blogs provide, offer further multi modal affordance in creating attractive content representations and collaborative tasks, engaging learners in knowledge exploration, fostering the learners' reflection and willingness to take responsibility over their learning (Calder & Campbell, 2016; Stewart et. al., 2011). However, the theoretical foundations underlying mobile learning research should be further examined, to inform the design of the mobile apps and contents, and to ground it more in the educational practice, with the objective of supporting the assessment of students' higher-level cognitive outcomes, cognitive load, and skill-based outcomes (Cheung & Hew, 2009; Zydney, 2016).

Analyzing further the research reviews focusing on effectiveness of using mobile devices in education, it transpires that most of the studies implement a qualitative approach, which surely allows to detect the main challenges associated with the tools adoption, but constrains a deeper evaluation of the effects produced by the specific moderator variables (Sung et. al., 2016). In relation to the higher education context, for instance, the research suggests that the technological progresses of mobile devices and the increased availability of mobile apps can be a key for the innovation of academic teaching models and research methods (Canuel & Chrichton, 2015; Hahn, 2014), nevertheless the studies related to integration of mobile technology in higher education focus mainly on the delivery of information or selection of data for library services, or the use of mobile apps within the classroom environment (Hennig, 2014; Hinze et. al. 2017), rather than on their application in the context of the research process, or the implication that ICT adoption can have on the methodology (Hinze et. al. 2022; Morris et. al.,2016; Schepman et. al.,2012;).

Some researches focusing on using **blogs** attempted to ground the theory into the pedagogical practice analysis, reporting about how such tools offer a great support to school students' autonomy and interaction with peers and instructors, promote collaborative participation in creating and managing content, improve the quality of multimedia teaching and learning processes (Álvaro-Tordesillas et. al., 2020; Campillo-Ferrer et. al. 2021), enhancing student-centered learning and teaching process, and supporting progresses in the educational outcomes (García et. al., 2014; Jacobs, 2004; Poore, 2013, Tammets, 2010; Tammets et. al., 2000). Liao et. al. (2013) attempted to further investigate the motivation factors influencing students' engagement, in relation with the impact on learning outcomes when blogging, and identified three types of elements, namely utilitarian (i.e., perceived effectiveness), hedonic (i.e., perceived enjoyment) and social identity (i.e., group distinctiveness). Analyzing the use of edublogs as learning tools from the students perspective, Martín Montilla and Montilla-Coronado (2016) highlighted their value as motivating resource for self-expression, communication and autonomous learning, posing the accent on the fact that that they offer the possibility to link the educational contents with personal experiences. Similarly, Pérez-Nevado et. al. (2012), focusing on the perceived usefulness of edublogs to stimulate communication, reported a as key factor, the flexibility that such tools provide to students in expressing their ideas and thoughts on educational issues. Along these lines, Pardo-Baldoví et. al. (2020) emphasized that students motivation in using blogs is grounded on the possibility to share resources and information that they could use in their future professional career. Campillo- Ferrer et. al. (2021) findings showed that the use of blogs facilitate students to develop their digital literacy, enhance their social and civic skills, and rise their self-perceived motivation (Campillo-Ferrer et. al. 2021). Ifinedo (2018) examined the factors influencing students' continuance intention to use blogs to learn, and applied constructs from relevant theoretical frameworks, including the Technology Acceptance Model (TAM), Social Cognitive Theory (SCT), Innovation Diffusion Theory, and Expectation–Confirmation Model (ECT), showing that perceived usefulness and perceived compatibility have positive effects on students' attitudes towards using blogs. Furthermore, the author established that attitude and satisfaction are determinants of students' continuance intention to use blogs, introducing further the attempt to determine the impact on learning outcomes.

The analysis of the empirical research conducted by Sung et. al. (2016) on the use of mobile devices as tools in educational interventions, include studies that considered the impact on learning outcomes and applied different durations, combinations of hardware, ages of users, implementation settings, teaching methods, and domain subjects. The authors reveal that the overall effect of using mobile devices in education is greater than when making use of desktop computers, or when not using mobile devises. Their publications further disclose that the use of mobile learning is more effective if deployed in an inquiry-oriented learning approach, or game-based learning approach. In particularly short-duration interventions, and in the informal educational environments, mobile learning results effective to enhance self-directed study and cooperative learning. These findings contribute to set guidelines regarding the effective implementation of mobile devices in the learning environment, but highlight that more elaborate instructional design developments, and pedagogical frameworks, are needed to facilitate the investigation of the impact of apps on learners learning outcomes. The present study attempts to take the most form these findings, selecting a mobile application whose contents were co-designed with educational practitioners and students to adhere to learning activities and goals part of the daily practice.

1.3.2 Situated and scenario based learning, the potential of serious games and simulations

The education sector's interest in experimenting with mobile technologies to support learning, has led the research in this area to investigate the impact of using mobile applications in teaching and learning, which has empirically confirmed the positive value of apps in terms of impact on learners' motivation and engagement. Indeed, all studies that focused on subjects specific learning outcomes, confirm how motivation and engagement positively influence learning achievements. Exploiting this potential, app development has been increasingly oriented by gamification elements. Gamification involves applying game dynamics to the educational mobile application, in order to influence behavior, stimulate engagement, and increase motivation in performing a task or achieving a learning goal. Gamification provides opportunities to simulate case scenarios that imitate the real world (Curtis, 2012), creating highly interactive, and dynamic scenario-based learning environments, that employ aspects of gaming (Westera, 2008), allowing players to interact, experiment, and manipulate variables (Prensky, 2001), introducing a ludic aspect into the learning experience. Scenario-Based Learning (SBL) provides meaningful learning experiences by engaging students in authentic environments to support reflective practices and active learning in a real-world problem and in a subsequent solution finding process (Marocco et. al. 2019). Playing activates an engaging learning experience, and it is an important mediator of learners socialisation with experience and knowledge acquisition, in which the participants voluntarily invest while deriving enjoyment (Prensky, 2001). Serious Games design embeds the effective principles of the Game Theory, effectively combined with the Social Learning Theory approaches, which facilitate the easily absorbing of knowledge through role play, and keep learners engaged (Cheng et al. 2013; Li, & Tsai 2013) in the educational experiences, with a view to achieving specific learning goals and outcomes (Cheng et. al., 2016).

Serious Games scenarios consist of real life fictional situation in which learners play a role in a position of conflict, confrontation or collaboration with each other (Sauvé et. al., 2005), based on a structured storytelling, managed by mathematical rules varying the degree of difficulty through which learners progress overcoming obstacles, finding solutions to become victorious, all while learning. Educational games promote logic, skills development, and knowledge acquisition, in a thought-provoking and pleasant way that lets students learn while being engaged in an entertaining situation (Maragos & Grigoriadou, 2005). In particular, when the dynamics interaction between the player (input) and the system (output) is enjoyable, and implemented on previously acquired information and gained experiences (Anastasiadis et. al., 2018; Rossiou & Papadakis, 2007;), the leaners immersion in the game flow results increased, as the leaner focuses on the goal, and feels gratified in performing a task (Galetta, 2013). Educational games embed a constructivist learning environment, considered productive for an engaging and meaningful learning (DeKanter, 2005; Kiili, 2005), as they are suitable to be designed to include futures that enhance curiosity, fantasy, role-playing tasks, rules, goals, challenges, competition, control, fun, motivation, interaction, adaptability, feedback, and multimodal presentations. Such futures promote excitement, interest, engagement and the feeling of accomplishment, but most of all allow to embed educational objectives, and subject related contents in the game scenarios, to support learning achievements applying a more student-centered and motivating approach (Cheng et. al., 2013; Malone, 1980; Huang & Johnson, 2008; Papastergiou, 2009; Prensky, 2001; Woo, 2014). Furthermore, serious games are defined as an excellent tool to facilitate situated learning, and support experiential learning, besides promoting innovative thinking, cooperation and problem solving skills, as for their real life scenario based characteristics (Gee, 2005; Prensky, 2001). In fact, the game mechanism of challenge, keeping engaged, and reword, enhancing satisfaction and motivation, are key factors in captivating students' interest and enhancing their learning ability and performances. Such dynamics can facilitate the understanding of abstract concepts and word meanings, as well as their representation in the social context, also supporting the learners feeling of control of their own learning path (Burguillo, 2010; Erhel & Jamet, 2013; Yee, 2006). Activating the attention mechanisms in problem solving, playing stimulates new ideas and creative or unconventional solutions, fosters concentration and retention of information and knowledge. Furthermore, the problem-based game scenarios allow the learner to actively experiment and critically reflect on the consequences of choices and behaviors in a safe environment (Gee, 2007; Li & Tsai , 2013), Within the scope of situated learning theory (Cobb & Bowers, 1999; Lave & Wenger, 1991), the scenario based learning is one of the current approaches that reinforces meaningful contextualization of learning contents with real life situations (Yetik et. al., 2012). Scenario based learning forms a prospect for learners being more active and responsible in determining the learning path, and improving skills applicable to real life situations (Sorin, 2013). Scenario based learning helps bridging the gap between theory and practice (Errington, 2011;) as it allows connections with the real world, so that learners could challenge themselves in future encounterable situations (Sheridan & Kelly, 2012).

The demonstrated value of serious games as effective tools supporting learning, provides a concreate background to consider their use as a medium to implement a technology enhanced pedagogy. This assumption, is promoting several subjects' specific studies, that do not only keep particular attention on the elements influencing the impact on students learning outcomes, but also critically test the digital game-based learning approaches that embed curricular contents and goals within the development of app contents. The present study moves from such considerations selecting a game based mobile application that engage learning in the exploration of real life scenarios.

1.3.2.1 The possible uses of learning analytics in the context of gamified learning experiences

Gamification is based on the contribution of several disciplines, including human-machine interaction, computer graphics and animation, cybernetics, AI, etc., that are correlated with the leaner interaction with the system device and content, and affect the modalities of learning and knowledge acquisition. Today’s technologies allow to track the user's choices through metrics and analytics systems, which not only influence the student behavior, but allow to monitor, and analyse, the interactions, to provide feedback, in some cases in form of personalised changes in the game path. This allows to engage the learner into an experience, simulating a real file scenario, and permits to provide the leaners with the opportunity to influence the course of the game, experiencing the impact of different interaction choices. The structure of the game, competition based, tasks oriented, problem solved oriented, generates measurable game behaviors, so every interaction is the result of a chosen action, that can be monitored and tracked obtaining quantitative data through metrics and analytics, to be transformed into deployable real time instant feedback. Furthermore, such data can be used to predict the leaners course of actions, permitting to influence them throughout the game path. The use of adaptive learning supported by learning analytics, is today, largely proposed as a strategy to support student centered, and personalized learning processes. Data mining techniques are offering several important opportunities in the education field (Aldowah et. al., 2018; Banihashem et. al., 2018), as means for measurement, collection, understand of data, related to the learner behavior in the context of the learning scenarios (Ylmaz, 2021). Learning analytics can support monitoring the learning performance, detect learning difficulties and emotional states, facilitating a learner-centered approach and the personalisation of follow-up learning strategies based on data results (Wong, 2017). Such systems can convey a real-time feedback to students about the correctness of the performance, improving in this way the academic success and motivation (Di Serio et. al., 2013). Although there is, so far, little transfer of the research results to the real educational context (Ruipérez-Valiente, 2020), to confirm the effectiveness in real educational context; the advantages that learning analytics can bring into the learning approach seem meaningful (Ifenthaler & Yau, 2020). In particular, if considering the opportunities in terms of tracking learners' performance, predicting and evaluating outcomes to deploy a more formative assessments of learning (Guzmán-Valenzuela et. al. 2021).

To conclude, it should be highlighted, that to create effective interventions in real education contexts, it is necessary to formerly investigate the modalities and effects of students' interaction with the learning analytics tools (Ifenthaler & Yau, 2020; Jivet et. al., 2020), and consider those aspects in relation with pedagogical approaches and learning stretegies implications (Fernández-Morante et. al, 2022; Larrabee Sønderlund et. al., 2019; Liu et. al., 2021).

1.3.3 The implications of engagement and motivation on learning outcomes, the value of Virtual (VR), Augmented (AR) and Mixed Reality (MR) in education

Panke (2016) highlights some important developments in educational technology: bring own device, learning analytics and adaptive learning, marker spaces, virtual reality and augmented reality, active computing and robotics.

Virtual Reality (VR) can be generally defined as computer-generated simulation of a realistic experience. Currently widely used in gaming (Meldrum et. al., 2012;), and applied particularly for simulations in the context of military training (Alexander et. al., 2017), surgical procedures (McCloy et. al. 2001), and assistance or diagnosis in psychological treatments (Freeman et. al. 2017), in other fields such as education (Ahn et. al., 2017; Hamilton et.al. 2021; Hew & Cheung, 2010; Kavanagh, 2017), as well as learning and social skills training (Gillies et. al. 2019), is only recently becoming object of exploration.

The attempts to introduce VR solutions in the education context are frequently driven by the opinion that such systems can enable innovative teaching methods, supporting deeper learning experiences compared to traditional approaches, as they provide learning environments where learners explore and experience scenarios resembling models of the real life world (Chung, 2012; Cipresso et. al., 2018) This hypothesis raises from the records acknowledging that VR stimulates interactivity, enjoyment (Hudson et. al., 2019; Zhang et. al., 2019), and motivation (Cheung et. al., 2013; Jacobson et. al., 2005). Several studies report positive findings about the strengthens of Augmented Reality (AR) to provide live, and absorbing learning environments, that enhance long-term retention (Huang et. al., 2010; Rizzo et. al., 2006), and learning performances (Lu & Liu, 2015), particularly in the case of learners preferring a visual, auditory or kinesthetic learning style. Chiang et. al., (2014) and Chien et. al. (2010), highlight, in fact, that AR systems support the possibility to learn visualizing and acting on composite phenomena, that traditionally students study theoretically, without the possibility to see and test in real world.

Augmented Reality is a VR related concept, but instead of reframing the reality, in AR the computer-generated content is linked or embedded into the real world experience, so that both can be experienced together. AR tools have the potential to support a better understanding of concepts through learning activities based on inquiry, as they fill the gaps between real-world situations and abstracts concepts using simulated modeling, and allow to link real-world content with digital learning sources at the right place and time (Cahyono et. al., 2020; Poçan et. al., 2022). Inquiry-based AR activities have great potential in education and encourage cooperative and autonomous learning (Martin-Gutierrez et. al., 2015), arising opportunities for novel experimentations in this field. AR is in fact a more recent technology than VR, but is has been investigated and used in several research areas such as architecture, engineering, construction (Chi, 2013) and entertainment (Hung, 2021). AR is still emerging in the scientific scenarios related to education, even if it shows a high interdisciplinary potential as a tool supporting learning (Bacca et. al., 2014; Delello, 2015; Nincarean et. al., 2013). For instance, extensive review of Akçayır and Akçayır (2017), Chen (2017), Merchant et. al. (2014), and Slater and Sanchez-Vives (2016), report evidences about VR application weakness and advantages, in the context of several research areas, including education, highlighting that is especially powerful in the teaching of mathematics and to train visual-spatial abilities. Analyzing the reviews, a relevant number of papers refer to university or pre-university learning, with particular attention to the teaching of scientific subjects (physics, astronomy, chemistry, etc.). Another area in which AR seems to be widely explored is adult training. Referring to both university education and adult training, the results show a significant percentage of papers reporting applications in the medical fields at different levels. Regarding school education, not many experiences have been reported, very little concerning young children and in the field of disability, apart from the research conducted by Standen et. al. (2001). However, existing research demonstrate that AR applications are effective at multiple level of education, and that students appreciate them (Huang et al., 2010).

The definitions of VR and AR although dissimilar, report some communal features: immersion, perception to be present in an environment, interaction with that environment and narrative (Ott & Freina, 2015; Slater, 2009). **Immersion** concerns with the stimulation of senses, with the interactions modalities, and the similarity of the stimuli with the real word. Jennett et. al. (2008) associate the concept of immersion with the notion of involvement in the play, which produces lack of awareness of time, and of the real world, as well as a feeling of “being” in the task environment. The perception is created by surrounding the user with images, sound or other stimuli, that provide a very absorbing and perceptually convincing environment. These affordances support a novel approach to learning, by inferring meanings from the experiences within virtual reality, combined with previous background skills (Kavanagh, 2016).

Although not successful from a commercial point of view, the studies conducted in educational context using AR and VR prototypes, undoubtedly confirm that such technologies promote leaners enjoyment (Ferracani et. al., 2014) and motivation (Akçayır & Akçayır, 2017; Cheung et. al., 2013), when compared to non-AR experiences. Certainly the elements of curiosity, fantasy, and control, presented by AR, have the potential to trigger emotional commitment towards a learning activity. Nevertheless, motivation and enjoyment are construct related to several other factors, and the study of these variables requires a deeper analysis that will be presented later in chapter two.

The richness of virtual and augmented reality is particularly evident when learning requires abstraction and high problem solving abilities, as VR and AR triggers the visualization abilities thanks to the simulation mechanism, and support the capacity to perceive, imagine in a creative sense, assisting the mind's capacity to conceptualize things, with the ultimate result of reducing the cognitive load (Burdea & Coiffet, 2003). Technologies as such, also strongly support collaboration, as they allow learners to be connected with peers and instructors in real time, being simultaneously aware of the others actions, and active part of a discussion, while sharing several contents and materials at the same time (Cheung, et. al. 2013; Ferracani et. al. 2014) and receiving immediate feedback from their tutors.

The majority of the studies focusing on AV and VR are grounded in the constructivist pedagogy, as the interaction with such educational systems encourages active learning, and triggers learners' responsibility on generating meaning and construing knowledge (Huang et. al., 2010). The constructivist learning paradigm, suggests that learners actively, and continually, build their own subjective representation of reality, based on the interaction between their ideas, and the experience they trial (Dewey, 1985; Huang et. al., 2010). A **meaningful learning experience** allow the learner to reflect upon, and contextualize, building a personal representation of the situation incorporating new information into pre-existing knowledge. (Dewey, 1985; Huang et. al., 2010). This is preferable to traditional and more passive approaches. and most of all. it should be noted that simulated explorations in virtual environments are a successful mean to provide leaners with the prospect to experiment infeasible interactions. which would otherwise be impossible.

Despite these encouraging results, VR and AR systems miscarried to achieve extensive implementation in education, probably because of several jeopardizing factors. Apart from the costs associated with technical equipment, and the training constraints connected with teachers confidence adopting new methods and tools, AR and VR systems usability can be found in the literature as the most frequently mentioned issue, either related to interface design, interaction quality, or readability (Hsieh et. al., 2010). Likewise, usefulness, which refers to the effectiveness of the system to fit the purpose in relation to the educational context, is often mentioned as encompassing issues connected with lack of students' engagement. This is most frequently described in the form of 'boredom' expressed by students (Hsieh et. al., 2010), and recalls the attention on the fact that, the novelty of using VR for education, can reduce the probability for boredom, but anyway a poor educational design (even within VR) can still result in a lack of engagement (Allison & Hodges, 2000). Furthermore, despite the fact that much of the literature analyzed seems aiming to inform the design of strategies for the use of VR in education, very few studies appear grounded in a solid pedagogical reasoning, while it is crucial to investigate how VR and AR features can bring pedagogical benefits. Lee et. al. (2008), for instance state that, a broad framework identifying the theoretical constructs, or participant factors and their relationships in the particular educational domain, should be developed further, in order to capture the role, they have, in determining the learning process and learning outcomes. Sanchez et. al. (2000), about this, conclude that investigating the characteristics of the applicable use of VR in education, is an open and challenging task.

It is in fact difficult to find a reference model in the literature that allow to investigate how VR or AR influence the learning process and learning outcomes. Some models, as in the case of Lee and Wong (2008), Salzman et. al. (1999), Shang et. al. (2006), Winn (1993), provide a useful guidance for developing VR and AR learning environment capable of improving the quality of student learning. Designing features that are appropriate to support the learning process, is indicated as a mean that might help investigating the relevant constructs or factors influencing the learning process. More in details, defining how interfaces should be designed to support usability, might allow to investigate on the role of individual characteristics in VR/AR environments. Setting learning goals and interconnected learning activities as a starting point of the instructional design process, might support the investigation of the psychological learning process involving the learners. Salzman et. al. (1999) highlight, in fact, that before developing an immersive VR learning environment, it is important to determine the concepts to be learnt, because VR's features might support the learning of one concept, and at the same time hindering the learning of another. Wiley

(2000) attempts to connect the concept of learning objects to instructional design and presents three components of a successful learning object implementation: an instructional design theory, a learning object taxonomy, and "prescriptive linking material" that connects instructional design theory to taxonomy, providing such guidance as "for this type of learning goal, use this type of learning object." A recent model developed in the context of the MaTHiSiS H2020 project seems a possible guideline for the implementation of learning scenarios that allow to investigate the variables that influence the learning outcomes by monitoring the learning process, particularly as it further attempts to solve the issue about the granularly of the learning object from an instructional point of view as a problem of scope. This model in fact introduces the definition of Smart Learning Atoms (SLAs) as the smallest complete pieces of knowledge, competence and/or skills, which cannot be further reduced to more primitive notions, and that can be learned and assessed in a single, short-term learning process iteration from a learner[2].

1.3.4 Embodied cognition and transformation of the learning experience applying Tangible User Interfaces (TUIs)

Sherman and Craig (2003), classify immersion into mental, and physical (or sensory), both contributing to the experience. Milgram and Kishino (1994), suggest that when Augmented Reality exists along a continuum between the real and virtual worlds, gives rise to "mixed reality". Skarbez et. al. (2021) define Mixed Reality (MR) as an environment in which virtual world and real world objects, and stimuli, are presented together within a single percept. This concept introduces the idea of an experience in which the learner perceives simultaneously, and across different senses, both real and virtual contents. This, add the opportunity to enrich the user experience, involving visual, auditory, and haptic cues, by using functionalities that allow the leaner to navigate and control objects in the artificial environment. This shift in the user interaction is concretised computationally coupling physical objects, and digital data, or more precisely embodying the interaction with virtual contents into physical objects.

In 1995, Fitzmaurice et. al. introduced the concept of a "Graspable Interface", Hiroshi Ishii in 1997 presented the notion of "Tangible Bits", as concrete ways to bridge the gap between cyberspace and the physical environment, by making digital information (bits) tangible. Well known commercially distributed Lego Mindstorms TM, Lego/Logo robotic construction kits are

[2] Managing Affective-learning THrough Intelligent atoms and Smart InteractionS (2017). D3.1 The MaTHiSiS Smart Learning Atoms http://mathisis-project.eu/sites/default/files/mathisis/public/content-files/deliverables/MaTHiSiS%20D3.1The%20MaTHiSiS%20Smart%20Learning%20Atoms.pdf

“Digital Manipulatives” (Resnick et. al., 1997; Zuckerman et. al., 1998) that evolved from the MIT Media Lab research, to build educational computationally enhanced versions of physical objects, with which children can explore concepts while playing. All such examples acknowledge that computation is becoming embedded and embodied in physical objects, and that such tangibles become the user interaction touch point with the system. Furthermore, user interaction gains a physical characteristic and potentially become multisensory enhanced, using an integrated physical-virtual device. The contents navigation is tangible and manipulable, supporting active “doing” rather than just observing. When such “smart objects” are enriched with smells, textures or thermal characteristics, the sensory stimulation contributes to support a multisensory perceptual experience. Such concepts share three characteristics that Dourish discussed in 2001 under the term “tangible computing” (Dourish, 2001) when mentioning that there is no single locus of control or interaction. Instead of just one input device, there is the possibility to include coordinated interoperable different devices, and objects, as interfaces at disposal for the user interaction. The sequencing of actions is not enforced, but it can become multimodal. Furthermore, the opportunity to design the objectives used as interfaces, allow the use of affordances to guide the user performance.

Nowadays, human-computer interaction frameworks, define the key characteristics of “Tanbigle User Interfaces” (TUIs) as concerning with notions focusing on representation and control: tangible interfaces give physical form to digital information, employing physical artifacts both as representations and controls for computational media (Ishii & Ullmer, 1997). The framework conceived by Koleva et. al. (2003), extends the understanding of TUIs, by considering the different ways in which physical and digital objects can be computationally coupled, focusing on the configurability of the coupling and mediated effects, introducing the concept of coherence continuum, where the level of coherence characterizes the extent to which connected physical and digital objects might be perceived as being the same thing. This point of view opens the reflection on the different ways in which this link may be manifest, and about the transformation effect this could have on the user experience. An example is the magnet tool in the “Surface Drawing System” (Schkolne et. al., 2005), which changes the meaning of the drawing action by altering the existing geometry. Waving the magnet near the region of a drawing pulls that region closer to the magnet.

Focusing on the notion of reality-based interaction, Jacob et. al. (2008), suggests an observation on the interaction styles with the real world, identifying four styles that are typically leveraged: na¨ıve physics, that qualify human common sense knowledge of basic physical phenomena; body awareness and skills, consisting in people awareness of their body and capacity to control and coordinate it; environment awareness and skills, meaning the awareness of surrounding people and environment; social awareness and skills, outlining the consciousness of sharing the environment with and the skills of interacting with. Active interaction and experimentation of situations is fundamental in the learning process, as it triggers competences and knowledge acquired in similar contexts in the further development of knowledge, as part of a situated dynamic process of thinking, problem-solving, and perceiving, in the context of the social environment and related actors and objects (Dewey, 1993; Glassman, 2001; Kolb, 1998; Lave & Wenger, 1990). Learning is a process of personal construction of meaning by the learner through experience, and this meaning development is influenced by the scaffolding of prior knowledge with the reflections activated during a new current experience, depicting both cognitive and emotional information from several sources: visual, auditory, kinesthetic, and tactile (Coulson & Harvey, 2013; Mazzucato et. al. 2020).

These considerations open a further reflection on the way the information of the digital word are fed into the physical world and contrariwise in a system applying TUIS, and additionally about how reality based interaction can impact on the construction of the experience, particularly a learning experience. Regarding the first point, these augmented physical objects function not only as input devices, but also as outputs, and closely related temporally and spatially, providing users with parallel feedback loops. The action of the user on the object sends information to the system for processing, but the object also receives, reproduces or displays the results of that processing out to the user. This is the embodiment dimension of Fishkin taxonomy, classifying TUIs (Want et. al.1999) that describes how “close” modalities of input are tied to output (with the scale ranging from “distant” of “environment” and “nearby” to “full”, where e.g. “nearby”). An example that seems appropriate as playful learning interfaces is presented in figure 1, and it is called the Learning Cube (Terrenghi et. al., 2005): a cube augmented with embedded sensors and LCD displays placed on each face, on which the interaction operated by the user, is to turn the cube to the side with the right answer, and then shake it. If the right site is selected, the program moves on to the next question; if not, the user can try again.

Figure 1 The Learning Cube (source Terrenghi et al., 2005)

From this prospective, TUI) represent a system embodying the interaction with physical objects that store knowledge, either in form of digital contents. or in form of metaphors that build connections with real world skills and experiences. The concept of metaphor used in Fishkin (Want et. al 1999) taxonomy classification of TUIs, and further proposed by Koleva et. al. (2003), is strongly related to the positive effects on the resulting interface, and it is suggested as key element to be considered for future successful TUIs design guidelines (Oppl & Chris Stary, 2011). In fact, the analogy between the tangible object, the action performed with it, and the concept and procedure the user might have previously experienced, is fundamental in the process of exploration that guides the interaction with the system. Possibly, the more the tangible objects evoke in the appearance the elements of the user's real word, the more the user will be guided to behave in accordance with the real life situation that the object recalls.

A similar distinction between "representation" (appearance) and "behavior" (usage), included in the TAC-Approach for TUIs specification (Shaer et. al., 2004), provides a starting point for considering metaphors importance during TUIs design, as it seems that using mental models in human-computer interaction design increases the usability (Gatsou, 2015) of the system. This interpretation takes incentive from Johnson-Laird (2010) vision of mental models as a form of knowledge representation, also referred to, as sets of conceivable representations of the available information, the manipulation of which triggers the reasoning. Erickson (1990) furthermore follows-up mentioning that metaphors "*function as natural models, allowing us to take our knowledge of familiar, concrete objects and experiences and use it to give structure to more abstract concepts*" while Carroll et. al. (1998) propose that the metaphor approach "*seeks to increase the initial familiarity of actions, procedures and concepts by making them similar to actions, procedures and concepts that are already known*".

In accordance with this input-output double function, that seems highly correlated with the process of re-enactment of real life situations. Markova et. al. (2012) review, adds an additional criterion within TUI definition, consisting in "continuity". This concept claims how TUIs support and call the user to interact further with the system beyond one initial input, providing a response that attract a further action. As Hornecker and Buur (2008) framework suggests, the direct manipulation of material objects that represent an interest, can invite the users to interact conversationally, by appealing to the sense of touch, providing sensory pleasure and playfulness. Creating legible relations between the cause and the effect, in the process of objective manipulation and information processing, certainly impacts on the acceptability of the system. Marshall et. al. (2003) outline exploratory tangibles as models that users try to understand, while expressive tangibles represent tools that allow the learners to create their own representations. Broadening the reflection on TUIs, emphasizing the opportunities for expressiveness and meaning of bodily movement, over the physical device employed to generate "data" processing, allows to think about how the design of TUIs can influence the level of contextualization of the experience in relation with in real spaces and social contexts. Body movement, and spatiality, are inherent properties of tangible interfaces, in fact TUIs are embedded in space, take up real space, are situated in a social context, and users need to move in real space when interacting with, so the body movement results as an integral part of the experience interaction (Dourish, 2001; Hornecker & Buur, 2006). Hornecker et. al. (2008) assert that manipulating tangible objects exploits intuitive human spatial skills. The spatial nature of tangible interfaces can support perceptual inferences, in particular when reading transitive, symmetrical, and asymmetrical relations. Not surprisingly, one of the research areas in which TUIs are applied, is related to the sensorimotor domains, and many studies confirm that TUIs are a valuable tool for training skills in this field, particularly in the context of special needs. Kim and Maher (2008), for instance, conducted a comparative study of Graphical User Interface (GUI) and TUI for a design task, and confirmed a clear benefit of TUI on promoting visual-spatial abilities. In this area, a more recent development is related to the application of TUI's supporting learning for children with special needs. Topobo (Raffle et. al. 2008) construction kit, presented in figure 2, is an example of tool supporting perceptual-motor skills training, providing sensorial experience and supporting collaboration.

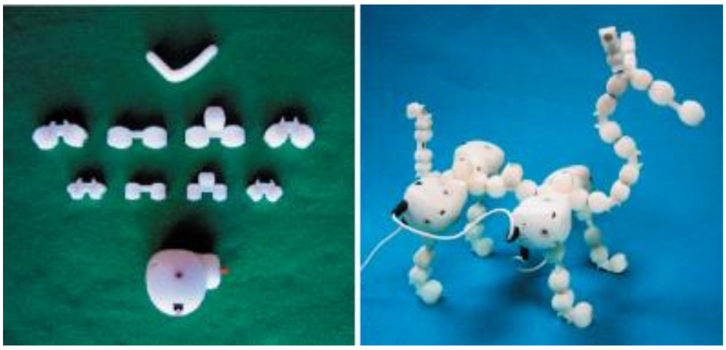

Figure 2 Topobo system (on the left) and an animal creation (on the right) (Source: Raffle et. al., 2008)

Jacob et. al. (2009) further suggested that grounding the interaction on preexisting skills, and knowledge from the non-digital world, results in a mental effort reduction between users' goals for actions, and the means to execute those goals (Norman, 1999; Shaer & Jacob. 2009). Furthermore, studies acknowledge how gesturing supports thinking and learning (e.g. Goldin-

Meadow, 2003; Nooijer et. al., 2013; Skulmowski & Rey 2003; Stieff et. al., 2016; Toumpaniari et. al., 2015). Price et. al. (2002) confirms the hypothesis that associating an unfamiliar concept with a tool that promotes a sense of familiarity, can stimulate creativity, inquisitiveness and reflection. The Child Tangible Interaction (CTI) framework (Antle, 2007) further highpoints how leveraging children's body-based understanding of concepts and spatial schema can provide positive learning opportunities. Taking advantage of the experimentations conducted augmenting toys to increase their functionality and attractiveness, TUIs dominant areas of application seems related to learning, and in particular oriented to support planning and problem solving, to reinforce information visualization and exploration, and to exercise social communication. These include, for example, Tinkersheets (Zufferey et. al., 2009), which supports learning about logistics, or Storymat (Ryokai et. al., 2009), presented in figure 3, a playable carpet where the learner detects RFID-tagged toys that are placed upon it and that can record and replay stories. The Kidstory project (O'Malley & Stanton, 2002) tags children's drawings with wall projections, so children can interact and navigate the story physically. Ely the Explorer (Africano et. al., 2004), presented in figure 4, is also an interactive play system that mixes touch-screen technology, tangible toys, and RFID-tagged cards, to support collaborative learning about geography and culture, while practicing basic literacy skills. Related to literacy education, WebKit, (Kabisch et. al. 2005) allows to augment cards tagging on line contents on which learners can then walk across.

Figure 3 Two children playing on the StoryMat (Source: Ryokai et. al 2009)

Figure 4 Ely the Explorer - Exercise 2: RFID tagged cards (Source: Africano et. al 2004)

Evidently, a convincing application for TUIs, in educational and learning contexts, is **storytelling**, proved to be successful for the development of high cognitive processes, such as thinking, reasoning, or learning. It supports the ability to construct mental images, and involves learners in the discovery of concepts and expression of self-constructed meanings. Frequently evaluated in the context of language, memorization and reading comprehension, it supports collaborative, as well as autonomous learning (Ponticorvo et. al., 2017). As for their characteristics, TUIs provide the opportunity to tag into a physical objects a specific meaning (Miglino et. al., 2013) and augment it with sensory, auditory and tactile channels, that can enhance the learning experience (Di Fuccio et. al., 2018) making it more engaging and motivating. Furthermore, allow to situate learning within authentic context and culture, anchoring enquiry based activities to such "Smart Objects" that recall real-life experiences, enhance social connectivity, and trigger the emotional sphere.

Theories of embodied cognition embrace this view, that thinking of an object triggers the reproduction of the experience previously collected with the object (Barsalou, 2008; Glenberg & Gallese, 2012), relying on prior experience connected to the manipulating objects, moving around, eating and smelling things (Zwaan, 1999). In fact, neuroscientific studies reveal that handling objects, exploring spatial information, music, faces, flavors, odors, evokes sensorimotor responses, i.e., body-related activity in the brain (Pulvermüller, 2013). Barsalou's (2008) perceptual symbol systems framework, as one of the dominant theoretical approaches of embodied cognition, accounts that humans generate multisensory representations of their environment, and use their sensory neural structures when mentally imagining an object or action (Macedonia, 2019). Based on the embodied interpretation of human cognition, several studies in the field of education are recently involving multisensory processing to construct meaningful learning experiences (see for instance Koning & Tabbers, 2011). A valuable example is the Multi Activity Board (MAB) (Di Fuccio et. al., 2018), an active board where children can develop their multisensory story, using all the senses in order to learn some contents, by placing objects logically connected with smelling jars that contain a specific odor. STTory (Di Fucccio et. al., 2016), presented in figure 5, a tool for digital and multisensory storytelling, a hybrid physical/software tool that enhances traditional blocks and methods, for teaching in kindergarten and primary schools, composed by an active table able to recognize real objects, enhanced with smelling jars and tasting jars, using the RFID technology.

Figure 5 STTory hardware and software (Source: Di Fuccio et. al. 2016)

Much is also reported in the literature, about storytelling effectiveness as a pedagogical tool in the development of language skills in first (L1) language, and also in a foreign or second language (L2), irrespectively learners’ age or background (Cameron, 2001; Isbell et. al., 2004). In addition, experimental research demonstrated that action meaning is highly relevant in language learning (Cook et. al. 2006; Iverson & Goldin-Meadow, 2005;). This is explicable considering investigations centering the brain connections between language and action systems: hearing a word seems to be connected with activation of its articulatory motor program, and understanding an action word seems to bring an immediate and automatic thought of the action to which it refers (Pulvermüller & Friedemann, 2005). The articulatory perception–action loops might also be important as a cortical basis of short-term verbal memory (Baddeley, 2003). Similarly, the mirror neuron theory entails that action understanding arises from an association between the perceived actions of others and one’s own action control system, likewise the comprehension of action-related language seems to entail that words are mapped into the actions that can be self-performed (Pulvermüller, 1999).

Recently the use of digital stories is employed in studies examining the effects of storytelling on the language learning process and some experimentations are lately employing TUIs to develop prototypes supporting language, and culture learning, through embodied interaction (see Afrilyasanti & Basthomi, 2011; Atta-Alla, 2012; Chang & Yang, 2011; Sadik, 2008; Skinner & Hagood, 2008; Yang & Wu, 2012; Zheng et. al., 2011). Make a Riddle (Hunter et. al., 2010) teaches children spatial concepts and basic sentence-construction skills, and TeleStory is designed to teach vocabulary and reading by enabling children to influence a story. PageCraft (Budd et. al., 2007) associates tangible supports with text and multimedia contents displayed on the screen. EULALIA (Mazzucato et. al., 2020) proposes a technology enhanced learning tool providing multimodal communication and multisensory applications that transform the approach to language learning, immersing the player/learner in a simulated scenario that situate the knowledge in a context with an interactive storytelling approach.

Embodied learning taxonomies (e.g. Clifton et. al., 2016; Johnson-Glenberg et. al., 2014) emphasise bodily engagement and motor activation, as foremost characteristics implied in knowledge retention, either in the case of higher level of embodiment, or in the case of less stronger forms of activity (Tran et. al., 2017). In line with such remarks, some researchers defined a medium degree of interactivity to be best suited for increasing learning performance (Kalet et. al., 2012) suggesting that the bodily involvement should not be used as an indicator of instruction embodiment (Johnson-Glenberg et. al.,2014), nor can it be expected as inevitably enhancing the learning performance (Tran et. al., 2017), as its value is much more related to the deeply embodiment of the knowledge within the learning task (Wilson & Golonka, 2013).

This approach allows comparisons between learning settings including bodily activities, and those enabling learning without requiring a motor activity (Johnson-Glenberg et. al., 2014), or supports the evaluation of systems employing multiple sensory modalities against those providing one modality (e.g. Skulmowski et. al. 2016). Mavilidi et. al. (2015) for instance operationalized this integration concept by comparing a language learning intervention that supports bodily enactment of foreign language words with learning interventions providing bodily exercises without a relation to the learning contents (Skulmowski & Rey, 2018). The idea is built on the notion of affordances (Gibson, 1977), based on which we perceive the world in terms of what we can do, that is, in terms of its pragmatic meaning. Cognition, as embodied and enactive, is dynamic and interplays between brain and body, between the body and the environment. Seeing affordances in objects, involves intuiting possibilities for action, or interaction beyond the mere physicality, or physical presence of the object. As objects are metaphors the learners bring knowledge into existence, through acting upon the objects, applying skills and abilities. The idea of enactivism, developed by a number of researchers, (e.g., Gallagher, 2005; Di Paolo, 2009; Noë, 2004; Varela et. al., 1991) is that bodily processes, not only sensory-motor processes but also affective processes, shape the way the perceiver thinker experiences and considers the world, and interacts with others. As previously mentioned in relation to serious games, the concept of metaphoric meaning is well demonstrated in role-playing, introducing the prospective to dialogically develop a stable sense of relationships with the learning experience, by prompting the users during the game, to act out their understandings, using their bodies and adapting those understandings via salient channels of feedback. This concept of enacting metaphor is driven in mixed reality technologies such as those that provide haptic feedback. An example is MEteor - Metaphor-Based Learning of Physics

Concepts Through Whole-Body Interaction in a Mixed Reality Science Center Program (Lindgren et. al., 2013), a simulation of planetary astronomy, presented in figure 6, where children are guided through a series of levels in which they encounter a progression of physics principles, and interact with the system predicting the consequence of their actions (e.g. they launch an asteroid and have to predict the effects of gravitational forces), while feedback about their responses are provided (Gallagher, 2015). The concept adhere well to the digital storytelling approach, as well as to Scenario Based Learning (SBL), providing meaningful learning experiences by engaging students in authentic environments to support reflective practices and active learning in a real-world problem and in a subsequent solution finding process (Marocco et. al., 2019). In EULALIA tools (figure 7 and 8) for instance, as scenarios are sequences of communicative situations, they offer a means of incorporating real-world variables, including a domain, context, tasks, language activities and, in which “Can-Do” descriptors can be integrated as learning objectives, together with aspects of strategic, pragmatic and linguistic competence as enabling objectives, and quality criteria for evaluation purposes (Mazzucato et. al., 2020).

Figure 6 MEteor A participant in the immersive environment, adjusting the spring before launching the asteroid in level 3 (Source: Lindgren et al., 2013)

Figure 7 Eulalia Prototype (Mazzucato et al., 2020)

Design a path consisting of one or more stages, in which several sections are connected, in which the image/ map is divided.	
Narrators' request	*Hello! I am looking for the biggest castle in Naples, whwre I can find it?*
COMPETENCE AND DOMAIN	Real world interaction, especially listening comprehension
Target point on the map	*D1 – physical object or card or sensitive point*
LEARNING ACTIVITIES	Listening activity Vocabulary and question practice
Narrator's feedback (if answer is correct)	*The biggest castle is Castel Sant'Elmo*
Media typology	*Video*
Narrator's feedback (if answer is wrong)	• *Unfortunately, this is not, please retrying* • *Your solution is not correct, please try again* • *Retry, the right solution is another* • *No, the answer is not correct* *This is not, please try again*
ASSESSMENT	Responses to comprehension tasks
LEVEL	A1
Insert Narrator's request for the next step	Now please the castle the is less famous than Castel Nuovo

Figure 8 Template version of EULALIA OER

Chapter 2

Determinants of use and adoption of a technology in the education context

Different models attempt to measure technology adoption and integration, both in the workplace and in the educational and training context. Some of them are interrelated such as the Rogers' (2003) Diffusion of Innovations (DOI) theory, the Concerns-Based Adoption Model (CBAM) of Hall (1974), Zaltman and Duncan's (1977) Strategies for Planned Change, Ely's (1990) Conditions for change, and the Systemic Change Process (Reigeluth & Garfinkle, 1994). This chapter attempts to outline the most relevant factors throughout the most significant theoretical frameworks.

Rogers (2003), defines technology adoption as a decision of "*full use of an innovation as the best course of action available*" and defines as rejection a decision "*not to adopt an innovation*" (p. 177). An innovation is defined as "*an idea, practice or object that is perceived as new by an individual* " (Rogers, 1995, p. 11). Williams (2003) describes ICT integration as the means of using any ICT tool to assist teaching and learning. Adoption Theory examines the individual choices to accept or reject a particular innovation and eventually the extent to which that innovation is integrated into the context, generating a behavioural change. Diffusion Theory describes instead how an innovation spreads through a population and relates to factors such as time and social pressures (Williams, 2003). The adoption as well as the integration of ICT into learning and teaching are first of all influenced by several factors, which facilitate or act as barriers: **personal characteristic, institutional characteristics, and technological characteristics**.

2.1 Personal characteristics influencing the technology adoption

Personal characteristics such as age, gender, educational level, educational experience, experience and attitude towards innovation technologies use, in general, and for educational purpose in particular, can influence the adoption of a technology.

2.1.1 Gender moderating influence in technology acceptance

Gender moderating influence in technology acceptance is a topic of relatively recent appearance. The Unified Theory of Acceptance and Use of Technology – UTAUT (Venkatesh et. al., 2003) aims to explain user intentions to use a system and subsequent usage behaviour. UTAUT model (see figure 9) reveals that the gender of the adopter has a moderating effect on the relationship between intention to adopt and its determinants. These determinants of intention include three different constructs: performance expectancy, defined as the degree to which the potential adopter believes using the focal technology will help him/her to increase job performance; effort expectancy, defined as the degree of ease associated with using the system; and social influence, considered as the degree to which the individual perceives as important that others believe she/he should use the technology (Venkatesh et. al., 2000). The mechanisms by which gender differences arise, need to be further investigated before applying such knowledge to actual technology adoption situations, as several studies claim that gender is not a predictor of ICT integration into teaching and learning (Norriset et. el., 2003) and that quality training on technology can help reduce gender inequalities (Kay, 2006).

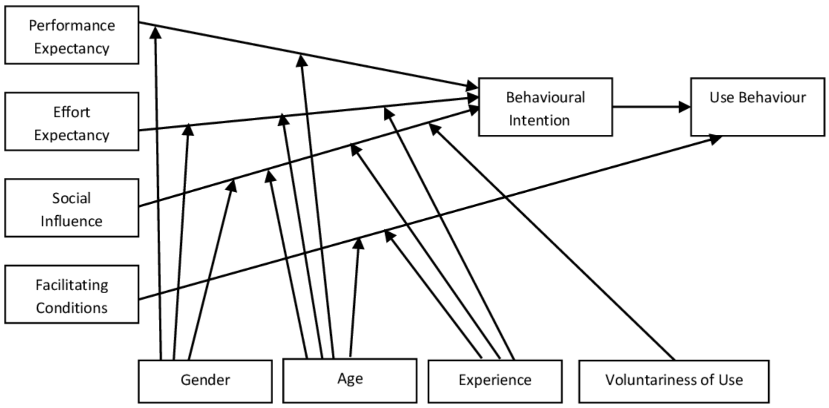

Figure 9 Unified Theory of Acceptance and Use of Technology (UTAUT) (Source: Venkatesh & Davis, 2003)

Guo et. al. (2008) studies on the relationship between **age** and information communications technology (ICT) competency of teachers, report minor differences in the case of elementary in-service and pre-service teachers 20 to 40 years old. Waugh (2004) comparative study aiming to predict technology adoption based on personal attributes, indicate as predictor variables the subject area, experience, age, and gender, highlighting age and subject area as the two statistically significant technology adoption predictor variables: technology adoption reduces as age increases. Other studies found age may (Alexander, 2002) or may not (Tondeur et. al., 2008) be a factor in technology integration in teaching and learning practices.

2.1.2 Educational practitioners' education level and experience using a technology as key factors of integration of technology

Regarding **educational level, and experience**, Stephenson et. al. (2006) identify three areas of computing education typically included in the secondary curriculum, highlighting the scope difference: 1) educational technology, defined as using computers across the curriculum to support learning other disciplines, manipulating and sharing information; 2) information technology, identified as learning about computers and technology itself; and 3) computer science, intended to be the study of computers and algorithmic processes, including their principles, their hardware, and their impact on society. Several authors analyse, instead, the relationship of use of computer technologies in education and teachers training preparation on the use of technology (for example Baek, Jong & Kim, 2008; Buabeng-Andoh, 2012; Giordano, 2007; Hernandez-Ramos, 2005; Mirzajani et. al., 2016; Niederhauser & Stoddart, 2001; Russell, et. al., 2007; Wong & Li, 2008) reporting that teachers with a long track of teaching experience tend to be less keen to use and integrate ICT into their teaching. Additional studies likewise suggest that effective use of technology is related to the user comfort levels (Gorder, 2008), identifying teachers' professional development as key factor to successful integration of computers into classroom teaching. Both for beginner or experienced, training programs aiming to develop teachers' competences in technology use (Bauer & Kenton, 2005; Franklin, 2007; Wozney et. al., 2006), or supporting teachers practice to reorganizing tasks, or student learning based on technology use, positively impact on teachers' attitudes towards technology use (Hew & Brush, 2007; Plair, 2008) and successful integration of technology in the classroom (Muller, 2008). In fact, quality training upkeep teachers transforming teaching practices, particularly when the programs concentrate on ICT based pedagogies instead of technical issues, supporting teachers in the practice of applying technologies in learning, (Brinkerhoff, 2006; Diehl, 2005; Lawless & Pellegrino, 2007; Wozney et. al., 2006). Teachers need training that show them how to integrate ICT to facilitate teaching and students' learning (Plair, 2008), designed to support the application of ICT in school and within the curriculum programs to supplement teaching and learning activities (Chen, 2008) and giving teachers the opportunity to practice the technology, learn and collaborate with peers. This knowledge understanding increases their confidence and attitudes towards technology (Lawless & Pellegrino, 2007; Wepner et. al., 2006), and enhance integration of technology into their teaching. Teachers training programs that embrace educational practices and strategies to address beliefs, skills and knowledge, improve teachers' awareness and insights in advance, in relation to transformations in classroom activities (Levin & Wadmany, 2008).

The innovation process taking place in education and training, frequently challenge teachers and educational practitioners to adopt and integrate ICT into teaching and learning activities, but most of the case studies reveal that teachers' preparedness to integrate ICT into teaching can determine the effectiveness of the technology, and the substantial difference with its effective introduction in the classroom. Anxiety, lack of confidence and competence, fear to embed the use of technologies in the daily practice, greatly influence the adoption and integration of technologies into teaching. Therefore, an understanding of the mechanism underling the influence of teachers attributes towards technology adoption and integration into teaching and learning is highly relevant.

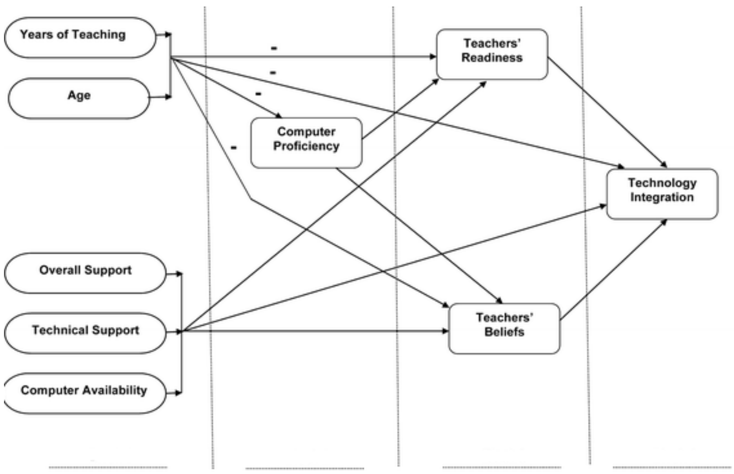

Figure 10 Path model to technology integration

2.1.3 Teachers' attitudes and beliefs towards technology as factors that influence adoption of ICT.

Teachers' attitudes and beliefs towards technology are constantly confirmed as factors that influence adoption of ICT into teaching. Positive attitudes to ICTs, and/or their use in education, are often proposed to be enabling factors, while negative attitudes are definied as disabling factors (Drent et. al., 2008; Pelgrum, 2001). If teachers' attitudes are positive toward the use of educational technology, then they can easily provide valuable insight towards the adoption and integration into the teaching and learning processes. The direct influence of attitudes can be categorised into two groups: attitudes to technology (Delcourt et. al., 1993) and attitudes to ICT use in education (Herman et. al., 2008). However, positive attitudes about ICT use can vary from a use in education generally positive to a more specific attitude related to the use ICT in daily work with students in classrooms, strongly related to the concept of integration of ICT in everyday teaching practice, referring to the use of technology to enhance the student learning experience. The more

experience teachers gain, the more likely they show positive attitudes towards technology (Rozell & Gardner, 1999). Positive attitudes are expected to foster technology integration in the classroom (Hermans et. al., 2004) as for the successful transformation in educational practice, user need to develop positive attitudes toward the innovation (Woodrow, 1992).

According to Bandura (2002), people regulate their behaviour on the basis of belief systems, particularly beliefs of **personal efficacy,** defined as the power to produce desired outcomes and forestall undesired ones; and self-efficacy, defined as the belief in one's own ability to execute a certain course of behaviour successfully. In relation with individuals' intentions to use information technology, **self-efficacy** theory relates to an individual's perception of ability to competently use a technology, which is concerned with the perception of ability to apply skills when using technology for broader tasks (Compeau & Higgins, 1995) and particularly to promote education. Research suggests that a strong sense of computer self-efficacy among teachers influences both how often and the reason ICT is used in everyday educational instructional practice (Chang & Tung, 2008). Christensen and Knezek (2006) described computer self-efficacy as computer confidence in competence.

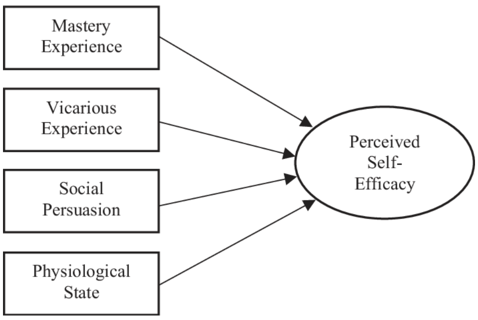

Figure 11 Bandura's model of the sources of self-efficacy and the outcomes (Source: Najib et. al., 2021)

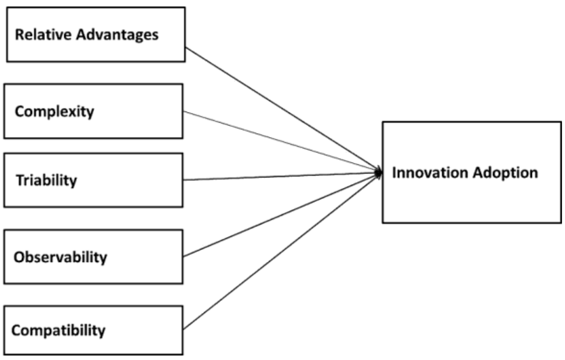

Figure 12 Diffusion of Innovation Theory (Rogers, 1983) (Source: Turan et. al., 2015)

ICT use seems to be a link between Bandura's (2002) Self-Efficacy Theory (SET) and Social Cognitive Theory (SCT) and Rogers's (1983) Theory of Innovation Diffusion, in that both self-efficacy and attitudes to ICT use are positively related to experience. In this sense, **familiarity** with technology use makes people more positive regarding ICT use, which also results in a greater feeling of self-efficacy (Player-Koro, 2012). Thus teachers' confidence refers both to the teachers' perceived likelihood of success on using ICT for educational purposes and on how far the teacher perceives success as being under his or her control (Peralta & Costa, 2007). Evidences suggest that when teachers report negative or neutral attitude towards the integration of ICT into teaching and learning, they also account lack of knowledge and skills that allow them to make "informed decision" (Bordbar, 2010). Furthermore, teachers declaring to have more experience with computers, report to have more confidence in their ability to use them effectively (Peralta & Costa 2007). To conclude, teachers' competence relates directly to their confidence (Jones, 2004). On the other side, it seems confidence and adoption can not be directly related to teaching experience. In fact, while some research report that teachers' experience in teaching do not influence their use of technology in teaching (Niederhauser & Stoddart, 2001), other research report that teaching experience influence the successful use of ICT in classrooms (Giordano, 2007; Wong & Li, 2008).

2.2 The influence of institutional characteristics on ICT adoption and integration

Other factors influence ICT adoption, particularly if integration is meant to be cross-curricular, rather than a separate course or topic in itself. The integration is successful when a technological tool is applied to enhance student learning in every subject (Grabe & Grabe, 2001), to support educational goals such as skills for searching information, collaboration, communication and problem solving, which are important skills to prepare pupils for the knowledge society (Drent & Meelissen, 2007). The potential role of ICT is exploited if a change occurs in the learning teaching paradigm from instructivist to constructivist, supported by teachers as effective agents able to make use of technology in the classroom, within the mainstream activities, part of the daily curriculum implementation. Thus, school management should be able to develop a vision (Anderson & Dexter, 2000), provide appropriate models and methodologies, support experimentation and training, stand-in towards acceptance of innovative goals and the role of teachers as changemakers. The process of change implementation is planned along three stages, namely adoption, implementation and **institutionalization** (Fullan, 1991) and underpins institutions and programmes, supporting teachers to understand how the new technologies can best be used in the pedagogical context. Teachers must have the opportunity and time to learn, exercise, reflect, and discuss their practice, in order to develop a pedagogy that incorporates technology (Kearsley & Lynch, 1992). Within the educational context practice, when integration occurs, and technology is used in lessons, the two important elements of teaching and learning, which are content and pedagogy, must be joined (Earle, 2002). Teachers' **professional development** is in fact a key factor to successful integration of computers into classroom teaching, but to be a strong determinant for effective use of technology in the classroom, should concentrate on the pedagogical aspects supporting its deployment to transform teaching and learning practice, including practice in real context and teamwork among colleagues, instead of concentrating on technical aspects (Sandholtz & Reilly, 2004). Is is in this context important to recall, that individuals are capable of learning not just from their own experiences, but from the experiences of those around them (Bandura, 1986).

Another important aspect is the context within which the school develop its innovation process (Rogers, 1995). The **social and economic background** as well as the community support can influence the implementation of ICT in education. On one side, access to ICT infrastructure and resources in schools is a necessary condition to the integration of ICT in education (Plomp et. al., 2009). On the other side, school culture, defined as "*the basic assumptions, norms and values, and cultural artefacts that are shared by school members*" (Maslowski, 2001, pp. 8–9) is another important element to consider, strongly influenced by the **community culture and mainstream policies** (Devos et. al., 2007). Hence, if the technology is effectively integrated, there is accordance between the culture and values of the school and the technology (Albirini, 2006). Community actors such as policy makers, media representative and families, play in this case a fundamental part. Parents role is also particularly important in this context, as the change occurs more quickly when they are encouraged to participate in, and contribute to support the school's management towards an ICT introduction and integration plan (Bangkok, 2004). At school level, lack of ICT infrastructure, old or poorly maintained hardware, lack of suitable educational software, limited access to ICT, are factors that obstacle their effective use in the educational context (Balanskat et. al., 2007), but it is fundamental to consider the importance of selecting the appropriate kind of tools, besides suitable training programs, to support effective teaching and learning (Tondeur et. al., 2008). Access to appropriate technology means that affordances and constraints (Friedhoff, 2008) of a technological tool need to be carefully considered when the tool is incorporated in lessons. Furthermore, technical support is also a relevant aspect, as if there is a lack of technical support available in a school, then it is likely that technical maintenance will not be carried out regularly, resulting in a higher risk of technical breakdowns (Becta, 2004).

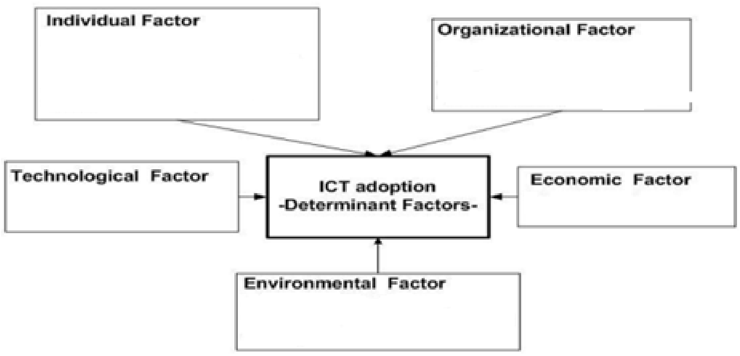

Figure 13 ICT adoption determinant factors

2.3 Technological Characteristics

Following the Diffusion of Innovation (DOI) Theory, technology characteristics influence the diffusion processes of an innovation, and are significant factors impacting on technology acceptance, and individual adoption of the technology. The definition of the characteristics of each technology is strongly related to its design and functionality development, and its "*ability to dramatically improve performance of production processes, goods and services by means of innovation*" (Watanabe et al., 2009, p. 738). Technology adoption is in fact conceived both as a social developmental process, and an individual construct, strongly related the perceptions of a technology (Watanabe et. al., 2009). Among the many variables that can influence a system acceptance and use, two determinants are particularly important in relation with personal ICT choices: perceived usefulness and ability of the technologies to meet needs, and level of complexity in use (Davis, 1989; Kraut et. al., 1988). Performance gains are often obstructed by users' unwillingness to accept and use available systems (Bowen, 1986), but people tend to use, or not use an application, to the extent they believe it will help them perform their job better. The degree to which a new technology meets the habits, values, past experiences and needs of the potential adopter is defined by Rogers (1983) as **perceived compatibility**, affecting a system use through usefulness and perceived ease of use (Agarwal & Karahanna, 1998). Compatibility has a positive relationship and significant effect on their perception of services' usefulness, as compatibility means less substantial changes in the adopters' operational practices (work/learning style and prior experience), which leads to less effort to use. Several studies confirm that individual users' perception of technology compatibility has a positive and significant impact on their perception of technology's usefulness (Kristensen, 2016; Wu &Wang, 2005) and establish compatibility an important determinant of students' usage of learning technologies (Chen, 2011; Lai et. al., 2012). As described later in chapter three and five, perceived compatibility is a construct included in the model used in the present study, aiming to contribute to identity if users perceive the system as respondent to their experience and habits, besides the capacity of the system to respond to effectively support the performance of their work. In fact, Chen et. al. (2002) and Ifinedo (2017) combine TAM with compatibility from innovation diffusion theory to explain and predict intention to use technologies.

Chapter 3

Evaluating and explaining the impact of a technology: key constructs implied in the study

As previously mentioned in chapter one, technologies can potentially support, facilitate and innovate learning. Their introduction and integration is determined by several factors, explored in chapter two. Effective use can be assessed in terms of the changes triggered in pedagogical models and is also facilitated by several elements, such as predisposition, ability to use, etc. But above all, it is important to pay attention to the impact that technologies have on learning in terms of learners' perceived outcomes. On this it seems that research has only recently been focusing. This Chapter will focus on the key constructs implied, to understand their relationships with learners' perceived impact on learning. This will allow to identify a model suitable to capture the factors that influence the perceived impact on learning in case of use of an innovative technology, to ground the empirical study presented in chapter four and five.

3.1 Perceived ease of use and perceived usefulness as predictors of user acceptance of technological information systems

Explaining user acceptance has been a long-standing ration for predicting and explaining user adoption of a certain technology, and an increasing number of recent studies confirmed that perceived usefulness and perceived ease of use are predictors of user acceptance of technological information systems (Smarkola, 2007). Moving from Social Cognitive Theory (SCT), the Theory of Reasoned Action (TRA or ToRA), Innovation Diffusion Theory (IDT), and decision-making theories, Davis (1989) identified two perceived characteristics about an innovation to predict technology acceptance and usage outcomes. Such constructs have been applied to different educational settings (Farahat, 2012; Park et. al., 2008), including the adoption by students and teachers (Ma, Andersson, & Streith, 2005) of laptop-based testing (Baker-Eveleth et. al., 2007), and online learning systems (Ndubisi, 2006).

Perceived **ease of use**, is defined as the "*degree to which a person believes that using a particular system would be free of effort*" (Davis, 1989, p. 320), and separated conceptually from self-efficacy (Venkatesh et. al., 2000). Perceived **usefulness,** is defined as "*the degree to which a person* *believes that using a particular system would enhance his or her job performance*" (Davis, 1989, p. 320). Perceived usefulness is claimed to have a consistent influence on future individual use of a technology (Adams et. al., 1992; Agarwal & Prasad, 1998a; Lippert & Forman, 2005).

In 2003, Venkatesh and Davis empirically compared the most commonly theoretical frameworks and models used to understand adoption and use of technology: Motivational Model – (MM) Theory of Diffusion of Innovations (DIT), Social cognitive Theory – SCT, the Theory of Reasonable Action - TRA, Theory of Planned Behavior -TPB, Combined TAM and TPB – C-TAM- TPB, Model of PC utilization – MPCU, the Technology Acceptance Model (TAM) (Davis et. al., 1989, to define a unified model to understanding technology acceptance and subsequent usage.

UTAUT	TRA	TPB	TAM	TAM2	IDT	SCT
Performance Expectancy	Beliefs, Attitude	Beliefs, Attitude	Perceived Usefulness	Perceived Usefulness	Relative Advantage	Outcome Expectations
Effort Expectancy		Perceived Behavioral Control	Perceived Ease of Use	Perceived Ease of Use	Complexity	Self-Efficacy
Social Influence	Subjective Norm	Subjective Norm		Subjective Norm, Image		
Facilitating Conditions				Result Demonstrability	Compatibility, Observability, Trialability	

Figure 14 Summary of Previous Theories and Models in ICT Adoption Research (Source Kim & Crowston, 2011)

The Unified Theory of Acceptance and Use of Technology (UTAUT), includes four key determinants of usage intention and behaviour: performance expectancy, effort expectancy, and social influence. The first three are direct determinants of usage intention and behavior, and the fourth is a direct determinant of user behavior. Individual differences, such as gender, age, experience, and voluntariness of use, are theorised to moderate the impact of the four key constructs on usage intention and behaviour. In all the models, performance expectancy construct is the strongest significant predictor of intention, defined, as already mentioned, as the degree to which an individual believes that using the system would help him or her to attain gains in job performance. Effort expectancy, defined as the degree of ease associated with the use of the system, is captured by three constructs from the models: perceived ease of use (TAM/TAM2), complexity (MPCU), and ease of use (IDT). It is interesting to note that each of them is significant only during the initial phase of the new behaviour (post- training), becoming non-significant over longer period of usage. Social influence, as mentioned above, is defined as the degree to which an individual perceives that important others believe he or she should use the new system. It is represented as subjective norm in TRA, TAM2, TPB/DTPB and C-TAM-TPB, social factors in MPCU, and image in IDT, and becomes significant when use is mandated instead of voluntary and in the early stage of the new experience. The mechanisms underpinning social influence on individual behaviour are summarized as: compliance as altered intention, to respond to the social pressure; internalization and identification related to altered belief structure. Facilitating conditions are defined as the degree to which an individual believes that an organisational and technical infrastructure exists to support the use of the system, and is exemplified by three different constructs: perceived behavioural control (TPBI DTPB, C-TAM-TPB), facilitating conditions (MPCU), and compatibility (IDT). Each of them is operationalized to include aspects of technological and/or organizational environment. The empirical results indicate that facilitating conditions do have a direct influence on usage beyond that explained by behavioural intention (Venkatesh & Davis, 2003).

The UTAUT is still a relatively new model requiring further validation, while the TAM has a long history in the research literature, confirming its broad proficiency explaining users' behaviour across a broad range of end-user and contexts (Chuttur, 2009; Davis et. al., 1989; Holden, & Karsh, 2010; Lai, 2017; Morris & Venkatesh, 2000; Venkatesh & Davis, 2000) It is unquestionably the leading ground theory for investigating acceptance of learning technology (Abdullah & Ward, 2016; Farahat, 2012; Park, Lee & Cheong, 2008; Šumak et. al., 2011; Weerasinghe & Hindagolla, 2018), like mobiles (Sánchez Prieto et. al., 2016.), Personal Learning Environments (PLEs) (del Barrio-García et. al., 2015), and Learning Management Systems (LMSs) (Alharbi & Drew, 2014), as well as open-source Moodle LMS (Sánchez & Hueros, 2010), e-learning and m-leaning technology (Landry et. al., 2006; Ngai et al. 2007; Roca et. al. 2006; Saadé & Bahli 2005; Saadé & Galloway 2005). For this reason, TAM represents in the current study the reference model to investigate acceptance and intention to use the proposed technology in educational context to support learning performance.

3.1.1 Technology Acceptance Model (TAM) theoretical Framework

The Technology Acceptance Model (TAM) is an adaptation of the Theory of Reasoned Action - TRA and Theory of Planned Behaviour - TPB (Ajzen, 1985), developed to demonstrate user acceptance of information systems, and to interpret potential users' behavioural intention (BI) to use a new technology in a specific situation (Legris et. al., 2003) based on two primary factors: the user's **perception of usefulness (PU)** and their **perception of ease of use (PEOU)**. It assumed that the two predictors work together to determine behavioural intention, and that the perceived ease of use is a predictor of the perceived usefulness. Furthermore, Davis et. al. (1992) included **perceived enjoyment (PE)** as an intrinsic element that influences the user's behavioural intention to use the technology, defined as "*the extent to which the activity of using technology is perceived to be enjoyable in its own right, apart from any performance consequences that may be*" (p. 113). **Perceived ease of use** lead to attitude toward **use**, behavioural **intention to use** and **actual use.** Furthermore, TAM seeks to provide a source for depicting the impact of external factors on internal beliefs, attitudes, and intentions, suggesting that usage is determined by behavioural intention BI, viewed as being jointly determined by the user's attitude toward using the system (A) and perceived usefulness (U), with relative weights estimated by regression: BI= A + U (Davis et. al., 1989). The A-BI relationship represented in TAM implies that, all else being equal, users form intentions to perform behaviours toward which they have **positive affect**, or in other words, based on a cognitive appraisal of how it will improve their performance. TAM does not include TRA theory of reasoned action's subjective norm (SN) as a determinant of BE, because of its uncertain theoretical and psychometric status (Davis et. al., 1989). Furthermore, according to TAM, Attitude towards use (A) is jointly determined by usage (U) and ease of use (EOU), with relative weights statistically estimated by linear regression: A = U + EOU. EOU is also theorized to have a significant effect on A by two basic mechanisms: self-efficacy and instrumentality. The sense of efficacy triggers **intrinsic motivation** and is theorized to be grater when the system is to interact (Bandura, 1982) and when is greater the ability to carry out the system operations (Lepper, 1985). The direct EOU-A relationship defines this motivating aspect of EOU (Carroll &Thomas, 1988; Malone, 1981).

Usefulness, and variables similar to it, such as perceptions of performance impacts, relevance and importance, are also linked to usage (U) (DeSanctis, 1983; Swanson, 1987) and TAM suggests that U directly effects BI over and above A. Hence, U is proposed to have a positive influence on A. U and EOU constructs are observed as distinct but related, as external variables such as effort saved due to improved EOU can enable more work execution applying the same effort, having direct effect on U: U = EOU + External Variables. Furthermore, perceived ease of use is conceived determined by external variables: EOU = External Variables considering that system features such as menus, icons, mice, and touch screens and feedback, are envisioned to augment usability (Bewley et. al., 1983). External variables thus internal beliefs, attitudes, intentions and the various individual differences, situational constraints and institutional controllable interventions, impact on behaviour indirectly (Davis et. al., 1989). The final model that will be included in this research excludes the attitude construct to understand the explanatory power of perceived ease of use and perceived usefulness on system acceptance. Attitude towards using a technology is in fact omitted by Davis et. al. (1989) in their final model because of the partial mediation of beliefs on intention by attitude, a weak direct link between perceived usefulness and attitude, and a strong direct link between perceived usefulness and intention.

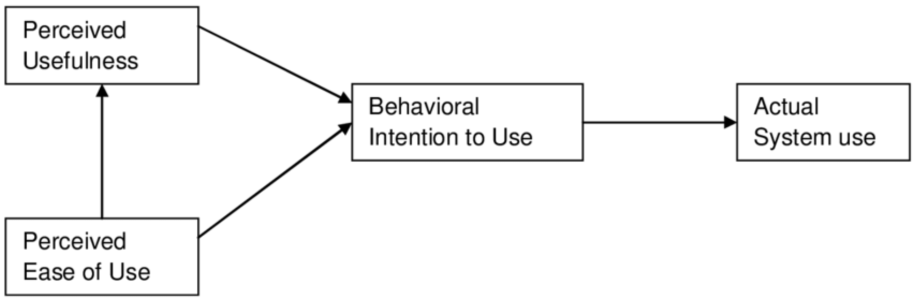

Figure 15 Technology Acceptance Model (Source: Davis et. al., 1989, Venkatesh 2003)

3.2 Perceived Enjoyment

Perceived Enjoyment is defined as the degree to which the activity of using technology is perceived to be enjoyable in its own right apart from any performance consequences that may be anticipated (Davis, et. al., 1992; Venkatesh & Davis, 2000). Several studies establish the construct of perceived enjoyment to be connected with perceived usefulness and perceived ease of use in exploring the intention to use technology (Chesney, 2006; Van der Heijden, 2004; Wu et. al., 2007). For examples, is confirmed to be substantial in explaining behavioral intention to use computers (Igbaria et. al., 1995), the internet (Moon & Kim 2001; Teo et. al., 1999), and blogs (Hsu & Lin, 2008).

Within the TAM framework (Davis, 1992) perceived enjoyment is considered an addendum to the model similar to **intrinsic motivation**, which drives the enactment of an activity based on the sole satisfaction of performing the activity per se. As an example, Venkatesh and Speier (2000) established that game-based training method, intended to enhance intrinsic motivation, results in higher enjoyment and higher perceived ease of use, compared traditional a training method. In addition, the effect of enjoyment on perceived ease of use enhances over the time as users gain experience with the system use. These findings advise that perceived ease of use is influenced by the extent to which users perceive the system use as enjoyable. In summary, Davis et. al. (1992) found that usefulness and enjoyment are significant determinants of behavioural intention, and Venkatesh et. al. (2000) disclosed that enjoyment influence perceived usefulness via ease of use. Perceived usefulness measures how users believe their productivity can be improved by applying a technology, while perceived enjoyment emphasizes the pleasure, and satisfaction, deriving from the specific activity conducted with the application of a technology, and plays a significant impact on the user's intention to use and adopt a technology, completing the influence of perceived usefulness, and perceived ease of use of the technology. The Role of perceived enjoyment in the students' acceptance of an augmented reality-teaching platform is investigated in one of the recent endeavours to understand students' technology acceptance that demonstrates that enjoyment is a key factor influencing intention to use (Balog & Pribeany, 2010). In another recent study, it is confirmed to influence the degree to which teachers find enjoyable or interesting the integration of mobile AR applications in their teaching, demonstrating that perceived enjoyment affects the users attitude towards such emerging technologies (Teo & Noyes, 2011).

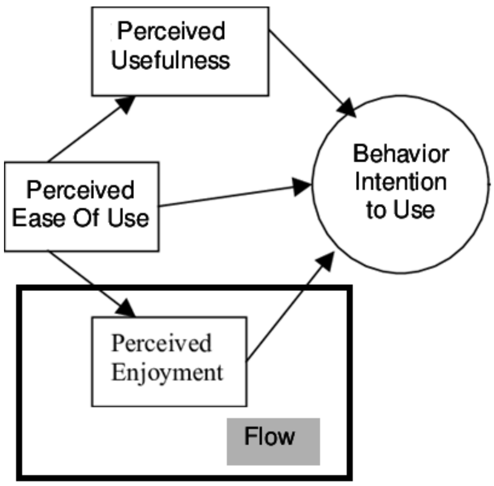

Figure 16 A revised technology acceptance model to include a perceived enjoyment construct, adapted from Davis et al. (1992), and Venkatesh et. al. (2000)

Individuals are engaged in activities because this generates joy and pleasure (Straker & Wrigley, 2018; Teo & Lim, 1997). Other authors provide the definition of "perceived pleasure" as the extent to which using a technology is perceived as enjoyable in its own, apart from all the performance consequences resulting from its use (Mwiya et. al., 2017; Straker & Wrigley, 2018; Venkatesh & Bala, 2008; Yahia et. al., 2018), acknowledging the contruct as an intrinsic motivation with a significant impact on technology acceptance, particularly for **hedonic systems** (Davis et. al., 1992; Nysveen et. al., 2005; Teo et. al., 1999; van der Heijden, 2004). The close connections between perceived ease of use and hedonic is noticeable in other studies applying the TAM model (Saadé et. al.,2008; Venkatesh & Davis 2000). In line with consumer behaviour literature that distinguishes between utilitarian and hedonic products (Hirschman & Holbrook 1982), an hedonic systems is described as aiming to provide self-fulfilling value to the user, so designed to provide a fun experience; in contrast to an utilitarian systems, which aims to provide instrumental value to the user, such as support task performance encouraging efficiency (Goodhue & Thompson, 1995). This provides the opportunity to reflect on the implications of technologies design tailored to exploit intrinsic motivation, and to investigate further how the interface and user interaction modalities with the devise, influence a technology acceptability in terms of both perceived usability and perceived enjoyment. It is known for example that individuals often seek experiences in multiple sensory modalities (sounds, tactile, scents, visual stimuli), often recalling previous knowledge or experiences, to have a pleasurable experience that involve emotional arousal and/or cognitive stimulation (Hirschman & Holbrook, 1982).
These aspects attract a considerable attention when it comes to understanding the impact of the use of a technology on the learning outcomes, and lead the reflection on the charachteristics that a technology, and contents it deploys, should have in oder to positively support a learning path. This is one of the reasons why this study is based on the application of a technology that has been designed to fulfil task requirements, with respect to the functions it is meant to upkeep in educational context, while supporting a playful, pleasure, unjoyful learning experience.

The emerging concept of "emotional usability" (Kim & Moon, 1998), moved by the more and more frequent use of technologies in different contexts of users daily lives: less anchored to instrumentality and efficient accomplishment of tasks, and more related to entertainment and interaction. In relation to the educational context, it is becoming of interest, the importance of building and recognizing the pedagogical mechanics of play and games, as they present aspects that leverage novel teaching and learning processes that involve students meaningfully (Burns & Gottschalk, 2020). A growing interest in the interplay of learning and emotion, is also evident. The definition and explanations of **emotions** is multifaceted, and in relation with learning it requires a contextual shift from experimental research in laboratories to the classroom real context (Hascher, 2010). To extremely summarise, it is pointed out that emotions regulate learning activity influencing metacognition: positive emotions foster learning, and negative emotions are detrimental (Bless & Fiedler, 2006). Positive emotions ease the work on tasks demanding learners' creativity and fantasy (Fredrickson, 2001). Thus, cognitive processes seem to be enhanced by positive emotions leading to more and more non-conformist, divergent thinking; while negative emotions direct student's attention to themselves instead that towards the task solving, because they try to find ways to get rid of the bad feeling (Hascher, 2010). In fact, engagement does increase when activities are tailored to the personal needs and emotional state of the learner, and if the system promotes positive affective states that in turn promote learning (Standen et. al., 2020) Positive emotions, and feelings of success, during learning, increase self-efficacy beliefs and motivation. Positive emotions also encourage students to become attached to difficult tasks and previous failures (Trope & Neter, 1994). Thus, possible undesired effects of mood can be coped if students develop a sense of personal belonging to the learning contents, engaging them in unjoyful learning activities.

As a result, besides efficiency and functionality, technologies become accepted based on criteria such as friendliness, pleasurable, and aesthetic. People with a pleasurable perception of the **enjoyment** from using the product are more likely to perceive it useful (Csikszentmihalyi, 1990; Sun & Zhang, 2008) In the emotional usability concept, enjoyment is more related to adoption than usefulness (Mahlke, 2007; Jordan, 2000). Gaver and Martin (2000) claim in facts that these aesthetics aspects should be developed with respect to the functions and cultural roles they are meant to support. By the way, this intrinsic value beyond functional values, satisfies users' needs and motivates them (Postrel, 2002). Positive affective emotion also makes users to perceive themselves as having generous time to complete a task, and it actually reduces the perception of workload related with using the technologies (Sun &Zhang, 2008) Users want to achieve not only certain well-defined goals, but also involve the sense of affective responses (Hassenzahl, 2003).

The more enjoyable a product is the more useful a product can be perceived. Drawing upon the concept of emotional usability some authors suggest that future Human Computer Interaction must focus both on the pragmatic aspects of interactive products to fit to behavioural goals, as well as about hedonic aspect, such as stimulation (i.e. personal growth, an increase of knowledge and skills), identification (i.e. self-expression, interaction with relevant others) and evocation (i.e. self-maintenance, memories (Logan, 1994, Hassenzahl, 2003). Heijden (2003) proposed a new concept, “Perceived Attractiveness,” for the TAM model in the internet context, defining it as the degree to which a person believes that the website is aesthetically pleasing to the eye, and stating that perceived attractiveness of the website influence usefulness, enjoyment and ease of use. Huang et. al. (2007) also observe that perceived enjoyment has a positive impact on perceived ease of use, in the context of mobile learning. Venkatesh & Davis (2000) define this intrinsic motivation as “computer playfulness”. the degree of cognitive spontaneity in microcomputer interactions (Webster & Martocchio, 1992), connected to perceptions of pleasure and satisfaction from performing the behaviour (Vallerand, 1997), that is system-independent and related to the perceived ease of use construct. The construct of computer playfulness includes the desire for fun but also involves exploration and discovery, challenge and curiosity (Malone, 1983). Agarwal and Karahanna (2000) propose the multi-dimensional construct called “cognitive absorption,” as a state of involvement with software, demonstrating a significant influence on perceived usefulness. High **cognitive absorption status**, which makes high impact on perceived usefulness, is enjoyment. The concept seems similar to that of flow (Csikszentmihalyi, 1998a) to explain the pleasure arousing from immersion in activities. **Flow** consists in the experience of people acting with total **involvement**, also defined as **engagement** (Chen et. al, 2004; Csikszentmihalyi, 1998b). Flow arises when people focus only on the ongoing activity and lose their self-consciousness (Nakamura, & Csikszentmihalyi, 2009), and it is measured by perceived enjoyment, among other variables (Ifinedo, 2017), and requires a few characteristics: (1) define goals with practicable rules; (2) support adjustments of action based on capabilities (autonomy); (3) provide feedback on participants performance; (4) support concentration (Csikszentimihalyi & Rathunde, 1993) also conceived as intense feelings of engagement (Sung & Yun, 2010), immersion and absorption of user not willing to stop playing computer games (Herz, 1997).

Drawing upon such concepts, several authors suggest that future Human Computer Interaction must focus both on the pragmatic aspects of interactive products to fit to behavioural goals, as well as about hedonic aspect, such as stimulation (i.e. personal growth, an increase of knowledge and skills), identification (i.e. self-expression, interaction with relevant others) and evocation (i.e. self-maintenance, memories (Hassenzahl, 2003; Logan, 1994).The model used in this study thus includes enjoyment in order to explore if the proposed technology is enjoyable besides any performance consequence airing from its use and which are the implications this factor on perceived impact on learning.

3.3 Satisfaction

As previously indicated, perceived enjoyment is a significant variable in the Flow Theory framework, and several studies highlight a positive effect on satisfaction, specifically with the use of technology (Ifinedo, 2017a). Satisfaction refers to the extent to which a user is pleased with using a technology for a particular purpose (Ifinedo, 2017; Liao et. al., 2015). Satisfaction refers to how satisfied students are with the experience of technology-mediated learning (Balderas et. al., 2018; Ifinedo, 2018; Muñoz-Carril et. al., 2021) demonstrating that high levels of satisfaction in students, positively impacts on motivation, which also influence positively the perceived learning experience (Chow & Shi, 2014; Hernandez-Selles et. al., 2019; Ifinedo, 2017; Liu, 2016; Molinillo et. al., 2018). Additional studies provide evidence of perceived ease of use and perceived usefulness significant positive effect on satisfaction and on the perceived impact on learning (Bhattacherjee, 2001; Bölen, 2020; Oghuma et.al., 2016). Educational satisfaction is described as students' subjective emotional response to an educational experience or educational services provided (Choi, 2005; Hascher 2010) and can indicate directions for enhancing the quality and effectiveness of educational outcomes to improve educational content (Athiyaman, 1997; Han & Sa, 2021; Oldfeld & Baron, 2000), to meet or exceed the learner's expectations (Spreng & Mackoy, 1996) and enhace learners' participation (Palmer & Holt, 2009).

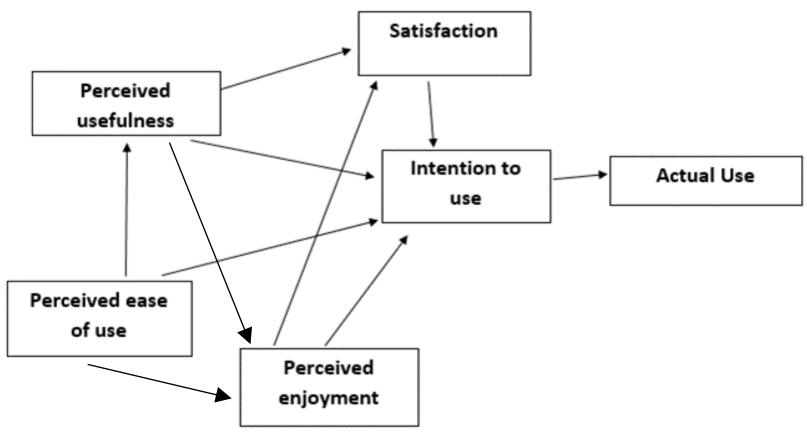

Figure 17 A revised model to include perceived enjoyment and satisfaction constructs

Satisfaction also has a key positive effect on intention to reuse or continue using a technology (Bhattacherjee & Hikmet, 2008; Kim & Chang, 2020; Venkatesh et. al., 2012). Researchers in various fields are investigating satisfaction positive effect on continuous technological tools acceptance intention, such as the use of web portals (Yang et. al., 2005), mobile Internet (Hong et. al., 2006), web based services (Lee & Kwon, 2011), mobile instant massaging (Oghuma et. al., 2016; To et. al., 2008). In the framework of the Expectation Confirmation Theory (ECT) (Bhattacherjee, 2001), which is the basis of the Expectation Confirmation Model – ECM, the user intention to continue using a technology is in fact dependent on three variables: the user's level of satisfaction with the technology; the extent of user's confirmation of expectations; and post-adoption expectations, in the form of perceived usefulness (Lee, 2010).

In the present study the satisfaction construct is considered as a combination of the user's cognitive judgment and emotional response (Oliver, 1977) and it is included to examine the degree of satisfaction and acceptance of the proposed technology to support learning. In this context, satisfaction can be also regarded as a variable representing the educational outcomes themselves (Han & Sa, 2021), measuring the effects it has on student learning gains, while considering the efforts implied to use the technology for the first time.

3.4 Confirmation

User's satisfaction with a technology is determined by the user's confirmation of expectations and perceived usefulness post-adoption or post use experience (Bhattacherjee, 2001). The confirmation construct suggests that users who obtained the expected benefits through the usage experiences of the system, consequentially report a positive effect on their' satisfaction. Based on the expectancy-confirmation paradigm, users' perceived usefulness has a positive effect on their satisfaction with technology use, by working as a base-line for reference against confirmation judgments (Lee, 2010). Lower expectations and/or higher perceived performance trigger a greater confirmation, which results in positive influences on user satisfaction and continuance intention (Hayashi et. al., 2004). In other words, the extent to which student expectations are met (Hossain Hossain & Quaddus, 2012). The model used in the present study integrates Expectation-Confirmation Model (ECM) and TAM to capture post use acceptance in the satisfaction construct. Confirmation in this case refers to how much a student's expectations about the learning experience match with their perceived performance of the technology during the learning experience.

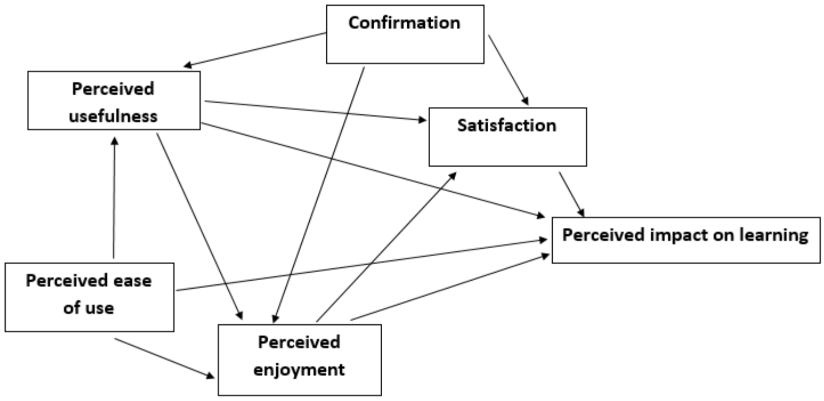

Figure 18 A revised model to include a perceived enjoyment and satisfaction as factors influencing perceived impact on learning

3.5 Factors influencing students perceived impact on learning

Introducing, and most of all integrating ICT in education, is strongly related to teachers and students' intention to use and adopt a technology, and such intent depends on several predicting and explaining factors illustrated in the previous paragraphs. The question related to the impact of technology on learning remains open. In today's educational context the introduction of ICT is strongly encouraged by European and national institutions (Digital Education Action Plan 2021-2027)[3], and presupposes that technology can support and enhance learning, opening implications and possibilities related to positive outcomes on the pedagogical approaches, learning strategies development, and learners performance. Many are the studies reporting on the benefits in ICT, Koc (2005) for instance, mentioned that using ICT enables students to communicate, share, and work collaboratively anywhere, any time. ICT support student-centered and self-directed learning: Brush et. al. (2008) have stated, for instance, that ICT tools help students to explore and solve problems. McMahon's study (2009) demonstrated that technology positively supports the acquisition of critical thinking skills. ICT enhance the development of a more a creative learning environment, and provides more creative solutions to different types of learning inquiries. (Chai et. al., 2010). ICT supports a constructive learning approach, facilitating students directing on higher-level concepts rather than less meaningful tasks (Levin & Wadmany, 2006). ICT supports gamified learning approaches (Gee, 2011) that enhance students' motivation and engagement by incorporating game design elements (Dichev & Dicheva, 2017). Several studies demonstrated that

[3] European Commission Digital Education Action Plan 2021-2027 https://education.ec.europa.eu/focus-topics/digital-education/action-plan

students who learned academic content in the technology enhanced classroom, outperformed those who learned the content without technology (Carle et. al. 2009). Qiao (2009), mention achievement in language learning; acquisition of learning skills and computer literacy; gaining of positive digital habits; development of problem-solving skills; diversification of the learning experiences; support consolidating concepts; reinforcing historical learning; and reducing the burden on the teacher. Although it is affirmable that the scientific literature highlights the positive impact of ICT on learning, it should be mentioned, that most of the studies report results related to the introduction of a particular technology, inquired within a certain population and following a specific method. Following this approach, several studies also investigate educational practitioners' perception and restitute a picture of widespread awareness among teachers that integrating ICT can introduce a positive shift in the teaching methods, where instructions and feedback are mediated by ICT tools creating a more active and collaborative learning environment (Mafuraga & Moremi, 2017; Nair et. al.,2016; Sangrà & Sanmamed, 2010; Yumurtaci, 2017). Besides the evaluation of a specific technology in the context of education, and the study of its positive implications on the learning approaches, the ultimate objective of the investigation related to the introduction of technology in education should be the outcomes it generates in terms of perceived impact on students learning, and this is why the present study focuses on such element in connection with the other considered variables. Several studies clearly indicate that technology-learning systems assist students in their learning process which eventually improves their academic performance (Al-Hariri & Al-Hattami, 2017; Bhuasiri et. al., 2012; Chunwijitra et. al., 2013; Sandars, 2012). The positive potential of ICT on students motivation towards learning and the positive implications on engagement within the learning path, can be also found in the literature (Kunina-Habenicht & Goldhammer, 2020; Miller et. al., 2012). Other studies suggested instead that ICT do not have a great influence on students' learning outcomes (Ernst & Clark, 2012; Salomon & Kolikant, 2016; Steiner & Mendelovitch, 2017). In the context of the present study, perceived impact on learning can be defined as the learners' views about the positive effects and value of the contribution of the technology within their learning.

3.5.1 Perceived impact of learning relationships with the other variables considered in the present study

As previously highlighted, the TAM model indicates that perceived usefulness is one of the key constructs for the analysis of technology-mediated learning processes (Cabero-Almenara & P´erez, 2018; Doleck et al., 2017; Ifinedo, 2017a) and is one of the paradigms considered in the present study. Perceived usefulness in fact refers to the extent to which a learner believes that learning through technology will enhance the learning performance (Alenazy et. al., 2019). Previous studies have found evidence that perceived usefulness has a positive significant effect both on satisfaction and on the perceived impact on learning (Bölem, 2020; Muñoz-Carril et. al. 2021). Some authors (Bölem, 2020; Chow & Shi, 2014; Ifinedo, 2017a; Mansouria & Piki, 2016) have established satisfaction as a relevant factor with a positive effect on the perceived impact of technology-mediated learning. Similarly, several studies focusing on the application of technology in learning have shown a positive association between perceived usefulness and attitude towards use (Stone & Baker-Eveleth, 2013). Attitude and perceived enjoyment imply intrinsic motivation and increase the relative likelihood of students having a positive perception of the impact on learning. (Balderas et. al., 2018; Ifinedo, 2018). Many studies debate about the effect of emotions on learning), and some of them demonstrate that enjoyment has a positive effect on learning outcomes (Hernik & Jaworska, 2016; Leung et. al., 2014; 2018; Wang & Lieberoth, 2016). In numerous studies a connection between cognitive development and enjoyment is also highlighted, affirming that the ability to implement newly acquired skills is associated with increased levels of pleasure (Kashdan et. al., 2004) and that feelings of enjoyment can be triggered (Watson & Tellegen, 1985) when tasks are performed. In fact, students' ability to achieving learning goals is associated with satisfying student experiences (Braxton et. al., 2014). Many research has linked enjoyment to perceived impact on learning in the case of use of computing technologies and applications (Mansouria & Piki, 2016) demonstrating students' enjoyment to be related to their effort and performance (Schukajlow & Krug, 2016), predicting self-regulation skills and academic achievements (Ahmed et. al., 2013). As previously indicated, perceived enjoyment is a significant variable in the Flow Theory framework, and studies have shown a positive effect on satisfaction in connection with the use of technology (Ifinedo, 2017a) and this has an impact linked to the learning experience and its effects (Muñoz-Carril, 2021).

It should be recalled that in the context of this study, perceived enjoyment refers to the perception of students within the proposed technologically mediated process of learning, regardless of the result of the collaboration process itself.

Chapter 4

The EULALIA framework and App development

An empirical study is part of this research project, oriented toward investigating the factors that influence students' perceived impact on virtual and mixed reality-enhanced learning, also to capture the differences between the two technologies since there are not many analyses with this purpose in the literatures. Such empirical study is supported by the use of a game based application, called EULALIA, in the context of higher education. EULALIA allows the deployment of an embodied and experiential approach to learning. It is designed to function in both virtual (VR) and mixed reality (MR), modality, this latter characterized by the embodiment of interaction with VR elements and physical objects (Smart Objects or Tangible User Interfaces – TUIs) that mediates the interaction between the learner and digital interface. EULALIA approach was conceived to enhance the teaching and learning methodologies of the university language centers of 4 countries (Italy, Malta, Poland and Spain) through the integration of innovative and inclusive learning tools based on the paradigm of Scenario Based Learning and Game-Based Learning. In particular, it supports the acquisition of knowledge about the tangible and intangible cultural heritage of a country/region/city different from that of origin, combining virtual and multisensory physical dimensions. EULALIA was developed in the context of the EULALIA European funded project[4], that run between October 2019 and September 2021, coordinated by the University of Naples Federico II[5]. The following paragraphs present the theoretical assumptions that from the analysis of the literature carried out allowed to outline the pedagogical approach underpinning the technical development of the application. An interdepartmental research path to which the candidate contributed especially with regard to the development of the theoretical framework and design of the contents and learning materials within the technical development of the app, as described in details below and recounted in the cited articles.

[4] EULALIA "Enhancing University Language courses with an App powered by game-based Learning and tangible user Interfaces Activities)[4], co-founded by the Erasmus+ programme of the European Union, in the call Key Activity 2 – Strategic Partnership (Grant Agreement 2019-1-IT02-KA203- 063228). https://eulaliaproject.eu/it/

[5] The project involved as partners the following Universties: University of Alicante, University of Malta, European University Foundation, Adam Mickiewicz University in Poznań and Smarted S.r.l.

4.1 The theoretical framework and learning approach

Two main theoretical frameworks initiate the conceptualization of embodied knowing underpinning the approach that EULALIA proses: experiential learning (Dewey, 1938; Kolb, 1984) and situated cognition (Caffarella, 2000; Kindley, 2002; Lave & Wenger, 1991; Hung, 2002). Within in EULALIA, learning is conceived as a process whereby knowledge is created through the transformation of experience. The internalization of the learning experience, fundamental in the learning process, is successful when concepts and knowledge are anchored to real-life problems and scenarios (Mazzucato et. al., 2020); learning cannot be separated from the context where it takes place, it is a contextual experience that occurs through interactions with the environment (Caffarella, 2000). Learning is a process of personal construction of meaning by the learner through experience, and that meaning is influenced by the scaffolding of prior knowledge with the reflections, activated during a new current experience, drawing forth cognitive and emotional information from several sources: visual, auditory, kinaesthetic, and tactile (Mazzucato et. al., 2020) The exploration and interpretation are central in the knowledge acquisition process (Pask, 1986), and learning is most successful when in control of the learner, as part of an active and continuing cycle of experimentation and reflection (Kolb, 1984). Successful learning is a constructive process that involves seeking solutions to problems, to relate new experiences to existing knowledge (Sharples et. al., 2002). Furthermore, experience is thought to be a bodily event, as the body is itself the site of learning and a vehicle for learning (Di Fuccio et. al., 2016; Grizioti & Kynigos, 2018; Matthews, 1996; Toto & Limone, 2020), that involves senses and perception in the mind/body action and reaction within learning process.

Humans tend to perceive the world around them as made of affordances (Gibson, 1979; Wilson et. al. 2013) that are opportunities for action. It is clear that for humans is essential to be able to perceive the world around them and to navigate through it (Argiulo & Ponticorvo, 2020; Di Fuccio et. al., 2017). Considering experience and thus learning as a bodily event refers more generally to the embodied cognition paradigm (Davis & Markman, 2012; Lancioni et. al., 2019;). In other words, the interactions between the body and the environment, in which that body is immersed, play a key role in shaping the way someone thinks and feels. Mind is not isolated from the body (Macedonia, 2019; Miglino et. al., 2014), but it is rooted in it. According to this paradigm, only thinking of an object, or a concept, bring about the experience linked to it (Barsalou, 2008). As a matter of facts, many studies on human brain confirm that seeing, or smelling, or tasting, or listening to something, activate the same brain networks as merely thinking of the same concepts

(Pullvermuller, 2021). It can follow that action is crucial for learning (Davis & Markman, 2012) as it could help building references in conceptual knowledge. For example, empirical evidences show that second language education and mathematics need embodied strategies as a base for enhanced understanding and learning (Macedonia, 2019). In this context, multisensory approach is particularly central in the “enculturation” processes (Thyssen, 2019), which include norms and values acquisition of cultural elements (Herskovitz, 1948). In fact, socialization and maintenance of values, ideas, and concepts, have always been considered involving embodied learning, rather than mere “mental processing” (Grosvenor, 2012; Rizzolatti & Craighero, 2002), considering the senses as “mediating” between mind and body, idea and object, self and the environment. A complete and multisensory experience with a culture different from that of origin is built when coming in touch with cuisine, art, and way of living. Reflective observation and active situated experimentation are a continuum process, triggered by tasks of the cultural heritage narrative, whilst concrete experience and abstract conceptualization is a perception continuum, indicating the emotional response toward the task arousal. Within this multisensory process, new knowledge and competences emerge as a result of the current experience; evoking previous knowledge that is understood and checked to be used in the current scenario, becoming incorporated into a more advanced framework of knowledge (Skulmowski & Rey, 2018; Tarozzi & Francesconi, 2013).

EULALIA is a technology enhanced learning tool providing multimodal communication and multisensory applications that transform the approach to learning, immersing the player/learner in a simulated scenario that situate the knowledge in a context with an interactive storytelling approach (Mazzucato & Argiulo, 2021). In EULALIA, Scenario-based learning (SBL) provides meaningful learning experiences by engaging students in authentic environments, to support reflective practices and active autonomous learning. In such multimodal storytelling system, the learner is guided through the exploration of a map, virtual or physical depending on the selected modality, and learn while challenging real-world problems in a subsequent solution finding process (Marocco et. al. 2019). The application has the structure of a serious game, in which the player deals with multidimensional data through a gamified learning experience, in which visual and spatial, auditive and tactile aspects interact thanks to the use of VR combined with Tangible User Interface (TUIs) applications (Mazzucato et. al., 2020). In this framework, the interactions are built as problem-oriented tasks and the narrative of scenarios is hinged on tangible and intangible cultural elements, virtual or physical depending on the selected modality. Within this paradigm, the use of TUIs allows a continuous interaction between virtual contents and physical elements, between the user and the digital interface, e.g. a software installed on PC or smartphone.

The user interacts with the digital or tangible interface, and is guided by and artificial agent to perform actions within scenarios whose virtual contents are anchored to physical and real objects, characterizing elements of the tangible and intangible cultural heritage. Scenarios facilitate learners to practice in real life simulated situations. As scenarios are sequences of communicative situations, they offer a means of incorporating Common European Framework of Reference for Languages (CEFR)[6] descriptors into the language learning path. The CEFR-based scenario provides a set of real-world variables, including a domain, context, tasks, language activities, in which "Can-Do" descriptors can be integrated as learning objectives. In addition, the scenarios adhere to a storytelling approach. As previously mentioned, digital storytelling is a well-known framework for enhancing achievement and learning motivation (Yang & Wu, 2012) that supports positive outcomes, among others, in the context of second language learning (Green, 2013; Kim, 2014; Liu et.al., 2018). Furthermore, it is largely recognised, that knowledge and the world are both construed and interpreted through action and mediated through the symbol use (Ackermann, 2014. in Tokoro, M. & Steels, 2014), so the EULALIA approach seems particularly appropriate in the context of language and cultural learning.

As mentioned, the EULALIA App has the structure of a serious game, a game which "primary goal is education rather than entertainment" (Michael & Chen, 2005). The application combines utilitarian training aspects with playful means that reinforce engagement and enjoyment, balancing accuracy and accessibility, graphics and interaction. In this framework, the effectiveness of the learning process is directly elated with learners' engagement and enjoyment in learning activities (Hamari et. al., 2016), in line with the Universal Design for Learning framework (UDL) (Meyer et. al., 2014). Furthermore, EULALIA approach was conceived starting from Digital Game Based Learning (DGBL) literature, that considers how technology features are effective to tackle lack of student's motivation or low level of confidence (O'Malley & Fraser, 2004). TUIs, in fact, constitute a tools "to think with", that offers a natural, immediate and accessible form of interaction, that promote learners' active exploration and hands-on engagement (Zuckerman et. al., 2005) but also enhance reflection as they allow to learn abstract concepts through concrete representations (Resnick 1998; Rogers & Muller, 2006).

According to Fröbel's ideas of DGBL (Brougère, 2007), the educational value of learning results from the contextualization of knowledge in a challenging situation where the players can assess their way of thinking and behaving, developing what is needed to adjust it to the situation (Sanchez

[6] Council of Europe: The Common European Framework of Reference for Languages. Learning, Teaching, Assessment. Cambridge University Press, Cambridge (2001).

et. al., 2017). From this prospective, the mixed reality, and Tangible User Interfaces (TUIs) in particular, represent a system embodying the interaction with the physical world and its objects part of the scenarios, which supports knowledge acquisition through experience. From a cognitivist learning perspective, this mechanism can support the storing of new knowledge related to the physical world of the culture object of the learning. This is done either through expressive or explorative activity (Marshall et. al., 2003; O'Malley & Stanton, 2002) as the physical interaction with the object allows the learner to construct knowledge of the world through experiencing it or manipulating it (Le Francois, 2000; Markova et. al, 2012). In this view, the learner acts and intervenes physically on the scenario, in line with the interactive story-telling approach (Thue et. al., 2007). The activities that students can play on the scenarios are built as tasks of an established narrative: making choices and solving problems, the player built his knowledge through simulated experience. Furthermore, TUIs allow to develop multisensory and multimodal learning experiences, as additional stimuli such odours can be added to physical object. The player deals with multidimensional data through a gamified learning experience in which visual, spatial, auditory and tactile aspects interact, augmented and mixed by virtual reality applications. Learning through multimedia potentially leads to deeper learning and understanding than within sessions that are presented solely in one format (Farías et. al., 2007). This seems particularly interesting in the context of language learning, since sensorimotor experiences are connected with cognitive functions within the language processing and comprehension. In a multisensory learning experience, when the player/learners understand words, the same sensorimotor areas are recruited as for interacting with the physical objects in a tangible environment (Jirak et. al., 2010).

4.2 The prototype design methodology: situated psychological agents

The methodology, adopted to design and implement the EULALIA educational game, is based on the Situated Psychological Agent Framework (SPAF) (Ponticorvo et. al., 2019), designed to empower psychological or pedagogical settings through the use of specific technology systems. SPAF methodology was deployed in the context of EULALIA by analysing real-life contexts to detect their structural and functional features, including situated psychological agents (SPA) (Ponticorvo et. al., 2019) to embed pedagogical models that favour the active involvement of the learner in the knowledge acquisition process (Dell'Aquila et. al., 2016; Dewey, 1986; Johnson & Johnson, 2008), conciliating it with the instructional process of the entertainment scope (De Freitas, 2018; Michael & Chen, 2005; Shute et. al., 2019; Xun & Ifenthaler, 2018). From this prospective EULALIA represent a good opportunity to investigate the impact of educational games on learning and teaching strategies. The first step of the app development, was defining the learning and game objectives. Then, following a design multi-level approach (Ponticorvo et. al., 2019), three interrelated levels were designed: the shell level, the core level, and the educational level, also named evaluation and tutoring level (Dell'Aquila et. al., 2016). At the shell level, representing the content visible and accessible to the player, the game dynamics and narrative (Neitzel , 2015) was framed, and so the actions that can be performed by the player were shaped, as the environment where those actions take place. Within the shell level, the core level represents the game engine of mechanisms and artificial intelligence rules (Gregory 2017; Söbke & Streicher, in Dörner et. al., 2005). The shell provides a semantic context to the educational activities, while the core level relates to learning objectives and accordingly to skills, abilities, and competences to be acquired. At educational level, the evaluation and tutoring system accompany the learner with the scope of maintaining high the interaction towards the effective accomplishment of the tasks that are connected to explicit educational goals (Baneres et. al., 2016, Serrano-Laguna et. al., 2014) to. According to the SPAF methodology (Ponticorvo et. al., 2017), the narrator is an agent supporting the listener during the learning experience, reading the story and stimulating a meaningful interaction with the listeners. The listener/learner is an agent situated in the learning scene, who actively participate to the story, interacting as guided by the narrator, selecting autonomously the actions, thus affecting the learning scenario. The story constitutes the narrative framework in which the learning experience is developed based on the tasks provided (Brunetti et. al. 2021). Within this structure the educational process that the EULALIA app recall, is similar to that of role-playing games, where the learner evolves the narrative, interacting with the scene according to the mechanism engine, while developing their competences. An artificial intelligence in from of a BOT provides guidance and support, enacting the learning environment, though not directly intervening as a scene actor. The role of this agent is similar to that of the educational practitioners interacting with the learner in the context of a formal educational environment. In the case of EULALIA the BOT is and On-Stage Agent (OSA) (Dell'Aquila et. al., 2017) situated in the scene/playground, supported by a Back Stage Agent (BSA) (Ponticorvo et. al., 2017) constituting the inner mechanism of the game, required to enhance the learning process within a well-defined educational process. The agents are fundamental to provide learners with feedback about their actions during the game experience interaction, and conduce the learners through a reflective process (Tthatcher, 1990) that supports the attribution of personal meanings to the learning experience (Petranek, 1992) and maximizes the learning process enhancing the connection to real-life contexts (Coppard & Goodman, 1979).

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4.3 The components supporting the interaction with tangible objects

The software allowing the scenarios development and logic is STELT (Smart Technologies to Enhance Learning and Teaching) (Di Fuccio & Matroberti, 2018; Miglino et. al., 2014) that combines the management of hardware components (as sensors) and software components (programming and developing environment, programs and activities for users, database for tracking user behaviour and an adapting tutoring system). EULALIA App can be installed on Android smartphones and Windows applications. STELT implements augmented and mixed reality systems based on RFID (Radio Frequency Identification) and NFC (Near Field Communication) technology, that also encompasses the communication protocols of the hardware (RFID/NFC readers) supporting the development of tangible interfaces application (Di Fuccio & Matroberti, 2018; Miglino et. al., 2014). It permits to link together smart technologies and physical materials, determining opportunities for the manipulative approach combined with the use of digitalized technologies (Cerrato & Ponticorvo, 2017). STELT can be a very flexible and useful tool to develop interactive and engaging learning environment. Each object, namely smart object (Kortuem, 2010) is equipped with a RFID/NFC supporting the connection object-meaning, making possible its association to a multisensory learning scenario (Di Fuccio et. al., 2016) In this context, a learning activity is deployed through a quest on a physical map by browsing sensitive STELT point with the phone equipped with NFC sensor. Each interaction on the map, by browsing and searching the next answer and exploring the mart objects that store cultural contents and language meanings, is part of the learning experience.

Figure 19 Develop a tangible map using NFC

4.4 Open Educational Resource (OER) collaborative design as a framework supporting self-determined, autonomous, and collaborative leaning

As mentioned, the main tool is a talking map, a technology enhanced learning tool embedding a multimodal storytelling system, in which a tutoring system in form of an artificial narrator guides the learner through the exploration of cultural elements representing the learning objects. Exploring the city map using the mobile device, the student improves the related language and cultural aspects. It is possible to develop a map for any aspect of the culture to be explored, linking the map to a game scenario and adding on the map as many digital contents as the elements added to the storytelling. Conceived as a tool supporting cultural and language education, EULALIA scenarios focus on three main fields, namely: 1) cultural heritage and traditions, 2) daily life situations, 3) second language acquisition. Such scenarios are delivered through language domain activities (i.e. Scratch) (Grizioti, 2018; Wilson, 2013) deployed via tangible user interfaces applications (Di Fuccio et. al., 2017; Lancioni et. al. 2019; Miglino et. al. 201, Ponticorvo et. al, 2018) as part of technology enhanced language learning strategies that enhance independent and autonomous learning (Nomass, 2013; Salaberry, 2001; Smith & Woody, 2000; Tsou, 2006). One of the strengths of EULALIA is in the fact the possibility of creating multiple and different scenarios based on the same structure, but inspired by different contexts. EULALIA authoring tool allows learners and educational practitioners to autonomously co-create new personalised scenarios, providing opportunities for self-regulated language learning strategies. By using the. In this view, the students and teachers are able to creatively design an Open Educational Resource (OER) (Huang et, al., 2020) co-creating their Language Learning Strategy (LLS), in the form of a game based scenario. In this process, students become responsible to construct their learning experience, moving from consumers to co-producers (Browne, 2010).

The approach underpinning the development of OERs is based on the concept that situational affordances are distributed across a network of learning objects (smart) storing a variety of digital contents, and take place when learners collaboratively and creatively generate new contents connections developing new knowledge artefacts (Siemens, 2005), self-directing and serf-regulating their learning path. Furthermore, in the context of EULALIA, OERs development reflects a collaborative and peer-to-peer approach, where teachers guide the tasks and learners act as sense makers (Mayer, 1006). Learning occurs as learners are able to probe their own construction of meaning against others' understandings; essentially negotiating meaning and knowledge (Panke, 2013).

The literature does not return guidance on TUIs design choices impacting on learning, and efforts to create TUIs based learning experiences seem to focus on the design of the TUI artefacts, not reflecting on the design of the learning activity in which they will be used (Antle & Wise, 2013). The pedagogical approach underpinning the development of Open Educational Resources (OERs) in the context of EULALIA is instead grounded on a solid pedagogical reasoning that pays attention on the importance of connecting learning contents, task and learning goals. It is grounded on the conception that situational affordances are distributed across a network of Reusable and Interoperable Smart Learning Objects that can function as the Learning Materials (LM) of course units as they store a variety of digital contents (Varlamis & Apostolakis, 2006). A course unit can be conceived as a scenario composed of several contents delivered on demand, across a network defined by instructional quests that related different Smart Learning Objects (Wiley, 2000). EULALIA attempts to define a practice of collaborative process to design TUIs learning activities that draws theoretically on studies from information processing, constructivist learning, embodied cognition, distributed cognition and computer-supported collaborative learning (CSCL). Furthermore, EULALIA approach to TUIs design took inspiration from the agile practices and AIMED method (Rocha et. al., 2017), focusing on the content and instructional design, partly taking inspiration from the approach for software development having sprints and incremental development phases (Molena, 2003) and partly taking advantage of the lessons learned from the process of designing artefacts (e.g. a prototype) (Zuckerman, 2005). The process of OERs design actively involved students and language lecturers in co-creation workshops. Selected classes of HEIs students were in fact involved in OERs development activities as part of the project. The workshops were carried out in groups applying brainstorming and sprint retrospective, promoting collaboration among peers and an enquiry-based approach. Both for lecturers and students taking part in EULALIA workshops it was the first opportunity to work with EULALIA. Topics of the OERs developed by teachers and students referred to cultural issues (well-known places, eminent people, sightseeing), potential issues that Erasmus students have to deal with in a foreign country (administration, using means of transport, accommodation, shopping), or related to the university functioning (library, official documents etc.), in line with the findings of the needs analysis conducted at the beginning of the project. The most common situations were related to Erasmus students' needs to use the local language for shopping (71.9 %), transports (64.9 %), university facilities (61.6 %) and accommodation (56.2 %). The OERs have different levels of language advancement from A1-B2 (CEFR).

OER Authoring tool in form of a scheme supporting the advancement of the scenario storytelling process, was provided, in line with digital game design tasks logic to support the design of interaction/task to be played in the game while exploring the scenario on a physical map. The guidelines to ensure adherence to the basic common structure for all OERs were provided with a Google form, in which the co-creators could find the structure of all scenarios, with a focus on the customizable elements. The form was organized in four parts: 1. the language to be learned and the level required by users to use the app, such as basic, independent or proficient user. 2. the first basic information about the scenarios such as the title, the artificial narrator and the map. 3. the structuring of the nodes of the interaction, such as the main steps of their story. So, students created the texts, the pictures and the audio files for both the requests, and the right or wrong feedback to be made by the narrator to support the learner. All the multimedia elements, such as pictures, videos and audio files, together with the map, could be loaded in a specific folder on Google Drive. All these elements, together with the quotes and the information collected through the forms, represented the narrative framework of each scenario. The OERs co-design workshops were facilitated by a “mentor” providing instructional strategies to the different learner groups, at the same time promoting students’ autonomy and responsibility over their own learning path, in order to conciliate OERs personalization and differentiation. In this perspective, OERs design and development combine the fundamental elements of the learning path development (e.g. learning objectives, tasks, and procedures) and ensure adherence of the OERS with the learning goals. Furthermore, this approach, makes OERS and TUIs design part of a learning path itself, introducing a novel approach that fill an exsisting gap within the literature. An exceptional result was achieved for the design, development and implementation of the scenarios. During the project we implemented a total of about 40 scenarios in 5 different languages. In figure 20, the implemented OERs for each language are observable.

All the OERs were transformed in a physical map, embedding the networks of Learning Objects, anchoring them to Tangible Smart Objects that mediate the interaction between the learner and the digital interface, involving sight, touch and smell, and making possible a multisensory learning scenario and an embodied learning experience (Di Fuccio et. al., 2016). The learning path is self-directed by the learner that activates the learning object of the scenario network path using the smartphone. The learner, and so the educational practitioner, can reuse, adapt, change, remix and finally, re-distribute and recombine them, developing different instructional learning path and new knowledge artefacts (Siemens, 2005), personalized based on age, learning goals, curriculum, resources, technical requirements, students need and learning difficulties, learning style.

At the end of the design workshops the participants evaluated the experience through an online survey and were invited to share their suggestions regarding the application in an open discussion. The results gathered clearly showed the great potential of the project and the interest not only of the teachers but also of the students themselves. At the same time, it is worth emphasising that among the advantages mentioned by the participants, it was highlighted that the App is an unconventional, engaging, usable and effective tool supporting learning, particularly in relation to the multimodal interaction it allows. Furthermore, it was mentioned that the opportunity to physically interact, activates a sense of personal control over a cooperative challenge. This characteristic of adaptability of the contents and path, to meet learners' abilities, enhances motivation, concentrations, engagement, confidence, and introduces a flow state that predicts students increased performance (Csikszentmihalyi, 2013; Nakamura & Csikszentmihalyi & Koehn, 2013). Flow is in fact supported when an activity challenge meets the learner's abilities and creates an ideal level of arousal, meaning it creates neither anxiety nor boredom (Panke & Seufert, 2013). Positively related to achievement, engagement does increase when activities are tailored to the personal needs and emotional state of the learner (Standen et. al., 2020).

Application	Name and link	Developer	English name	Language	Language level
	Zwierzęta w Polsce	AMU	Animals in Poland	Polish	B1 / B2 - Independent User
	Obiekty z Listy UNESCO w Polsce	AMU	UNESCO World Heritage Sites in Poland	Polish	A1 / A2 - Basic User
	A Spasso con Elena	UNINA	A tour with Elena	Italian	C1 / C2 - Proficient User
	Wycieczki z Poznania	AMU	Tours from Poznań	Polish	B1 / B2 - Independent User
	Viaggio nella Napoli dei misteri	UNINA	A journey through the secrets of Naples	Italian	C1 / C2 - Proficient User
	Ptaki	AMU	Birds from Poznan parks	Polish	A1 / A2 - Basic User
	Poznańskie graffiti i murale	AMU	Colorful city - Poznań graffiti and murals	Polish	B1 / B2 - Independent User
	Hasła i znaki – mowa miasta	AMU	Slogans and signs – the speech of the city	Polish	A1 / A2 - Basic User
	In Erasmus a Napoli	UNINA		Italian	
	Poznaj Polscy nobliści	AMU	Polish Nobel Prize winners - part 1	Polish	B1 / B2 - Independent User
	Conoce Valencia	UA	Let's know Valencia	Spanish	B1 / B2 - Independent User
	Poznaj polskich noblistów	AMU	Polish Nobel Prize winners - part 2	Polish	B1 / B2 - Independent User
	Tour gastronomico di Napoli	UNINA	Food tour of Naples	Italian	B1 / B2 - Independent User
	Alcoy puentes hacia su historia	UA	Alcoy: bridges across its history	Spanish	C1 / C2 - Proficient User
	Is-soppa	UM	The widow's soup	Maltese	A1 / A2 - Basic User
	Krajobrazy Polski	AMU	Landscapes in Poland	Polish	A1 / A2 - Basic User
	Polskie zupy	AMU	Polish soups	Polish	A1 / A2 - Basic User
	Podział Polski	AMU	Administrative Division of Poland	Polish	B1 / B2 - Independent User
	L-imdina	UM	Mdina - the silent city	Maltese	B1 / B2 - Independent Users
	Mieszkanie w Polsce	AMU	Living in Poland	Polish	B1 / B2 - Independent User
	Uniwersytet	AMU	University	Polish	A1 / A2 - Basic User
	Akweny w Poznaniu	AMU	Aquatic in Poznań	Polish	A1 / A2 - Basic User
	Polskie tradycje	AMU	Polish traditions and customs of Easter and Christmas	Polish	B1 / B2 - Independent User
	Specjaliści	AMU	Specjalists and services	Polish	B1 / B2 - Independent User
	Alicante	UA	Alicante. Musts for an Erasmus student	Spanish	A1 / A2 - Basic User
	Sławne osoby	AMU	Famous people who lived in Poznan	Polish	B1 / B2 - Independent User
	Muzea w Poznaniu	AMU	Museums in Poznań	Polish	A1 / A2 - Basic User
	Paella vegetariana	UA	Paella for vegetarians	Spanish	A1 / A2 - Basic User
	Drewniane kościoły	AMU	Wooden Churches in Wielkopolska	Polish	B1 / B2- Independent User
	Hasła i znaki 2	AMU	Slogans and signs – the speech of the city	Polish	A1 / A2- Basic User

Figure 20 OERs

4.4.1 Examples of OERs developed

All the OERs developed allow the user either to interact through a virtual or physical map. The different symbols on the map, also called smart objects (Liu & Baiocchi, 2016), store digital contents that compose the situational affordances network supporting the learning path. In fact, each interactive object on the map constitutes an interoperable Learning Object (Wiley, 2021) that can be reused within the storytelling to develop different instructional learning paths. EULALIA ground-breaking approach combines both the virtual and real dimensions, closely connecting them, as the interaction between the user and the digital interface is mediated by the tangible objects. For example, the outline of an historical building placed on the map of the city of Naples, as showed in figure 23, could have virtual or physical shape, can be moved on the map to compose a different exploration path, including details and virtual contents about cultural and historical information. In a typical exercise, the student explores the map interacting with the objects based on the system quests. If correctly placed, the system provides a confirmation statement (Great, bravo, Great job!). At the same time, the application allows the student to read or hear the information linked to the objects.

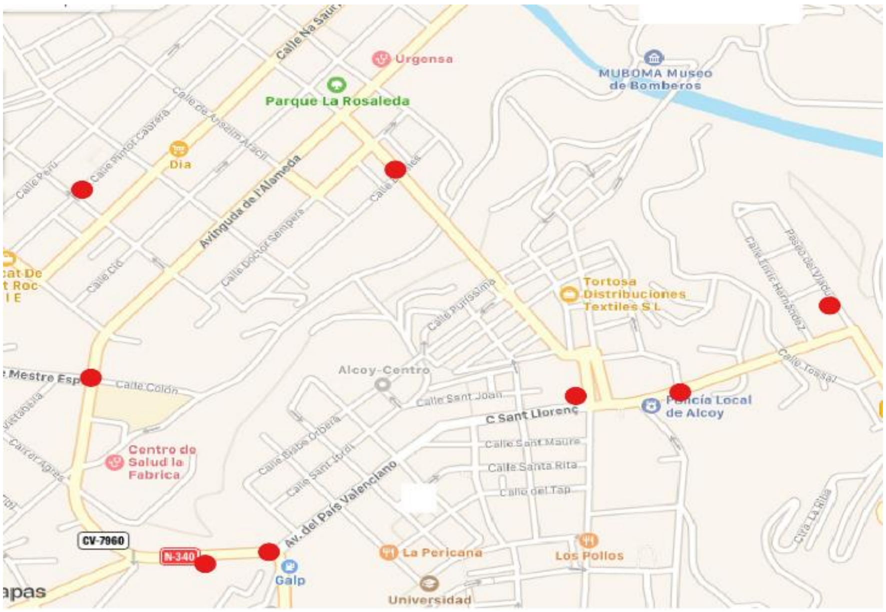

Figure 21 Example of interactive map "Conoce Valencia" developed during Eulalia workshop for teachers in Alicante, Spain

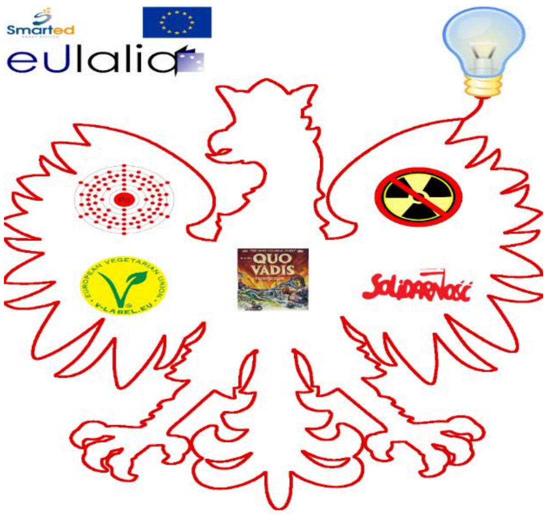

Figure 22 Example of interactive map "Famous Polish Nobel Prize winners" developed during EULALIA workshop for teachers in Poznań, Poland.

Figure 23 Example of interactive map "Explore University of Naples Federico II and the city of Naples, developed during the workshop in Naples, Italy

4.5 EULALIA preliminary pilot results

The EULALIA application approach aimed to integrate and innovate the learning methodologies of the university language centres for Erasmus students in the four HEIs involved in the project, by embedding an innovative learning tools based on the paradigm of Mobile Learning and Game-Based Learning methodology. Conceived within the scope of the EULALIA project as a tool supporting cultural and second language education, the scenarios focused on three main fields, namely: 1) cultural heritage and traditions, 2) daily life situations, 3) second language acquisition. Accordingly, the app was piloted in the context of the EULALIA project with the aim to evaluate the practice of a novel learning and teaching approach based on the introduction of the App, while observing the impact in terms of students' second language competences and cultural awareness about the hosting city, with a particular attention to the real life needs of the students leaving in a country different from that of origin.

Within the scope of the EULALIA project, the mixed-method research included 2 online student surveys (one pre-survey and one post-survey developed ad hoc) which received respectively 328 and 239 responses regarding the dimensions of perceived improvement of language competencies, and perceived improved competences about historical and cultural aspects of the hosting city. The target audience were foreign students and, more specifically: students having used the EULALIA application (hereafter called EULALIA group) as a supportive method in the traditional lessons; and a control group of students (hereinafter called Reference group) who did not use the EULALIA application and attended traditional classes only. The students participated on a voluntary basis among those taking part in the language courses offered and the language centers of the Universities partnering in the project[7]. The pre-survey and post-survey were respectively disseminated during the first weeks and at the end of the HEIs language courses in the four participating countries. An additional on line questionnaire focusing on accessibility, based on System Usability Scale (Brooke, 1996) was administered to teachers and lecturers who adopted the EULALIA app within their language courses at the University center. Among the same teachers and lecturers, 6 per country, for a total of 24, were engaged in interviews with the aim of collecting feedback useful to orienting the further application of the App in the context of the teaching and learning practice. The data were collected and analysed at country level[8] by the partners and reported as part of the project deliverables. Besides any possible reflection on the

[7] Universties: University of Alicante, University of Malta, Adam Mickiewicz University in Poznań
[8] Software used: Suvery Monkey, Jamovie, Qualtics, ATLAS.

consistency of the data, it is useful to report here some conclusions that it was possible to outline from the feedback collected. There remarks might support further applications of the app in the context of the learning and teaching practice.

Regarding the students' perception of improvements in terms of language competences, a relevant result to be mentioned relates to the fact that **major progresses were observable in the case of the students with an intermediate language level and above**, showing that the EULALIA App is most likely **suitable for students with a level of previous knowledge ranging from B1 to C1** (CEFR). Regarding the perceived acquisition of cultural knowledge of the host city registered, approximately 65% of respondents within the EULALIA group declared they felt that their **knowledge about the host city improved thanks to the language courses supported by the use of the EULALIA App**, compared to 57% of respondents registered in the control group that declared they have improved their knowledge thanks to the courses, based on traditional methods not appliying the use of Apps. More precisely, the EULALIA group of students reported that they have learnt about the university history (67%), the exploration of the campus (66%), the exploration of the city (68%) and the name of at least a famous person in the region they are hosted (58%) (see figure 24).

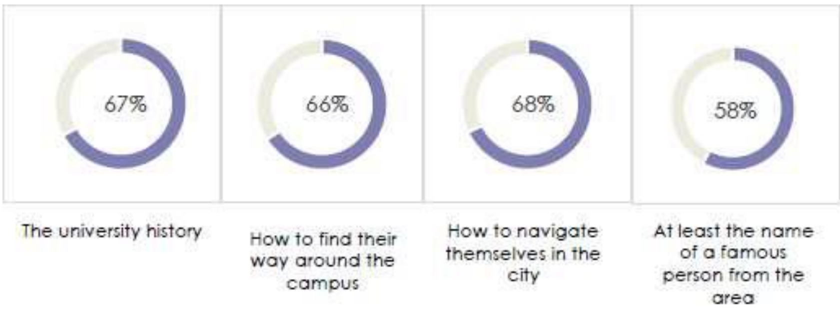

Figure 24 Results reported by the EULALIA group regarding the perceived gained knowledge of the hosting city culture

Regarding accessibility, EULALIA App was judged, by teachers and lectures involved in the experimentation, as a tool not presenting usability barriers and with a good accessibility for students with sensory disabilities. On regards, the vocal text reading tools were defined as functionalities supporting the App usability by students with learning difficulties. Moreover, the SUS scale administered to students at the end of the language course applying EULALIA, returned a usability score of 53,63 on the scale ranging from 0 to 100.

To summarise the evaluation and the feedback collected during the piloting, it should be mentioned that HEIs researchers involved in the project agreed that the experimentation conducted in the context of formal higher education, of a mobile learning application such as EULALIA, represented an **opportunity to introduce a learning approach more closely related to students' interests and needs**. Lectures reported that the app strongly **support students' motivation and enjoyment in the learning path**, and t**riggered their capacity to take responsibility over the learning path**, **positively contributing to the learning outcomes**. The feedback collected, acknowledged the App as an effective tool to **support students' self-directed learning strategies introducing enjoyment as a key element to be further investigated in relation to students perceived impact on learnin**g. HEIs lecturers involved in the pilot study recounted EULALIA as a proficient tool to support second learning acquisition and tangible and intangible heritage enculturation, and defined it as an **effective tool to introduce an innovative teaching approach**. The feedback collected highlighted positive opinions regarding the application of real life and fictitious examples, mentioning that **this introduces a shift in the teaching and learning approach in the way it adds to theoretical, traditional learning, the possibility to introduce subjects in relation to more actual, practical experience**. In particular, lecturers emphasised the added value of the OERs co-design approach, stressing the importance of having access to personalised materials co-created by students, and the prospective to embed the OERs development process an integral part of the language course. In terms of pedagogical innovation, lecturers defined the app potentially introducing a change in the practice of second language learning, as it enhances group dynamics, concentration, motivation and memorisation. Lecturers reported that students improved their capacity to communicate and experience local life, thanks to the context-based learning. **The collaborative approach introduced by the OERs development model was defined by lecturers as the most successful element introduced**. Clearly, the advantages of the co-creation approach introduced were evident for students and teachers as an effective way to foster creativity, enhance collaboration and peer learning. The feedback collected during the piloting, supports the position that in the case of EULALIA **the students exposed to gamified learning activities were more motivated and engaged than the students following a traditional approach**. Furthermore, EULALIA introduced a pedagogical shift as it **facilitated the contextualization of learning contents, opening opportunities for students to correlate them with real file situations**. Evidences also highlight EULALIA potential for transferability, thanks to the open and ready-to-use educational materials (OERs), and the possibilities offered by the authoring tool to create additional personalized contents. For all this reasons, the tool is suitable to be used to conduct further studies. In particular, the **HEIs lecturers participating in the pilot study highlighted the opportunity to develop a study focusing on the difference between the 2 modalities provided (i.e. Virtual and Mixed**) and this suggestion partly inspired the study described in the following chapter.

Chapter 5

The empirical study

The state of the art concerning the use of technology in education, explored in chapter one, suggests that tablets and handheld devices are among the most widely used and appreciated, in particular because of their effectiveness supporting flexible, ubiquitous, and personalised learning. Several studies explored the role of mobile applications as well as game based learning tools, to reinforce the motivation and strengthening the learning engagement, nevertheless many questions regarding the appropriateness of the content and pedagogical approaches of some mobile applications remain open. Taking the most from these findings, the present study is grounded on the use of a game based mobile application that was developed in a real educational context applying a participatory co-design approach. In fact, EULALIA game based scenarios and EORs allow to embed educational objectives and subjecting related contents, to support active and self-directed learning strategies associated with curricula goals. The App was conceived to deploy an experiential and situated approach to learning, engaging students in hands-on experiences and reflection, to connect knowledge to real-world situations, proposing activities that stimulate the learners in solving real-life problems in a safe simulated context. The gamification mechanisms not only provide real life scenarios keeping students motivated, but it is also proved by several studies to enhance satisfaction and enjoyment, key factors impacting on learning ability and performances. Despite the fact that the literature reports numerous analyses of the factors determining the use and integration of technologies in the learning context, a few studies consider the impact on learning outcomes. The literature, explored in charter two and three, allowed to outline the factors that affect students perceived impact on learning in the context of technology use. Grounded on such theoretical frameworks, the present study attempts to explore the perceived impact on learning of a game based application, the design of which was inspired by the Agent Based Modelling. In this framework the App is an enjoyable serious game, based on immersive everyday scenario storytelling, in which the learner is assisted by an artificial avatar in completing tasks that relate to situations that students would encounter exploring an unknown city and its cultural aspects. The learning approach underpinning the App development and the participative methodology used to create the learning contents, are the reasons behind the selection of this App to support the study, as they highlight the importance of providing technologies that are conceived to support learning outcomes, considering factors such as enjoyment, satisfaction, compatibility, and confirmation, besides acceptability. In addition, the App allows the use both in virtual reality and mixed reality modality. This opens the opportunity to explore the differences between the two interaction modalities, in terms of factors assumed as influencing students perceived impact on learning. In this way the present study unfolds in a still recently explored field of technology enhanced leaning, that related to the use of virtual and mixed reality, as well as of Tangible User Interfaces (TUIs), considered among the most innovative, while not fully explored in educational context. TUIs, in fact, bring a novel approach to learning, embodying knowledge within physical objects that students can interact with, building connections with the real word skills and experience.

5.1 Purpose of the study

Despite the fact that much of the literature analysed seem developed to inform educational design, very few studies appear grounded in a solid pedagogical reasoning, while it is crucial to investigate how the most recent technology development, such as virtual, augmented and mixed reality, can impact on learning. Virtual Reality can transform educational contents by creating a virtual world that provides immersive and engaging learning experiences. Mixed Reality (MR), and Tangible User Interface (TUI) in particular, represent a huge potential for Virtual Reality (VR), because can support rich haptic cues, changing the relationship of the learner with the technology interface. Moreover, the storytelling underpinning the learning path, allows a direct action of the learner within a real word scenario, that deploys a situated and embodied learning approach. In terms of impact on learning, the differences between VR and MR, two of the most innovative technologies currently receiving attention from the educational community, do not seem to have been the subject of considerable studies. This study attempts to explore such differences in order to contribute to the research in the field of mixed reality, particularly of tangible user interfaces, as recent innovations in the field of technology enhanced learning. In particular, the present study aims to investigate the differences between the VR and MR conditions in terms of factors that, as for the literature examined, are proved to impact on students' perceived learning outcomes.

Following the prescriptions of the Technology Acceptance Model – TAM (Davis 1989), Expectation Confirmation Model – ECM (Bhattacherjee, 2001), Innovation Diffusion Theory-IDT (Rogers, 2003) and the Flow Theory (Csikszentmihalyi, 1997), the theoretical foundations of the model underlying the present study indicate that Ease of Use (PEOU) and Usefulness (PUSS) are key determinants of user Perceived Impact on Learning (PIML). Students who perceive

technologies as easy to use experience positive impacts on their learning with the tools (Bhattacherjee, 2001; Bölen, 2020; Ifinedo, 2017; Oghuma et. al., 2016). Students who do not perceive technologies as difficult to use, are also more likely to perceive it compatible with their learning (Bhattacherjee, 2001). Reasonably, students that consider the technology meeting their expectations appreciate the advantages of using it for learning, and are also more satisfied with such use and enjoy it (Bhattacherjee, 2001; Hayashi et al. 2004; Ifinedo, 2017; Igbaria et. al., 1995a; Lee, 2010; Teo et. al., 1999), so Perceived Compatibility (PCMT) and Confirmation (CONF) positive influences Satisfaction and Enjoyment (PENJI). Satisfaction (SATI), that refers to how satisfied students are with the experience of technology-mediated learning, is affected positively by Perceived Usefulness (PUSS) and Perceived Ease of Use (PEOU) (Balderas et. al., 2018; Ifinedo, 2018; Muñoz-Carril et. al., 2021; Oghuma et. al., 2016) and it is demonstrated that influences positively the Perceived Impact on Learning (PIML) (Chow & Shi, 2014; Hern andez-Selles et. al., 2019; Ifinedo, 2017a; Liu; 2016; Molinillo et. al., 2018). Perceived Enjoyment (PENJI) that affects PUSS and Satisfaction (SATI) of users in terms of their use of emerging technologies, is also demonstrated to positively impact of perceived learning outcomes and performance (PIML) (Ifinedo, 2017; Lin, 2012; Mansouria & Piki, 2016; Teo & Noyes, 2011).
The present study seeks to investigate if Perceived Impact on Learning (PIML) is higher perceived in the case of students using the app in VR modality or in MR modality and eventually attempts to interpret this difference by investigating the statistical significance of PIML predictors and the relations existing between the variables included in the model.

5.2 Research method

A quantitative research design was applied using a two conditions between-subjects approach with participants randomly assigned to each condition: Virtual Reality (VR) and Mixed Reality (MR) applying the use of Tangible Objects (Tangible User Interfaces – TUIs). Data were collected administering a survey to 60 students as part of group a, VR modality, and 60 students as part of group b, MR modality, after they experienced using the EULALIA Application in the English language. Ethical clearance was obtained from the instructor's university research ethics board. Participation in the survey was voluntary. Prerequisites to participate were: being enrolled in a university degree course; being Italian mother tongue; being originally not from the city of Naples or the Campania region (to avoid bias related to previous knowledge of the learning contents of the scenario).

The measurement of each of the seven constructs includes 29 items (questions) that were adopted from the international literature where their reliability and validity was already established (Ifinedo, 2017). Items were adapted from Ifinedo (2017), not including the terms "MIS" or "my MIS course" and substituting the term "blogs" with the term "App". The seven-point Likert-type scale ranging from "strongly disagree" (1) to "strongly agree (7)" was used for the measurement of all the items. The complete form of the questionnaire used in the survey consisted of three units. The first unit included demographic questions and questions related to the prerequisites for participation, the second unit included questions related to their experience using apps (in general and to learn); while the third unit included the questions related to the measurement of the seven constructs, as reported in table 1.

Costruct	**Item no**	**Item descrption**
(1) Perceived Compatibility - PCMT	PCMT_1	Using the app fits well with learning
	PCMT_2	Using the app fits well with helping me to be efficient in learning
Ifinedo (2017), Chen, Lou, and Luo (2002) McGill and Hobbs (2008) and Lin (2012).	PCMT_3	Using the app is compatible with my learning
	PCMT_4	Using the app has provide me with good opportunity to lean
(2) Perceived ease of use - PEOU	PEOU_1	My interaction with the app to support my learning is very clear
	PEOU_2	Learning to use the app is easy for me
Ifinedo (2017), Davis (1989), Lee (2010)	PEOU_3	I found it easy to use the app for learning concepts
	PEOU_4	Overall, I believe that it is easy to use the app to support my learning
(3) Perceived usefulness - PUSS	PU_1	Using the app improved my learning performance in that subject
	PU_2	Using the app increased my learning effectiveness in that subject
Ifinedo (2017), Lee (2010)	PU_3	Using the app helped me learn better
	PU_4	Using the app are helpful in preparing for quizzes/tests
(4) Satisfaction - SATI	SATI_1	I am satisfied with the app as learning tools
	SATI_2	I am satisfied with the app as tools for creating and sharing knowledge
Ifinedo (2017), Lee (2010), Bhattacherjee (2001)	SATI_3	I feel satisfied using the app
	SATI_4	I am happy I used the app for learning
	SATI 5	I am pleased with the experience of using the app
	CONF_1	My experience with using the app was better then what I expected
(5) Confirmation - CONF	CONF_2	Using the app for learning was better than I expected
	CONF_3	The service provided by the app was better then I expected
Ifinedo (2017), Bhattacherjee (2001)	CONF_4	Overall, most of my expectations regarding using the were confirmed
(6) Perceived impact on learning - PIML	PIML_1	The use of the app has positive impacts on my learning the subject
	PIML_2	The use of the app is an important and valuable aid to me
Ifinedo (2017), Bhattacherjee (2001), McGill and Hobbs (2008) and Lin (2012)	PIML_3	I gained a clearer understanding of some app concepts from peers'
(7) Perceived enjoyment - PEN	PENJI_1	Using the app to learn is pleasurable
	PENJI_2	I had fun using the app to learn concepts and topics
Ifinedo (2017), Davis et al. (1992), Igbaria et al. (1995a, b) and Teo et al. (1999)	PENJI_3	Using the app to learn is pleasant
	PENJI_4	I found the app to be interesting
	PENJI 5	I found the use of the app to be enjoyable

Table 1 Questionnaire's items

The theoretical foundations of the model taken from Ifinedo (2017) are the Technology Acceptance Model – TAM (Davis 1989) and Expectation Confirmation Model – ECM (Bhattacherjee, 2001), the Innovation Diffusion Theory- IDT (Rogers, 2003) and the Flow Theory (Csikszentmihalyi, 1997). Ifinedo research revealed that Perceived Enjoyment (PENJI), Compatibility (PCMT), Usefulness (PUSS), Ease of Use (PEOU), and Confirmation (CONF) have positive influence on students' Satisfaction (SATI) with the use of the tool for learning. Perceived Enjoyment (PENJI) has the greatest influence on students' Satisfaction (SATI). Perceived Impact on Learning is positively influenced by Perceived Ease of Use (PEOU), Enjoyment (PENJI), and Satisfaction (SATI). The model, retrieved from Ifinedo (2017) and underpinning the questionnaire is represented in figure 25.

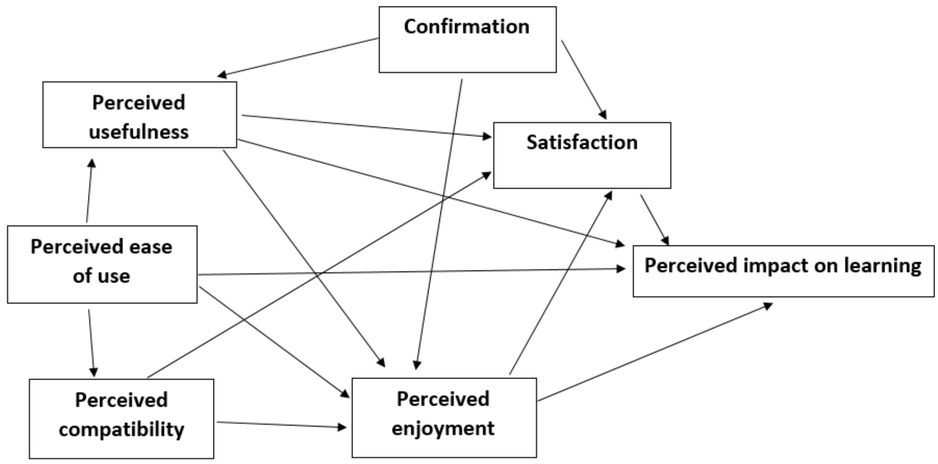

Figure 25 Ifinedo research model, developed from Ifinedo (2017)

5.3 Participants

Either group, a and b, was composed of 40 females (n = 60, 66,67%) and 20 males (n = 60, 33,33% %) between the age of 18 and 29. The mean age was 25 in the case of group a (standard deviation (SD =1.84) and 23 in the case of group b (standard deviation (SD = 3,14). All of them were enrolled in a university degree course and had never previously experienced the use of EULALIA App. In order to obtain homogeneity between group a and b, students were grouped based on gender, age group, familiarity using apps, and familiarity using apps to learn, then randomly selected. 87% of the participants declared to be familiar using apps, while 13% declared not to be familiar using apps, both in the case of group a and b. 57 % of the participants in both groups declared to have experience using Apps to learn, while 43% declared not having such experience.

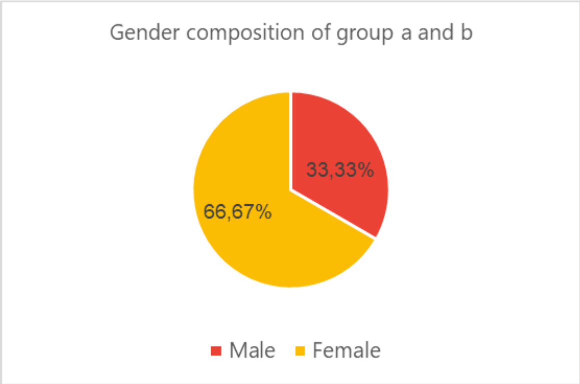

Figure 26 Graphic gender composition of group a and b

Gender	Group	Frequenze	% Total
Male	a	20	16.7 %
	b	20	16.7 %
Female	a	40	33.3 %
	b	40	33.3 %

Table 2 Frequencies of Gender

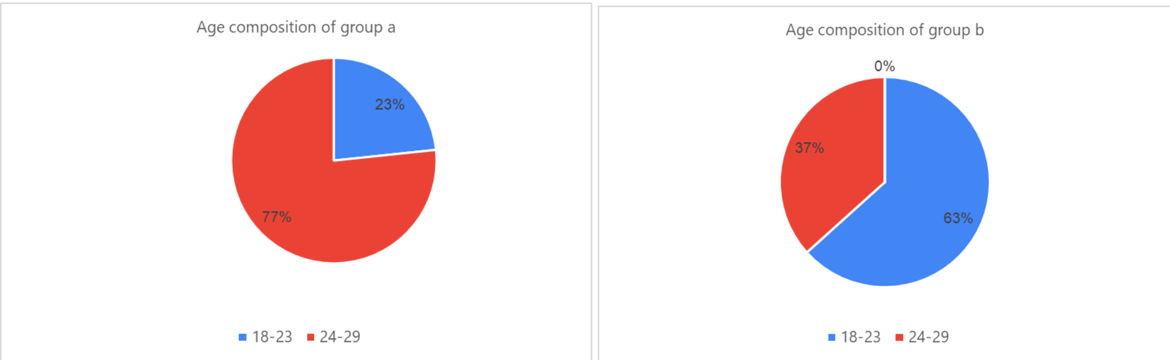

Figure 27 Graphics age composition of group a and b

	Group	N	Mean	Median	SD	Min	Max
Age	a	60	25.0	25.0	1.84	22	29
	b	60	23.0	22.5	3.14	18	29

Table 3 Mean of groups age

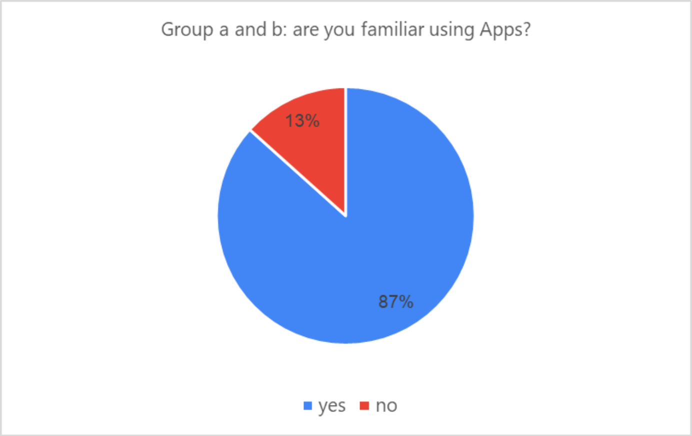

Figure 28 Graphic familiarity using Apps per group a and b

Are you familiar using Apps?	Group	Frequency	% of Total
yes	a	52	43.3 %
	b	52	43.3 %
no	a	8	6.7 %
	b	8	6.7 %

Table 4 Frequency of familiarity using apps

Figure 29 Graphic familiarity using Apps to learn per group a and b

Are you familiar using Apps to learn?	Group	Frequency	% of Total
no	a	26	21.7 %
	b	25	20.8 %
yes	a	34	28.3 %
	b	35	29.2 %

Table 5 . Frequency of familiarity using apps to learn per group a and b

5.4 Procedure

One or more rooms where to work with one student at a time were identified (pc room, teacher room, empty classroom, laboratory, etc.), and the setting was prepared for the VR and MR modality. Upon arrival at the laboratory students were assigned to one of the modality associating a unique code with the study condition and a progressive number. Students were called one at a time and information sheet and consent form were administered to be signed. Each student was instructed about how to start the appropriate modality and no support was provided during the activity experimentation. At the end of the activity, the questionnaire was administered to the student. Detailed information regarding the research objectives and the App were given to the students only after completing the questionnaire.

5.5 Setting and materials

The room or rooms dedicated to the study were comfortable, as quiet as possible to facilitate the concentration of the participant, equipped with a table and chair. The following equipment was required for each participant:

Virtual Reality modality:

- a smartphone on which was previously installed the application compatible with the selected scenario that the learner would have to explore. The smartphone constitutes the learner interface providing direct access to the learning experience.
- a pc for the participant to read the information sheet, to compile the consent form, and to fill in the questionnaire.

Mixed Reality modality:

- a smartphone on which was previously installed the application compatible with the selected scenario that the learner would have to explore.
- a physical map of the City of Naples set up on the table on which tangible objects are placed and equipped with NFC constituting the Tangible USER Interface (TUI) providing the learner the access point to the interaction with the learning contents and experience through the smartphone that activates the sensible NFC equipped points on the map.
- a pc for the participant to read the information sheet, to compile the consent form, and to fill in the questionnaire.

5.5.1 The game scenario

The methodology adopted to design and implement the EULALIA educational game in form of App was based on the Situated Psychological Agent Framework (SPAF) (Ponticorvo et. al., 2017), a methodology designed to empower psychological or pedagogical settings through the use of specific technology systems. EULALIA technology-enhanced learning tool provides the learner with a narrative framework, in which they have to make choices and solve problems in a multimodal and multisensory way. Structure of the interaction with the scenario can be summarized as follow:

The playground scenario. A space that delimitates the action options of the learner defined by the narrative structure: in the case of the VR modality a virtual map of the city of Naples accessible via smartphone downloading the App from Google Play selecting the scenario; and a physical map in the case of the MR modality including physical objects that can be manipulated by the learner and that are anchored to multimedia contents (video, audio, etc.). The city of Naples map (figure 30) supports the exploration of tangible and intangible cultural heritage in line with the learning objects: acquisition of knowledge about the language or cultural aspects of a country/region/city. The data included in the research sample correspond to participants not from the City of Naples and not from the Campania Region.

Figure 30 Playground scenario, maps of the city of Naples where sensitive points corresponding to cultural elements are equipped with NFC sensors

Learner: as a single player acting in the playground, exploring the map to discover the story and learn about a new country, changes the state of the scenario interacting with the storytelling.

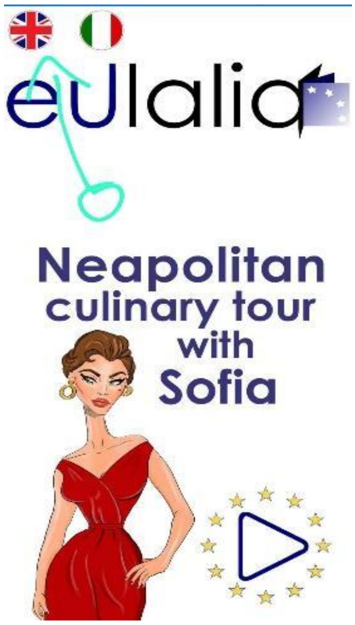

Figure 31 Learner exploring the physical map of the city of Naples using a smartphone

Figure 32 On Stage Agent, artificial intelligence narrator as in EULALIA app

Trainer: the researcher, who has educational, training, or assessment functions, can not modify the playground state but in the case of the present study checks the equipment, supervises the activity, interacts with the participant only before and after they have experienced the use of the app.

Back Stage Agent (BSA): the artificial intelligence not situated in the playground constituting the inner mechanism of the game storytelling that interacts directly with the OSA.

On Stage Agent (OSA): the artificial intelligence narrator, the Situated Psychological Agent (SPA) in the playground, interacting directly with the leaner and engaging the learner attention by telling anecdotes or asking questions to the learner that tries to satisfy the storyteller's request and continue the interaction within the scenario. It is represented in figure 32.

5.5.2 Virtual and Mixed Reality conditions

The scenario selected for the study share the same game logic and structure in the case of virtual reality and mixed reality modality. Both the virtual and tangible map of the city of Naples support the exploration of a storytelling made on interconnected learning contents focusing on tangible and intangible cultural heritage elements. The learner explores the map finding the points of interest of the story, following the artificial narrator suggestions and listening to its feedbacks. The storytelling progression and learning experience advance based on the learner interaction with the learning contents placed on the map. Using the Virtual Reality modality, the whole experience takes place on the user's smartphone. As for the **Mixed Reality modality** the learning experience is actuated on the talking physical map. In this case, sensitive points on the maps, namely Tangible Smart Objects are equipped with NFC tags to deploy the learning contents. So in this case the user interacts via a Tangible User Interfaces (TUIs) and the learning experience is augmented, enriched by elements pertaining to the physical word that connect the learning experience to real life contexts.

5.6 Data analysis and results

The following paragraphs introduce the constructs descriptive statistics, then present the results of the correlation test performed to identify and describe the relationships between the constructs, namely: Perceived Compatibility (PCMT), Perceived Ease of Use (PEOU), Perceived Usefulness (PUSS), Satisfaction (SATI), Confirmation (CONF), Perceived Impact on Learning (PIML), Perceived Enjoyment (PENJI). Finally, report the results of the tests undertaken to investigate the differences between the two conditions. All the analysis were performed using Jamovi.

5.6.1 Constructs descriptive statistics

5.6.1.1 Perceived Compatibility - PCMT

In table 6, the mean value and standard deviation for the construct Perceived Compatibility (PCMT) are given. The mean value of the VR condition is 22.2 (M = 22,2; DS = 4,48), while in the case of MR condition the mean value reported is 21,8 (M= 22,8; SD = 3,17). The values obtained seem to suggest that, in general, the students consider VR and MR technology compatible with their learning and a good opportunity to learn, but for some aspects of MR was apparently considered to fit better with learning, while VR was considered to fit better with helping students to be efficient in learning.

	Group	N	Missing	Mean	Median	SD	Minimum	Maximum
PCMT	a	60	0	22.2	22.0	4.48	12	28
	b	60	0	21.8	22.0	3.17	15	27

Table 6 Descriptives PCMT

In fact, results reported in table 7 show that the mean value of the MR condition for PCMT_1, and PCMT_4, is slightly higher than VR, while the opposite is noticeable in the case of PCMT_2 and PCMT_3. These difference will be further explored in the following paragraphs, per constructs and per item, and significant results will be reported.

	Group	N	Missing	Mean	Median	SD	Minimum	Maximum
PCMT_1	a	60	0	5.67	6.00	1.115	3	7
	b	60	0	5.80	6.00	0.403	5	6
PCMT_2	a	60	0	5.37	5.00	1.288	3	7
	b	60	0	5.28	5.00	1.180	3	7
PCMT_3	a	60	0	5.60	6.00	1.224	2	7
	b	60	0	5.13	5.00	1.384	1	7
PCMT_4	a	60	0	5.57	6.00	1.280	3	7
	b	60	0	5.58	6.00	1.211	2	7

Table 7 Descriptives PCMT per item

5.6.1.2 Perceived Ease of Use – PEOU

In table 8, the mean value and standard deviation for the construct Perceived Ease of Use (PEOU) are given. The values obtained seems to allow to point out that, in general, the students consider VR and MR technology easy to use. The mean value of the VR condition is 22,6 (M = 22,6; DS = 4,62) while in the case of MR condition the mean value reported is 22,5 (M= 22,5; SD = 3,90). The analysis per single item highlights aspects in favour of either modality.

	Group	N	Missing	Mean	Median	SD	Minimum	Maximum
PEOU	a	60	0	22.6	24.0	4.62	14	28
	b	60	0	22.5	23.0	3.90	8	28

Table 8 Descriptives PEOU

In fact, as reported in table 9, for PEOU_1, it seems that the interaction with the App to support learning was perceived clearer by students using it in VR modality then in the case of the students using the app in the MR modality. Furthermore, learning to use the app was apparently easier for the students using the app in VR modality then for the students using the MR modality (PEOU_2). Instead, the results seem to suggest that students using the app in MR modality found it easier for learning concepts, then students using the VR modality (**PEOU_ 3**). Additionally, based on students' belief, it seems that the app in MR modality was easier to support learning, then in the case of VR modality (**PEOU_** 4). These difference will be further explored in the following paragraphs, per constructs and per item, and significant results will be reported.

	Group	N	Missing	Mean	Median	SD	Minimum	Maximum
PEOU_1	a	60	0	5.53	6.00	1.29	3	7
	b	60	0	5.33	5.00	1.16	2	7
PEOU_2	a	60	0	5.82	6.00	1.16	4	7
	b	60	0	5.75	6.00	1.14	2	7
PEOU_3	a	60	0	5.60	6.00	1.25	3	7
	b	60	0	5.68	6.00	1.08	2	7
PEOU_4	a	60	0	5.65	6.00	1.31	3	7
	b	60	0	5.75	6.00	1.14	2	7

Table 9 Descriptives PCMT per item

5.6.1.3 Perceived Usefulness – PUSS

In table 10, the mean value and standard deviation for the construct Perceived usefulness (PUSS) are given. The mean value of the VR condition is 22,6 (M = 22,6; DS = 6,21) while in the case of MR condition the mean value reported is 21,3 (M= 21; SD = 4,08). The results obtained seems to suggest that, in general, the students considered VR and MR technology useful for learning, even if some differences are retraceable looking at the values per item.

	Group	N	Missing	Mean	Median	SD	Minimum	Maximum
PUSS	a	60	0	21.6	23.5	6.21	10	28
	b	60	0	21.3	21.0	4.08	8	28

Table 10 Descriptives PUSS

In fact, the results, reported in tables 11 per single item of the construct, seem to suggest that students using the app in MR modality perceived to have improved their learning performance in the subject, more than students who used the app in the VR modality (PUSS_ 1). Furthermore, students using the app in MR modality perceived it more helpful in preparing for quizzes/tests than the students using the app in VR modality (PUSS_ 4). Instead, the app in VR modality was perceived to have improved students learning effectiveness in the subject, more than in the case of students who used the app in the MR modality (PUSS_ 2). Similarly, the app in VR modality seems to have helped students to learn better than in case of students using the app in MR modality (PUSS_ 3). These differences will be further explored in the following paragraphs, per constructs and per item, and significant results will be reported.

	Group	N	Missing	Mean	Median	SD	Minimum	Maximum
PUSS_1	a	60	0	5.33	6.00	1.63	1	7
	b	60	0	5.38	5.00	1.21	2	7
PUSS_2	a	60	0	5.32	6.00	1.60	1	7
	b	60	0	5.15	5.00	1.30	1	7
PUSS_3	a	60	0	5.53	6.00	1.58	3	7
	b	60	0	5.33	5.00	1.16	2	7
PUSS_4	a	60	0	5.37	6.00	1.67	2	7
	b	60	0	5.40	5.00	1.30	2	7

Table 11 Descriptives PUSS per item

5.6.1.4 Satisfaction - SATI

In table 12, the value and standard deviation for the construct Satisfaction (SATI) are given. The mean value of the VR condition is 22 (M = 22; DS = 4,19) while in the case of MR condition the mean value reported is 20 (M= 20; SD = 3,20). Results seem to suggest that students using the VR were more satisfied then those using the MR.

	Group	N	Missing	Mean	Median	SD	Minimum	Maximum
SATI	a	60	0	21.5	22.0	4.19	11	28
	b	60	0	20.4	20.0	3.20	10	25

Table 12 Descriptives SATI

Observing the results included in table 13 for the mean and standard deviation of each item of the construct, it seems possible to derive that VR was considered more satisfying under all the specific aspects.

	Group	N	Missing	Mean	Median	SD	Minimum	Maximum
SATI_1	a	60	0	4.22	4.00	0.865	2	6
	b	60	0	4.02	4.00	0.748	2	5
SATI_2	a	60	0	4.25	4.50	0.932	2	6
	b	60	0	4.23	4.00	0.745	2	5
SATI_3	a	60	0	4.23	4.00	0.945	2	6
	b	60	0	3.97	4.00	0.780	2	5
SATI_4	a	60	0	4.45	5.00	0.928	2	6
	b	60	0	4.12	4.00	0.761	2	5
SATI_5	a	60	0	4.35	4.00	0.860	2	6
	b	60	0	4.03	4.00	0.843	2	5

Table 13 Descriptives SATI per item

5.6.1.5 Confirmation – CONF

In table 14, the mean value and standard deviation for the construct Confirmation (CONF) are given. The mean value of the VR condition is 21,4 (M = 21,4; DS = 6,08) while in the case of MR the mean value reported is 20,8 (M= 20,8; SD = 4,13). The results seem to suggest that in general students' expectations were met both in the case of MR and VR. Anyway, the mean and standard deviation per item, in table 15, seems to reveal that VR met slightly better the expectations.

	Group	N	Missing	Mean	Median	SD	Minimum	Maximum
CONF	a	60	0	21.4	22.0	6.08	8	28
	b	60	0	20.8	21.0	4.13	8	28

Table 14 Descriptives CONF

	Group	N	Missing	Mean	Median	SD	Minimum	Maximum
CONF_1	a	60	0	5.32	6.00	1.52	2	7
	b	60	0	5.17	5.00	1.17	2	7
CONF_2	a	60	0	5.37	6.00	1.59	2	7
	b	60	0	5.25	5.00	1.14	2	7
CONF_3	a	60	0	5.35	6.00	1.58	2	7
	b	60	0	5.15	5.00	1.22	2	7
CONF_4	a	60	0	5.37	6.00	1.58	2	7
	b	60	0	5.27	5.00	1.13	2	7

Table 15 Descriptives CONF per item

5.6.1.6 Perceived Impact on Learning - PIML

In table16, the mean value and standard deviation for the construct Perceived Impact on Learning (PIML) is given. The mean value of the VR condition is 16,4 (M = 16,4; DS = 4,16) while in the case of MR condition for the mean value reported is 16 (M= 16; SD = 2,88). The values obtained seem to suggest that in general students' experience using the App confirmed a positive impact on learning both in the case of MR and VR.

	Group	N	Missing	Mean	Median	SD	Minimum	Maximum
PIML	a	60	0	16.4	17.0	4.16	9	21
	b	60	0	16.0	16.0	2.88	7	21

Table 16 Descriptives PIML

Nevertheless, the results per single item, reported in table 17, seem to suggest that students experimenting the VR condition perceived that the App as an important and valuable aid more than students who experienced using the app in MR condition (PIML_2). Furthermore, it seems that students gained a clearer understanding of some App concepts from peers in the case of VR then MR (PIML_3). These difference will be further explored in the following paragraphs, per constructs and per item, and significant results will be reported.

	Group	N	Missing	Mean	Median	SD	Minimum	Maximum
PIML_1	a	60	0	5.43	6.00	1.50	3	7
	b	60	0	5.43	5.50	1.09	3	7
PIML_2	a	60	0	5.55	6.00	1.45	3	7
	b	60	0	5.25	5.00	1.10	2	7
PIML_3	a	60	0	5.45	6.00	1.35	3	7
	b	60	0	5.30	5.00	1.17	2	7

Table 17 Descriptives PIML per item

5.6.1.7 Perceived Enjoyment – PENJI

Table 18 prsents the mean values and standard deviations for the construct Perceived Enjoyment

	Group	N	Missing	Mean	Median	SD	Minimum	Maximum
PENJI	a	60	0	28.1	30.0	6.70	15	35
	b	60	0	28.0	28.0	4.72	15	35

Table 19 Descriptives PENJI

	Group	N	Missing	Mean	Median	SD	Minimum	Maximum
PENJI_1	a	60	0	5.58	6.00	1.39	3	7
	b	60	0	5.58	5.50	1.08	3	7
PENJI_2	a	60	0	5.58	6.00	1.42	3	7
	b	60	0	5.53	5.00	1.11	3	7
PENJI_3	a	60	0	5.58	6.00	1.41	3	7
	b	60	0	5.57	6.00	1.03	3	7
PENJI_4	a	60	0	5.72	6.00	1.35	3	7
	b	60	0	5.70	6.00	1.09	3	7
PENJI _5	a	60	0	5.62	6.00	1.39	3	7
	b	60	0	5.58	6.00	1.11	3	7

Table 18 Descriptives PENJI per item

The mean value of the VR condition is 28,1 (M = 28,1; DS = 6,70) while in the case of MR condition for the mean value reported is 28 (M= 28; SD = 4,72). The values obtained seem to allow to point out that in general students enjoyed the App both in the case of MR and VR. Anyway, looking at the results per single item, as reported in table 19, it seems that students who used AR reported higher level of enjoyment for all the specific aspects captured by the single items. In particular, students who used the app in VR modality to learn concepts and topics seem to have had more fun than those using the app in MR modality (PENJI_2).

5.6.2 Testing the normality and homogeneity

In order to verify the hypothesis, assumed based on the observation of the means and standard deviations for the items constructs, several tests were performed. Relevant results are reported in the following section. Prior to these, to test for the normality of the distribution of the constructs, a Shapiro-Wilk test was performed; while to test the homogeneity of variances, the Levene test was executed.

Results of the Shapiro-Wilk test showed in table 20, allow to detect that data associated to all the constructs as part of condition a (Virtual Reality) significantly deviate from a normal distribution, and that is also the case of data for the construct PCMT and SATI in the condition b (Mixed Reality).

	Group	PCMT	PEOU	PUSS	SATI	CONF	PIML	PENJI
Media	a	22.2	22.6	21.6	21.5	21.4	16.4	28.1
	b	21.8	22.5	21.3	20.4	20.8	16.0	28.0
Shapiro-Wilk W	a	0.933	0.893	0.857	0.924	0.890	0.878	0.862
	b	0.955	0.930	0.967	0.936	0.964	0.966	0.963
Shapiro-Wilk p	a	0.003	< .001	< .001	0.001	< .001	< .001	< .001
	b	0.027	0.002	0.105	0.004	0.077	0.092	0.064

Table 20 Shapiro Wilk

The results of Levene's test included in table 21 indicate the distributions could not be considered homogeneous in the case of all the variables.

Test Levene

	F	gdl	gdl2	p
PCMT	7.38	1	118	0.008
PEOU	6.30	1	118	0.013
PUSS	19.28	1	118	< .001
SATI	8.04	1	118	0.005
CONF	15.97	1	118	< .001
PIML	13.84	1	118	< .001
PENJI	14.68	1	118	< .001

Table 21 Leven test

5.6.3 The variables correlation

Spearman's correlation was performed to assess the relationships between the seven variables Perceived Compatibility (PCMT), Perceived ease of use (PEOU), Perceived usefulness (PUSS), Satisfaction (SATI), Confirmation (CONF), Perceived Impact on Learning (PIML), Perceived Enjoyment (PENJI). The average score of the multi items for each construct was computed. Results included in table 22 confirm that a significant positive relationship exists between the variables, in line with hypothesis stated in the literature and in accordance with Ifinedo (2017) model.

		PCMT	PEOU	PUSS	SATI	CONF	PIML	PENJI
PCMT	Spearman's rho	—						
	p-value	—						
PEOU	Spearman's rho	0.827 ***	—					
	p-value	< .001	—					
PUSS	Spearman's rho	0.813 ***	0.880 ***	—				
	p-value	< .001	< .001	—				
SATI	Spearman's rho	0.782 ***	0.777 ***	0.777 ***	—			
	p-value	< .001	< .001	< .001	—			
CONF	Spearman's rho	0.728 ***	0.758 ***	0.755 ***	0.773 ***	—		
	p-value	< .001	< .001	< .001	< .001	—		
PIML	Spearman's rho	0.787 ***	0.820 ***	0.853 ***	0.829 ***	0.838 ***	—	
	p-value	< .001	< .001	< .001	< .001	< .001	—	
PENJI	Spearman's rho	0.765 ***	0.781 ***	0.769 ***	0.795 ***	0.815 ***	0.835 ***	—
	p-value	< .001	< .001	< .001	< .001	< .001	< .001	—

Table 22 Correlation Matix *Note. * p < .05, ** p < .01, *** p < .001*

In fact, PCMT and PEOU are statistically positively correlated ($r = 0.827$, $p < 0,05$). PCMT and PUSS are statistically positively correlated ($r = 0.816$, $p < 0,05$). PCMT and SATI are statistically positively correlated with ($r = 0.788$, $p < 0,05$). PCMT and CONF are statistically positively correlated ($r = 0.744$, $p < 0,05$). PCMT and PIML are statistically positively correlated ($r = 0.803$, p < 0,05). PCMT and PENJI are statistically positively correlated (r = 0.784, p < 0,05). PEOU and PUSS are statistically positively correlated with (r = 0.873, p < 0,05). PEOU and SATI are statistically positively correlated (r = 0.796, p < 0,05). PEOU and CONF are statistically positively correlated (r = 0.767, p < 0,05). PEOU and PIML are statistically positively correlated (r = 0.822, p < 0,05). PEOU and PENJI are statistically positively correlated (r = 0.797, p <0 ,05). PUSS and SATI are statistically positively correlated (r = 0.768, p < 0,05). PUSS and CONF are statistically positively correlated (r = 0.767, p < 0,05). PUSS and PIML are statistically positively correlated (r = 0.852, p < 0,05). PUSS and PENJI are statistically positively correlated (r = 0.783, p < 0,05). SATI and CONF are statistically positively correlated (r = 0.771, p < 0,05). SATI and PIML are statistically positively correlated (r = 0.845, p < 0,05). SATI and PENJI are statistically positively correlated (r = 0.803, p < 0,05). CONF and PIML are statistically positively correlated (r = 0.845, p < 0,05). CONF and PENJI are statistically positively correlated (r = 0.825, p < 0,05). PIML and PENJI are statistically positively correlated (r = 0.852, p < 0,05).

5.6.4 Testing the constructs applying gender, age, and familiarity using Apps as grouping variables

The ANOVA Welsh test was performed using gender as a grouping variable for all the constructs, in order to investigate any statistically significant difference. The results do not highlight a statistical significant difference, as reported in table 23. Similarly, performing the ANOVA Welsh test applying age as grouping variable (18-23 and 24-29), no significant differences emerged, as reported in table 24.

	F	df1	df2	p
PCMT	0.393	1	71.1	0.533
PEOU	1.734	1	74.9	0.192
PUSS	2.038	1	73.4	0.158
SATI	0.407	1	79.5	0.525
CONF	1.296	1	76.6	0.259
PIML	1.081	1	76.4	0.302
PENJI	0.837	1	72.9	0.363

Table 23 One-Way ANOVA (Welch's) using gender as grouping variable

	F	df1	df2	p
PCMT	0.582	2	55.2	0.562
PEOU	0.318	2	51.7	0.729
PUSS	1.338	2	56.4	0.271
SATI	2.136	2	53.7	0.128
CONF	0.194	2	54.1	0.825
PIML	0.956	2	54.2	0.391
PENJI	0.751	2	55.1	0.476

Table 24 One-Way ANOVA (Welch's) using age as grouping variable

Instead, performing the ANOVA Welsh test applying as grouping variable the Familiarity using Apps (FAM_1), a statistically significant difference is detected, as reported in table 25, for the construct Perceived Usefulness (PUSS) ($p = 0.017$). Performing the Kruskal-Wallis test it is possible to highlight that students with no familiarity using Apps perceived this App more useful then students with familiarity, as for H_a μ no > μ yes ($p = 0.008$), as reported in table 26.

	F	df1	df2	p
PCMT	1.654	1	19.5	0.213
PEOU	2.223	1	22.8	0.150
PUSS	6.543	1	25.2	0.017
SATI	0.955	1	19.5	0.341
CONF	1.026	1	19.5	0.323
PIML	1.301	1	19.5	0.268
PENJI	1.129	1	20.7	0.300

Table 25 One-Way ANOVA (Welch's) using Familiarity using APPs as grouping variable

		Statistic	df	p
PUSS	Student's t	2.00	118	0.024
	Welch's t	2.56	25.2	0.008
	Mann-Whitney U	583		0.027

Table 26 Independent Samples T-Test Note. H_a $\mu_{no} > \mu_{yes}$

5.6.5 Testing the hypothesis for Perceived Impact on Learning (PIML) predictors

The tests performed in the previous sections confirmed the existence of a positive significant relationship between constructs. In order to further explore these relations, it was appropriate to perform a regression test to check on several hypotheses of which the literature informs. In particular, the hypothesis underlying the model taken from Ifinedo (2017) on which the present study is grounded. The aim was to reject the null hypothesis that there is no relationship in the population and that the relationship in the sample reflects only sampling error, while instead accept the following hypothesis:

H1: Perceived Ease of Use is a statistically significant predictor of Perceived Usefulness

H2: Perceived Ease of Use is a statistically significant predictor of Perceived Compatibility

H3: Perceived Usefulness is a statistically significant predictor of Satisfaction

H4: Perceived Compatibility is a statistically significant predictor of Satisfaction

H5: Perceived Compatibility is a statistically significant predictor of Perceived Enjoyment

H6: Confirmation is a statistically significant predictor of Satisfaction

H7: Confirmation is a statistically significant predictor of Perceived Enjoyment

H8: Perceived Enjoyment is a statistically significant predictor of Satisfaction

H9: Perceived Ease of Use is a statistically significant predictor of Perceived Impact on Learning (PIML)

H10: Perceived Usefulness (PUSS) is a statistically significant predictor of Perceived Impact on Learning (PIML)

H11: Satisfaction (SATI) is a statistically significant predictor of Perceived Impact on Learning (PIML)

H12: Perceived Enjoinment (PENJI) is a statistically significant predictor of Perceived Impact on Learning (PIML)

The average score for each construct was computed. Collinearity and normality test were performed and in all cases the results satisfied the conditions (VIF = 1; $p < 0,05$). Tables 27 summaries the results obtained, then confirms the hypothesis previously stated: H1, H2, H3, H4, H5, H6, H7, H8 ($p < 0,05$).

Path	R^2	β	t	p	Results
PEOU -> PUSS	0.761	1.07	19.41	< .001	H1 Accepted
PEOU->PCMT	0.684	0.75	16.00	< .001	H2 Accepted

			Overall Model Test			
Model	**R**	**R²**	**F**	**df1**	**df2**	**p**
1	0.852	0.726	313	1	118	< .001

Table 27 Model Fit Measures

Path	**R²**	**β**	**t**	**p**	**Results**
PUSS->SATI	0.768	0.552	13.04	< .001	H3 Accepted
PCMT->SATI	0.788	0.766	13.90	< .001	H4 Accepted
PCMT->PENJI	0.784	1.17	13.72	< .001	H5 Accepted
CONF->SATI	0.594	0.559	13.15	< .001	H6 Accepted
CONF->PENJI	0.681	0.918	15.88	< .001	H7Accepted
PENJI->SATI	0.645	0.523	14.63	< .001	H8 Accepted

Table 28 Regression test

Focusing on the statistical significance of Perceived Impact on Learning (PIML) predictors, that are the central focus of this study, the results reported in tables 28 and 29 reveal that PEOU has strong and positive relationship with PIML (β = 0,68; t = 15,67; p < 0,05). The predictor PEOU explains 67% of the variance in PIML and the model is significant (p < 0,05). As p-value is less than 0,05 it is possible to confirm H9 that Perceived Ease of Use (PEOU) is a statistically a significant predictor of Perceived Impact on Learning (PIML).

			Overall Model Test			
Model	**R**	**R²**	**F**	**df1**	**df2**	**p**
1	0.822	0.676	246	1	118	< .001

Table 29 Model Fit Measures

Model Coefficients - PIML

Predictor	**Estimate**	**SE**	**t**	**p**	**Stand. Estimate**
Intercept	0.665	1.0091	0.659	0.511	
PEOU	0.689	0.0440	15.674	< .001	0.822

Table 30 Model Coefficients – PIML

The results reported in tables 30 and 31 reveal that the predictor Perceived Usefulness (PUSS) has strong and positive relationship with PIML (β = 0,58; t = 17,69; p < 0,05). PUSS predictor explains

72% of the variance in PIML and the model is significant. As s p-value is less than 0,05 it is possible to confirm H10 that Perceived Usefulness (PUSS) is statistically a significant predictor of Perceived Impact on Learning (PIML).

Predictor	Estimate	SE	t	p	Stand. Estimate
Intercept	3.763	0.7242	5.20	< .001	
PUSS	0.581	0.0329	17.69	< .001	0.852

Table 31 Model Coefficients - PIML

The results reported in table 31 and 33 reveal that Satisfaction has strong and positive relationship with PIML (β = 0,80; t = 17,15; $p < 0.05$). SATI explains 71% of the variance in PIML and the model is significant ($p < 0,05$). As p-value is less than 0,05 it is possible to confirm H11 that Perceived Satisfaction (SATI) is statistically a significant predictor of Perceived Impact on Learning (PIML).

			Overall Model Test			
Model	R	R^2	F	df1	df2	p
1	0.845	0.714	294	1	118	< .001

Table 32 Model Fit Measures

Predictor	Estimate	SE	t	p	Stand. Estimate
Intercept	-0.594	0.9951	-0.597	0.552	
SATI	0.803	0.0468	17.153	< .001	0.845

Table 33 Model Coefficients - PIML

The results reported in table 34 and 35 reveal that Perceived Enjoyment (PENJI) has strong and positive relationship with PIML (β = 0,52; t = 17,69; $p < 0,05$). PENJI explains 72% of the variance in PIML and the model is significant ($p < 0,05$). As p-value is less than 0,05 it is possible to confirm H12 that Perceived Enjoyment (PENJI) is statistically a significant predictor of Perceived Impact on Learning (PIML).

			Overall Model Test			
Model	R	R^2	F	df1	df2	p
1	0.852	0.726	313	1	118	< .001

Table 34 Model Fit Measures

Predictor	Estimate	SE	t	p	Stand. Estimate
Intercept	1.425	0.8531	1.67	0.097	
PENJI	0.527	0.0298	17.69	< .001	0.852

Table 35 Model Coefficients PIML

5.6.6 The conditions differences

In this section the study investigates whether a difference is observable in terms of positive impact on learning between the VR and MR condition. The analysis conducted in the previous sections confirmed the hypothesis that Perceived Ease of Use (PEOUS) and Perceived Usefulness (PUSS) are positively correlated, and that statistically are significant predictors of Perceived Impact on Learning (PIML). Furthermore, as a significant positive correlation was confirmed between PEOU and Perceived Compatibility (PCMT). Thus, the following sections will first of all explore if a statistically significant difference is traceable between the two groups of students who experienced the App in VR (a) and MR (b) for these constructs. The objective is to derive in which condition students perceived the App more easier (i.e. their interaction with the app to support their learning is clear; learning to use the app is easy for them; using the app for learning concepts was easy) and useful to support their learning (i.e. to improves their learning performance in the subject; increases their learning effectiveness in the subject; helps them learning better, helps them preparing quizzes/tests), to eventually propose a possible explanation for a difference in the Perceived Impact on Learning, if detected between the use of AR and MR modality.

Secondly, the analysis previously conducted affirmed that Satisfaction (SATI) and Perceived Enjoinment (PENJI) are statistically positively correlated, then that statistically are significant predictor of Perceived Impact on Learning (PIML). The positive correlation was also confirmed between PCMT and SATI as well as PENJI, and between Confirmation (CONF) and SATI as well as PENJI. Thus, as a second step, the following paragraphs will explore which group of students perceived the App more compatible with learning (i.e. fits well with their learning, helps them to be efficient in learning) and meeting the expectations (i.e. their experience using the app in general, and for learning, is better than expected; the service the app provides is better than expected). In addition, the following sections will explore which modality group reported the App as more satisfying in general as well as a learning tool (i.e. using it to learn is pleasurable; fun to learn concepts and topics; pleasant, interesting) and more enjoyable (i.e. for creating and sharing knowledge), to derive information that could explain a difference, if detected, in the perceived impact on learning between the use of AR and MR modality.

In order to explore the above mentioned questions, and test the previously reported results, a non-parametric U test of Wilcoxon-Mann-Whitney and the ANOVA Kruskal-Wallis test, that do not require normal distribution, were executed to determine the significance of the statistical difference between VR and MR conditions. No statistically significant difference between the Virtual and Mixed Reality modality was found for the construct Perceived Impact on Learning (PIML) performing the ANOVA Kruskal-Wallis ($p = 0.474$) and the U test of Wilcoxon-Mann-Whitney ($U = 1588$, $p = 0.132$).

Similarly, no statistically significant difference between the Virtual and Mixed Reality modality was found for the construct Perceived Compatibility (PCMT) performing the ANOVA Kruskal-Wallis test ($p = 0.335$); and Wilcoxon-Mann-Whitney test ($U = 1617$; $p = 0.168$). No statistically significant difference between the Virtual and Mixed Reality modality was found for the construct Perceived ease of use (PEOU) performing the ANOVA Kruskal-Wallis test ($p = 0.685$); and Wilcoxon-Mann-Whitney test ($U = 1723$; $p = 0.343$). No statistically significant difference was found for the construct Perceived Usefulness (PUSS) performing the ANOVA Kruskal-Wallis test ($p= 0.283$) and Wilcoxon-Mann-Whitney test ($U = 1597$; $p = 0.136$) ($p = 0.142$). No statistically significant difference was found for the construct Confirmation (CONF) performing the ANOVA Kruskal-Wallis test ($p= 0.271$) and Wilcoxon-Mann-Whitney test ($U = 1592$; $p = 0.136$) ($p = 0.271$). No statistically significant difference was found for the construct Perceived enjoyment (PENJI) performing the ANOVA Kruskal-Wallis test ($p = 0.474$) and Wilcoxon-Mann-Whitney test ($U = 1665$; $p = 0.238$).

Instead, the results of ANOVA Kruskal-Wallis test on the construct Satisfaction (SATI), reported in in table 36, highlight a significant difference, as $p = 0,047$. Additionally, the results of the U test of Wilcoxon-Mann-Whitney reported in table 37 suggests that the hypothesis H_a $\mu a > \mu b$, is accepted as $U = 1424$, $p = 0,023$.

	χ^2	df	p
PCMT	0.930	1	0.335
PEOU	0.165	1	0.685
PUSS	1.151	1	0.283
SATI	3.962	1	0.047
CONF	1.211	1	0.271
PIML	1.259	1	0.262
PENJI	0.512	1	0.474

Table 36 Kruskal-Wallis

		Statistic	p
PCMT	Mann-Whitney U	1617	0.168
PEOU	Mann-Whitney U	1723	0.343
PUSS	Mann-Whitney U	1597	0.142
SATI	Mann-Whitney U	1424	0.023
CONF	Mann-Whitney U	1592	0.136
PIML	Mann-Whitney U	1588	0.132
PENJI	Mann-Whitney U	1665	0.238

Table 37 U test of Wilcoxon-Mann-Whitney
H_a μ a > μ b

5.7 Discussion

A quantitative research design was applied using a two conditions between-subjects approach, in order to explore how emerging technologies, such as virtual, and mixed reality, can impact on learning, and which are the significant relationships between the constructs involved. 2 groups of Italian mother tongue students, composed of 40 females (n = 60, 66,67%) and 20 males (n = 60, 33,3%) between the age of 18 and 29, enrolled in a university degree course, who had never previously experienced the use of EULALIA technology-enhanced learning tool, were involved in the study. Group a experienced the use of the app in the Virtual Reality modality (VR) and group b in the Mixed Reality modality (MR). Within both groups, 87% of the participants declared to be familiar using Apps, while 13% declared not to be familiar using Apps, 57 % declared to have experience using Apps to learn, while 43% declared not having such experience. EULALIA is an educational game in form of a mobile application, the development of which was inspired by the Situated Psychological Agent Framework (SPAF). It provides the learner with storytelling and scenarios, in which to make choices to complete tasks related to daily life situations, as part of a

learning path which ultimate learning outcomes is the acquisition of knowledge about cultural aspects of a country/region/city. The data included in the study sample correspond to participants not from the city of Naples, and not from the Campania region, and the scenario selected for the study shares the same game logic and structure in the case of virtual and mixed modality: the exploration in English language, of a storytelling made on the map of the city of Naples, embedded with interconnected learning contents focusing on tangible and intangible cultural heritage elements. The learner explored the map with a smartphone finding the points of interest of the story, following the artificial narrator (On Stage Agent - OSA) suggestions and listening to its feedbacks. The playground scenario consisted of a virtual map in the case of Virtual Reality (VR) modality, and a physical map in the case of Mixed Reality (MR) modality, enacted with Tangible Smart Objects (Tangible User Interfaces – TUI), equipped with NFC tags, through the use of the STELT platform, to embody content knowledge, and extend the learning experience connecting it to manipulable physical elements associated with real life contexts.
After experiencing the use of the App, the two groups of students filled in a questionnaire, retrieved from the Ifinedo (2017) model, which theoretical foundations are the Technology Acceptance Model – TAM (Davis 1989) and expectation confirmation model – ECM (Bhattacherjee, 2001), the innovation diffusion theory- IDT (Rogers, 2003) and the flow theory (Csikszentmihalyi, 1997). Based on this model, Perceived Enjoyment (PENJI), Compatibility (PCMT), Usefulness (PUSS), Ease of Use (PEOU), and Confirmation (CONF) have positive influence on students' Satisfaction (SATI). Perceived enjoyment has the greatest influence on students' satisfaction with the use of the tool for learning. Perceived impact on learning is positively influenced by perceived ease of use, enjoyment, and satisfaction.

It is acknowledged that VR is a technology that can transform education, providing immersive, and situated learning experiences. In terms of perceived impact on learning, Mixed Reality is used to embody the learning practice, because it can support rich haptic cues, changing the relationship of the learner with the technology interface, but moreover with the storytelling underpinning the learning path, allowing a direct action of the learner within a real word scenario, that deploys sensorimotor affordances. The present study confirms that, in terms of Perceived Impact on Learning (PIML), the experience of using the App had a positive impact on students learning, both in the case of MR and VR. The differences between VR and MR, so far not subject of considerable researches, was also explored in this study in terms of Perceived Impact on Learning. As for the results of the U test of Wilcoxon-Mann-Whitney ($U = 1588$, $p = 0.132$) and the ANOVA Kruskal-Wallis ($p = 0.474$) no statistically significant differences were found.

Based on the Spearman's correlation executed within the present study, a positive relationship was confirmed between Perceived Impact on Learning and Perceived Ease of Use ($r = 0.822$, $p < 0{,}05$), Perceived Usefulness ($r = 0.852$, $p < 0{,}05$), Satisfaction ($r = 0.845$, $p < 0{,}05$) and Enjoyment ($r = 0.852$, $p < 0{,}5$). Moreover, the regression test confirmed that Perceived Ease of Use, Perceived Usefulness (PUSS), Perceived Enjoinment (PENJI) and Satisfaction (SATI) are statistically significant predictors of Perceived Impact on Learning (PIML). The results of the present study acknowledge that the predictor PEOU explains 67% ($\beta = 0{,}68$; $t = 15{,}67$; $p < 0{,}05$) of the variance in PIML. The predictor PUSS explains 72% of the variance in PIML ($\beta = 0{,}58$; $t = 17{,}69$; $p < 0{,}05$). Perceived Enjoyment (PENJI) explains 72% of the variance in PIML ($\beta = 0{,}52$; $t = 17{,}69$; $p < 0{,}05$). SATI explains 71% of the variance in PIML ($\beta = 0{,}80$; $t = 17{,}15$; $p < 0{,}05$). This is in line with the studies conducted by Ifinedo (2017) reporting that students who perceived the technology to be easy to use, experienced positive impacts on their leaning. These findings are also consistent with other studies indicating a that perceived ease of use and perceived usefulness have a significant positive effect on perceived impact on learning (Bhattacherjee, 2001; Bölen, 2020; Oghuma et. al., 2016). The authors Chow & Shi (2014;), Hern´andez-Sell´es et. al., (2019), Ifinedo, (2017a), Liu (2016) and Molinillo et. al., (2018), also provide evidence that Satisfaction (SATI), referring to how satisfied students are with the experience of technology-mediated learning, influence positively the perceived learning experience (PIML), while Ifinedo, (2017), Lin, (2012), Mansouria & Piki (2016) and Teo & Noyes, (2011), reported that Perceived Enjoyment (PENJI) positively impact of perceived learning outcomes and performance.

Observing the analysis performed on the predictors of Perceived Impact on Learning, and the means and standard deviation values of the single items of Perceived Ease of Use, it is possible to point out that the interaction with the app to support learning was perceived clearer and learning to use the app was easier for the students using the VR modality. Instead, students using the app in MR modality, found easier using the App for learning concepts, and easier to support their learning, then in the case of VR modality. However, a statically significant difference between VR and MR was not found for the construct Perceived Ease of Use, performing the U test of Wilcoxon-Mann-Whitney ($U=1723$; $p=0.343$) and ANOVA Kruskal-Wallis test ($p= 0.685$).

Neither in the case of Perceived Enjoyment, a statically significant difference between VR and MR was not found performing the U test of Wilcoxon-Mann-Whitney ($U = 1665$; $p = 0.238$), and ANOVA Kruskal-Wallis test ($p = 0.474$). It is possible to affirm that students perceived both VR and MR enjoyable, pleasurable to be used to learn. As for the results reported by Ifinedo (2017), Perceived Enjoyment has the greatest influence on students' satisfaction, while in the case of this study Perceived Enjoyment explains 64% of the variance in Satisfaction, and Perceived Usefulness the 76%.

No statistically significant difference between VR and MR for the construct perceived Usefulness was found performing the U test of Wilcoxon-Mann-Whitney (U = 1597, p = 0.142), and ANOVA Kruskal-Wallis test (p=0.283). The students participating in this study considered in general VR and MR technology useful for learning. However, performing the ANOVA Welch test applying as grouping variable the familiarity using Apps, a statically significant difference was detected between VR and MR, for the construct Perceived Usefulness as F= 6,543, p = 0,017. Furthermore, the Kruskal-Wallis test results highlighted that students with no familiarity using Apps, perceived this App more useful, then students with familiarity, as for H_a μ no > μ yes (p = 0.008).

The ANOVA Kruskal-Wallis test, executed to test the statistical significance difference between the two conditions for the construct Satisfaction (SATI), confirms a significant difference, as for the construct SATI (p = 0,047). Additionally, the results of U test of Wilcoxon-Mann-Whitney executed to test the hypothesis H_a $\mu_a > \mu_b$, suggested that students who used Virtual Reality were more satisfied with the App as a learning tools then students using the Mixed Reality app (U = 1424, p = 0,023. Further investigations executing the Kruskal-Wallis test using gender, group age and familiarity using Apps, as grouping variable, did not highlighted a significant difference on Satisfaction, so a possible explanation about the difference between VR and MR should be retraceable in the Satisfaction predictors.

In order to explain the statistically significant difference in the perceived Satisfaction of the group of students experimenting the Virtual Reality app and Mixed Reality app, it is important to recall that the results of the regression test confirmed that Perceived Usefulness (PUSS) and Perceived Enjoinment (PENJI) are statistically significant predictors of Satisfaction, respectively explaining 76% and 65% of the variance in SATI. Additionally, a positive correlation was also confirmed between Satisfaction and Confirmation, as well as between Satisfaction and Perceived Compatibility. Respectively explaining 59% and 78% of the variance in SATI. This is in line with Ifinedo model, and other studies such as Liao, Huang, and Wang (2015) based on which Perceived Enjoyment (PENJI), Compatibility (PCMT), Usefulness (PUSS), and Confirmation (CONF) have positive influence on students' Satisfaction (SATI), referring to the extent to which the learner is pleased with using a technology for the learning purpose.

Now, looking at the results of the Satisfaction (SATI) predictors not already discussed in this section, they highlight that for the construct Perceived Compatibility (PCMT), a statically significant difference was not found performing the U test of Wilcoxon-Mann-Whitney (U =1617, p = 0,168), and ANOVA Kruskal-Wallis test (p = 0.335), suggesting that students considered both VR and MR technology compatible with their learning and a good opportunity to learn. Regarding Confirmation (CONF), the correlation test shows that it explains 59% of the variable in Satisfaction. Lower expectations and/or higher perceived performance in fact trigger a greater confirmation, which results in positive influences on user satisfaction and continuance intention (Hayashi et. al. 2004). Anyway, within the present study a statically significant difference was not found between VR and MR performing the U test of Wilcoxon-Mann-Whitney (U=1592; p=0.136) and the ANOVA Kruskal-Wallis (p= 0.271).

So, considering such results, it might be possible to suggest that the statistically significant difference between VR and MR as for the construct Satisfaction is perhaps related to the difference registered in Perceived Usefulness as for the familiarity using Apps. Satisfaction (SATI), that refers to how satisfied students are with the experience of technology-mediated learning, is affected positively by Perceived Usefulness (Balderas et al., 2018; Ifinedo, 2018; Muñoz-Carril et. al., 2021), and the results of the present study confirm this relationship. The students with no familiarity using Apps perceived the App more useful, compared to students with familiarity using Apps. Even if a statistically significant difference was found in Usefulness between VR and MR, the mean and standard deviation of the construct Usefulness (PUSS) highlight that VR was perceived by students more useful than MR. This information, might explain the statistically significant difference between VR and MR as for the construct Satisfaction, indicating that student who used the VR App were more satisfied then those using MR.

It is acknowledged that familiarity reflects the direct and indirect knowledge available to the individual (Alba & Hutchinson, 1987) and in this respect, few studies have examined the effects of familiarity on customers' evaluations and behavioral intentions (Söderlund, 2002). The authors who initiated the investigation of this factor, did it mostly in the field of marketing, and reported familiarity as having a moderating role on variables such as usability or Satisfaction of customers' use of website or applications for purchasing (Gursoy, 2001). Gefen et. al. (2003) for example applied the TAM model to Amazon and found that the users' familiarity has significant impacts on both Perceived Ease of Use and Usefulness. In studies focusing on initial adoption and continuance usage of applications for service and goods purchase, it has been demonstrated that compared to perceived ease of use, perceived usefulness shows more consistent results (Bhattacherjee, 2001a; Davis, Bagozzi, & Warshaw, 1989). Chuah et. al. (2016) applied the TAM to the wearable device market and reported that users' familiarity with the device category enhances PUSS. It can be suggested that users' higher degree of familiarity generated by their experience interaction with mobile apps leads to users' higher PUSS.

On the contrary, the present study highlighted that students with no familiarity using Apps in general, perceived this App more useful then students with familiarity. This is probably because users who are familiar with a product tend to judge new experiences based on their prior expertise, making a more elaborate evaluation, since their greater knowledge enables them to make more precise comparisons (Morgan et. al.,1996; Rufín et. al., 2012; Söderlund, 2002), while for students with no familiarity using Apps, the Virtual, Mixed Realty and Tangible User Interfaces in particular, appeared as novel and unknown technology, so from one side they were unable to adequately assess the benefits of its use in their learning activities based on previous experience, on the other side the effect of perceived novelty might have influenced students predisposition to consider the App an exciting and useful alternative to traditional learning tools. Several marketing research focusing on the use of Apps and website for goods purchase, report in fact that the novelty of an innovation or product can foster positive affective reactions such as excitement (Cox & Locander, 1987) and interest (Mukherjee & Hoyer, 2001), sometimes referred to as a "honeymoon" effect (Fichman & Kemerer, 1993). Subsequent research supports this assertion in that individuals who engage in novelty seeking "*might enlarge their perceived usefulness and playfulness*" (Lin & Yu, 2006, p. 115).

5.8 Limits of the study and future perspectives

This study represents an effort to incorporate elements from different theories, namely the technology acceptance model, social cognitive theory, innovation diffusion theory, and expectation–confirmation model, in order to explore the impact on learning of emerging technologies as Virtual and Mixed Reality and the relevant factors implied. However, it is not without limitations. First of all, the sample of 160 did not allow to perform a structural equation modelling, demanding 150-200 or larger (Boomsma & Hoogland, 2001; Hoogland & Boomsma, 1998; Kline, 2005; Tabachnick & Fidell, 2001), that would have supported the analysis of the influence of a set of variables on the others and the mediating effects. A possible future direction might focus on exploring the relationships within a model applicable exclusively to Mixed Reality and TUIs application, in order to fill the gap in this field of research, connected to the impact on learning of such technology. It would be also interesting to include the Familiarity in the model to a greater extend, following a more detailed reflection about how less familiarity with the use of

ICT tools, and the perception of novelty, can trigger a more positive attitude towards their use. In fact, the attempt to contribute to the research in the field of Virtual Reality, Mixed Reality and Tangible User Interface, emphasised a possible relevant connection between satisfaction and usefulness as for the familiarity with the tool that highlights that it crucial to narrowing the scope on the significance of familiarity on usefulness and in connection with satisfaction. Moreover, in order to comprehend the potential of TUIs within the educational practice, a mixed-method research design could be taken into consideration. Ultimately, to strengthen the value of findings in relation with the impact on learning associated with the use of technology, a pre and post supplementary test focusing on students' language and cultural awareness achievements could be added in the method.

Conclusions

Technology innovations are numerous and attractive, but above all promising advances and improvements in all sphere of life, opening up unedited scenarios for solving complex economic and social problems. Digital skills are defined as determinants for both employability social inclusion. The educational context clearly has a central role to play in this challenge, on the one hand directly related to training the digital skills for a confident and critical use of technologies themselves, and on the other hand managing and orienting the digitalisation process to ensure **technologies** truly empower the learning processes. For technology to be effective and integrated in education, it must be purposively **directed at supporting improvements in learning outcomes**, so it might surprise that there is little evidence that the adoption of these technologies is associated with improvements in learning effectiveness. The research should be more oriented to support the definition of technology characteristics for this purpose, identifying metrics for success and processes evaluation.

At primary, secondary and higher education level, the factors that obstacle the effective use of innovation technologies is certainly the lack of ICT infrastructure, but most of all is fundamental to consider the importance of training programs and the selection of suitable tools, to support effective teaching and learning. Where culture and policies, norms and values, can promote the innovation process, the preparedness of educational practitioners, to integrate ICT into the daily practice, can determine the effectiveness of the technology to support the change, from adoption to integration. Anxiety, lack of confidence and competence, fear to embed the use of technologies in the daily practice, greatly influence the individuals' intentions to use information technology, as **self-efficacy is the starting point for technology acceptance and successful integration.** It is clear that educational practitioners have the central role of change makers when it comes to innovation integration, and **professional development** can certainly impact on perception of ability to competently use a technology, but to be a strong determinant for effective use of technology, training programmes should concentrate on the pedagogical aspects supporting the transformation of the teaching and learning practice, including hands on experimentation in real context and peer work. The more **experience** educators gain, the more likely they show positive attitudes towards technology, fostering technology integration in the classroom and successful transformation of the educational practice resulting in students positive learning outcomes.

Within the educational context practice, when integration occurs, and technology is used in lessons, the two important elements of teaching and learning which are content and pedagogy must be joined, so emerge the importance of the appropriateness of contents and tools. Technology characteristics influence the diffusion processes of an innovation, and are significant factors impacting on technology acceptance, and individual adoption of the technology. Among the many variables that can influence a system acceptance and use, two determinants are particularly important in relation with personal ICT choices: level of complexity in use, perceived usefulness, and the capacity of the technology to meet needs us users. Moving from Social Cognitive Theory (SCT), the Theory of Reasoned Action (TRA), the Innovation Diffusion Theory (IDT), and decision-making theories, Davis (1989) identified ease of use and usefulness as the main characteristics about an innovation to predict technology acceptance and usage outcomes. Such constructs constitute the basis of numerous studies in the field of technology acceptance, also applied to different educational tools. It is unquestionably the leading ground theory for investigating acceptance of learning technologies, and exclude attitude mediating effect confirming a direct relationship between the constructs and intention to use. Performance gains are often obstructed by users' unwillingness to accept and use available systems, but people tend to use, or not use an application, to the extent they believe it will help them to better perform their task or reach their goal. The degree to which a new technology meets the habits, values and needs of the potential adopter is defined as perceived compatibility. Compatibility is a constructs from the Theory of Planned Behaviour included in extended versions of TAM as antecedent of technology acceptance outcomes, and has a positive relationship and significant effect on user perception of usefulness. Post-adoption studies also apply theoretical frameworks such as the Expectation Confirmation Theory (ECT) introducing Confirmation as positively affected by technology readiness. On the basis of a postadoption experience, the initial user expectation might shift. The updated expectation has vital influence on the consequent processes of perceived behavioural control, operationally defined as beliefs about the degree of control over the technology to be adopted to aid the learning process.

Identifying the factors influencing students' perceptions, and experiences in technology-enhanced learning, was a fundamental question in this research, very much related to students feeling of control and interest over the learning path, opening the exploration about the role that affective states play in the process. Participating actively in the learning process means being aware and responsible of the direction and objective, and underscores the importance of behavioural engagement in learning, that has often a positive association with emotional engagement, learning interest or satisfaction. Learning effectively refers to the extent to which a student acquires knowledge or skills thanks to the support offered by technology integration in the learning process, and learning satisfaction depicts student's assessment of the learning experience. Engagement does increase when activities are tailored to the personal needs and emotional state of the learner, and if the use of technology promotes positive affective states, that in turn promote learning. Positive emotions, and feelings of success, during learning, increase self-efficacy beliefs and motivation that consolidate the engagement and intention to continue using a technology to learn. A growing interest of the research in the interplay of learning and emotion, is evident even if still not fully exploited, and it should be noted that the definition and explanations of **emotions** is multifaceted, so in relation with learning it requires a contextual shift from experimental research in laboratories to the classroom real context, in order to observe the impact on learning of technology affordances. This is one of the reasons that motivated the choice to conduct the present study on a technology that can be used in real educational context, to better contribute to the research directed at grasping how the use of technology impacts on learning outcomes.

As mentioned, to be effective support for learning, a technological tool must meet certain characteristics of usefulness and ease of use, but the content and activities it proposes must also meet the needs of the learners, so that they feel engaged in the learning process and accomplish the expected outcomes. The EULALIA app was in fact developed following recent models, but accredited in the literature, based on the participation of trainers and students, and sustaining a correspondence between the didactic activities deployed by the digital tool, and the educational objectives proper to the everyday educational practices. The validation of this methodology, in the context of this research, offers a contribution towards the establishment of a best practice to guide future developments of usable and accessible applications, such as **game based** and **scenarios**

based learning tools, oriented to support the acquisition of learning outcomes, particularly in the field of culture and language. As reported later, the results of the study contribute to confirm the strengths of scenario based learning and game based learning in activating students' high **cognitive absorption status**, which makes high impact on enjoyment, perceived usefulness, and satisfaction, that contribute positively on learning outcomes.

In addition, the choice of the type of technology was deliberately oriented by the opportunities that mobile learning and game-based learning offer with respect to emotional engagement. **Mobile devices** are the most enabling today to bypass equipment availability, they are simple and portable, technically maintainable, flexible and familiar; the applications are agile to develop and make it possible to implement game-based scenarios, which combine goal oriented tasks with identification stimuli. Educational games promote logic, skills development, and knowledge acquisition, in a thought-provoking and pleasant way that lets students learn while being immerse in an **engaging experience flow**. Flow arises when people focus on the ongoing activity and feel immerse; it is measured by perceived enjoyment, among other variables, and requires: (1) define goals with practicable rules; (2) support adjustments of action based on capabilities (autonomy); (3) provide feedback on participants' performance; (4) support concentration also conceived as intense feelings of engagement, immersion and willingness to continue using the technology, play, learn. Scenario-Based Learning (SBL) provides meaningful learning experiences by engaging students in authentic environments to support reflective practices and active learning in a real-world problem and in a subsequent solution finding process. Playing activates an engaging learning experience, and it is an important mediator of learners socialisation with experience and knowledge acquisition, in which the participants **voluntarily** invest while deriving enjoyment. Serious Games design embeds the effective principles of the Game Theory, effectively combined with the Social Learning Theory approaches, which facilitate the easily absorbing of knowledge through role play, and keep learners engaged in the educational experiences, with a view to achieving specific **learning goals and outcomes**. Scenarios were developed with teachers and students to adhere to specific learning goals, and consist of real life fictional situation in which learners confront tasks and solve problems based on a structured storytelling, managed by mathematical rules varying the degree of difficulty through which learners train their skills and thus learn. Furthermore, this direction offered the opportunity to include in the research what are today the most innovative and less explored technologies, such as **virtual and augmented reality**. Promising for the features they offer, have been rarely object of investigation in relation to the impact on learning they enable.

The present research can perhaps be said to have contributed in this area by attempting to model a path of inquiry regarding the impact on learning of technologies, with emphasis on the variables that also influence the process in affective as well as cognitive terms. In particular, this work contribute to the findings regarding the use of virtual, augmented, and mixed reality in educational, not only regarding its acceptability, but also and more importantly, regarding other factors involved in assessing the impact on learning, closely related to the type of activities that the tool proposes, the responsiveness of the content to the learning needs, and the effect that the process in which they are proposed can have on the acquisition of skills or at least on students positive outcomes perceptions.

The analysis of the literature conducted, to find a model representing the intent of investigating the impact on learning of technologies, has showed how are still limited the studies that set this goal, even more so, that considering variables such as enjoyment and engagement. Ultimately, the TAM extended version of Ifinedo (2017) seemed suitable to support this study. The results of the present study make it possible to state that perceived enjoyment, compatibility, usefulness, ease of use, and confirmation have positive influence on students' satisfaction with virtual and mixed reality use. Perceived impact on learning is positively influenced by perceived ease of use, enjoyment, and satisfaction. This is in line with Ifinedo findings and makes possible the future use of the model within subsequent studies focusing on virtual and mixed reality impact on learning. An interesting result to consider is that as for the results presented by Ifinedo, perceived enjoyment has the greatest influence on students' satisfaction, while in the case of this study perceived enjoyment explains 64% of the variance in **satisfaction**, and perceived usefulness the 76%.

Furthermore, perceived usefulness is found to be higher perceived by students with no familiarity using Apps, and this opens opportunities for further explorations. **Familiarity** reflects the direct and indirect knowledge available to the individual, and few studies have examined the effects of familiarity on customers' evaluations and behavioural intentions, apart those in the field of marketing. Such studies report familiarity as having a moderating role on variables such as usability or satisfaction, and demonstrate that compared to perceived ease of use, perceived **usefulness** shows more consistent results. The impact on Usefulness in confirmed in the context of the present study but while previous researchers affirm that higher degree of familiarity generates higher perceived usefulness, the results here suggest that students with no familiarity using apps perceive higher usefulness of virtual and mixed reality in the context of learning. In fact, the results of the present study highlight that **novels stimuli** introduced by exciting technologies such as are virtual and mixed reality, caused strong arousal or emotion, which influenced perceived usefulness and possibly students' satisfaction. This makes evident the importance of investigating further the interplay between affective and cognitive beliefs when forming user attitudes that ultimately influence the adoption of an IT innovation.

Certainly this study contributes to the research in the field of technology enhanced learning and in particular of virtual and mixed reality to support learning, as it confirms that the experience of using both virtual and mixed reality was perceived by students as satisfying and enjoyable, having a positive impact on their learning. Additionally, an important aspect of the present study is that it has taken the first steps within an area still scarcely explored when it comes to virtual and mixed reality: the investigation of the differences between these technologies, comparing the use of virtual reality, to the use of mixed reality and tangible user interfaces, in terms of perceived impact on learning, usability and usefulness, compatibility and responsiveness to expectations, enjoyment and satisfaction.

On one side the results of this study contribute to the research on **tangible user interfaces** confirming their value in introducing a situated and embodied learning approach that support a positively perceived impact on learning. The findings confirm that shifting the interaction between the learner and the digital interface, to extend the learning experience, connecting it to manipulable physical elements associated with real life contexts, is effective in terms of making the learning experience enjoyable and satisfying. While previous studies highlighted from a qualitative point of view the advantages that TUIs introduce within the learning strategies, this study confirm empirically that situated and embodied learning approaches support engaging, pleasant, enjoyable and satisfying learning activities with positive impact on students learning. The results of this study are consistent with the affirmation that TUIs are an effective technology to deploy a learning approach that scaffolds prior knowledge with the reflections activated during a new current experience, depicting both cognitive and emotional information from sources that visual, auditory, kinesthetic, and tactile; but most of all confirm that TUIs are as effective as applications using virtual reality in terms of impact on learning, although the latter report higher levels of satisfaction in students who have used them.

To conclude by leaving a reference that highlights key elements and useful insights about practical implications both for end users and for those who would like to adopt the EULALIA App as well virtual or mixed reality technologies in a learning and teaching real life practice, the following table is an attempt to present the results of both the pilot, and empirical study, conducted in the context of the present research, accompagnied by a further reflection about the key elements for the integration in the educational context.

Key elements for the use of the virtual and mixed reality app in educational context
VR and MR technology compatible with learning and a good opportunity to learn
Easy to use and useful for learning
Support an ejoyable learning experience
Deploy a positive perceived impact on students learning
Perceived ease of use positevely impact on perceived learning outcomes
Perceived usefulness positively impact on perceived learning outcomes
Level of satisfaction positively impact on perceived learning outcomes
Level of enjoyment positively impact on perceived learning outcomes
Students with no familiarity using Apps perceive VR and MR technology more useful
Supprt scenarios based learning experience
Support gamified learning experience
Support personalisation of the learning materils and path
Support motivation and engagement in learning

VR versus MR	
It fits better with learning (Campatibility)	It fits better with helping students to be efficient in learning (Compatibility)
The interaction to support learning is clearer	It is easier for learning concepts
Learning to use the app is easier for the students	It is easier to use to support learning (Perceived Impact on Learning)
It is an important and valuable aid (Perceived Impact on Learning)	Improve more the the learning performance in the subject (Perceived Impact on Learning)
More satisfying under all the specific aspects	
Meet slightly better the expectations (Confirmation)	
It is an important and valuable aid (Perceived Impact on Learning)	
Using it to learn is enjoyable	Using it to learn is enjoyable
Students who used the app in VR modality to learn concepts and topics have more fun	
Portability and ubiquity	Supports connection with real life situation
Supports immersion	Supports a more interactivitve and embodied experience
Supports authonomous learning	Supports collaborative learning
	Supports self directed learning

Table 38 Key elements for the use of the virtual and mixed reality app in educational context

The use of mobile devices within education constitutes itself an element of innovation that creates a link with students' everyday experience, transforming this commonly used tool into a learning aid, empowering students to use it critically, responsibly and creatively, while supporting interactive and collaborative leaning as well as individualizes teaching. Tablets and handheld devices support ubiquitous and flexible learning, offering the opportunity to expand the boundaries of schooling allowing the learners to practice at their individual pace with the ultimate results of fostering their autonomy and critical consciousness to self-direct their learning path taking responsibility over it.

From this perspective, and given the ease with which Apps enable the development of differentiated and individualized pathways, made of materials that can be enriched with sensory stimuli and customizable scripts and activities, they easily support a learner-centered pedagogy, differentiated based on needs and difficulties. They offer the possibility to link the educational contents and pathway with personal experiences, especially if the storytelling is gamified, ludified including challenges and competitions, and designed based on scenarios that embed psychological models, as in the case of EULALIA and the serious games. A characterizing element of successful learning pathways with an impact on outcomes, as also demonstrated by the present research, is that enjoyment and satisfaction positively affect not only the motivation, but furthermore the students perception of impact on learning, so knowledge retention and skilla acquisition. It should highlighted that, for Apps and serious games to become learning tools that can be effectively integrated into curricular teaching, the activities that constitute the narration of the game should be consistent with pre-assigned learning objectives, in line with school curricula. Thus, it is important the involvement of learners and teachers in the development of the scenarios and learning materials, as an integral part the learning path, through which the students experience and acquires skills following a process of problem solving and meaning making. Moreover, when learning scenarios contain elements that recall real life situations, they are effective in activating prior knowledge and promoting experimentation of knowledge with respect to everyday life contexts. This situated learning model increases the memorization and, above all, makes learning more engaging, enhancing students' motivation with measurable learning outcomes.

Because of their characteristics, virtual, augmented, and mixed reality can reinforce the mechanism of engagement and immersion, with proved impacts on learning, strongly related to the leaner increased satisfaction and enjoyment. It is useful to recall the attention on the need for the tool to be first of all accessible, easy to use and easy to learn to use. In addition, to be considered by users as useful for learning, it must be engaging and containing elements that are familiar but also unexpected and surprising. The comparison of virtual and mixed reality shows that the former meets learners' expectations more closely and is deemed more compatible with learning objectives, while the latter offers more opportunities for connection between the learning path and the real-life situations in which skills are practiced. Mixed reality allows for the inclusion of physical forms of interaction that make the learning experience more interactive. Manipulation activates a reflexive and embodied practice as more related to a real-world action-challenge.

In this, tangible interfaces, linked to scenario-based pathways, typical of serious games, are very effective and are a technology that is easy to develop and use, low cost, and usable even in settings with limited availability of technologies and limited vocation for innovation. They require little training to be integrated in the pedagogy, other than that related to strengthening teachers' familiarity in creating content in line with curricular learning objectives. With regard to this aspect, it is desirable that each activity integrated into the storytelling of the game, is developed starting from a learning objective, involving more than one disclose according to different levels of difficulty, because this will allow students to practice their skills by experiencing the consequences of their interactions, and will ensure greater engagement, increasing satisfaction, enjoyment, motivation, with positive results on the learning outcomes.

Probably the optimal path that leads to an effective use of these tools in education is to exploit their playful aspects involving students in the collaborative creation of learning activities based on a given learning objective to be contextualized and related to real life actions that require the exercise of skills. Engaging learners in developing the game scenarios will strengthen their sense of responsibility with respect to the objectives and the learning path, and in this way, the exercises obtained will have very strong connection with the learners' daily interests and real file situations, therefore more engaging and motivating. Consequently, the game paths, which can also be enjoyed outside school hours, will support a satisfying experience, with positive repercussions on the skills acquired and a surprising response in terms of interest in the educational activities and peers' teamwork. The most suitable subject areas in the curriculum for the use of mixed reality are those that allow the development of a storytelling represented by means of interactive maps enhanced with real context elements represented by tangible smart objects, therefore foreign languages, literature, history, geography, science and physics, etc. and in any case, they are very effective in assisting the development cross-disciplinary pathways.

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