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Gamification and virtual reality for digital twin learning and training: architecture and challenges

Antonio BUCCHIARONE*

Motivational Digital Systems (MoDiS), Fondazione Bruno Kessler (FBK), Trento, TN 38123*, Italy*

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Abstract: Background Digital Twins are becoming increasingly popular in a variety of industries to manage complex systems. As digital twins become more sophisticated, there is an increased need for effective training and learning systems. Teachers, project leaders, and tool vendors encounter challenges while teaching and training their students, co-workers, and users. **Methods** In this study, we propose a new method for training users in using digital twins by proposing a gamified and virtual environment. We present an overall architecture and discuss its practical realization. **Results** We propose a set of future challenges that we consider critical to enabling a more effective learning/training approach.

Keywords: Digital twins; Virtual reality; Gamification; Learning; Training

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1 Introduction

Digital Twin (DT) technology is a relatively new notion that has piqued the interest of business and, more recently, academics[1]. Advances in industry 4.0 principles have aided the expansion of DT technology, notably in the manufacturing sector. A DT is characterized in various manner but is best defined as the seamless integration of data between a physical and virtual system in both directions[2].

The idea of DTs originated with NASA[1], and the industrial sector embraced DTs as an abstract form of product lifecycle management (PLM). However, the essential concept behind DTs remains unchanged: a virtual model that integrates all relevant knowledge about a real environment to address a specific issue. To represent complicated issues, engineering systems have long employed abstraction approaches. Moreover, the DT takes this concept a step further by enabling you to model and simulate an issue. In the simulation components of the DT, a range of machine and deep learning approaches, generally referred to as artificial intelligence (AI), play a key role[3]. AI assists in scenario simulation and autonomous decision-making through the DT. In addition, we may simulate engineering challenges using augmented reality (AR), virtual reality

***Corresponding author**, bucchiarone@fbk.eu

[1]https://ntrs.nasa.gov/citations/20210023699

(VR), and other methodologies.

While the nomenclature has evolved since DT technology first appeared in 2002, the underlying principle of the DT model has remained relatively constant. It is predicated on the concept that a digital informational construct about a physical system may be constructed as separate entities. This digital information is a ″twin″ of the information contained inside the physical system and is connected to it during the system's entire existence[4].

DTs are a reaction to the growing digitization of product development, manufacturing, and goods. Today's goods are sophisticated systems that perform their intended tasks and communicate with other components, products, clouds, and services through communication networks. These intelligent items are beneficial and need to be regularly/constantly maintained.

DT technology has become a facilitating technology in the education sector, enabling knowledge acquisition through advanced experiences[5]. Ideally, the DT concept should be based on various functional aspects, including real-time datasets, machine learning, reasoning, and simulation, to assist in making critical decisions. It helps in the creation of a virtual world using real-world experiences and interacts during activities such as production and learning[6]. Therefore, DT has three major aspects: the physical product, virtual or digital attributes, and the linkage between the two. DT technology typically provides solutions to different issues related to student learning experiences and knowledge development. For instance, it provides reliable opportunities for students to interact with learning materials through real and easily accessible experiences. 4.0 technology is critically designed to enable students to attain hands-on experiences through operation and interaction with relevant learning processes[2].

Today, students use personal gadgets to manage their course loads, assignments, and personal lives, including social media and general communications. Gaming is also popular in such gadgets, primarily as a source of entertainment. What if we could encourage student to regularly put in this effort to completing homework or improving their skills? How can they enjoy improving critical thinking or teamwork skills? Educators already use gamification, but it is now accessible in VR. The world is evolving at such a rapid pace in terms of technology that it is practically impossible for us to keep up with it, particularly in the realms of gaming and VR. Technology from television is now accessible to children to study with while having fun[7].

The focus on integrating digital technologies such as DTs will mitigate different issues related to learning processes, including the accessibility of learning resources and establishing inclusive and quality learning experiences for all students. Such technologies also provide extensive opportunities to optimize learning experiences, training, and teaching using automating tasks. This is achieved by minimizing the need for experience and knowledge in instructor's decision-making. In the classroom, the use of DT technology has significant benefits and has a significant influence influence on both students and teachers. In this case, it provides significant benefits, from the basic processes of curriculum design to the learning and teaching processes. It can also be used to ensure that content is updated. The simulation models created by this system are based on the requirements of the course. Overall, DTs significantly assist students in fulfilling their personal responsibilities when learning and increasing their knowledge acquisition motivation. DTs also enhance peer learning functions. DT technology has facilitated instructors in activities such as content delivery and overall assessments. However, despite the approval of this technology, learners who have used DT technology have reported that it is typically slow. In addition, the hardware components are expensive. Moreover, in learning, the major problems associated with DT are design-based. Some challenges include real-time adaptation of the technology, implementation of real simulation algorithms, LED level indicator visualization with simulation software, and minimal computation capabilities, particularly for simplified simulation tasks. Therefore, given that the virtual components integrated into a DT can be easily manipulated, making the necessary adjustments, and reducing the impact of these shortcomings is crucial.

The goal of this study is to present a new approach to training users using digital twins by enabling a gamified and virtual environment. We present the overall architecture and discuss its practical application. We propose a set of future challenges that we consider critical to for realizing a more effective learning/training approach.

The remainder of this paper is organized as follows. Section 2 explores initiatives in adopting gamification and virtual reality solutions for learning and training. Section 3 introduces the core elements that form the cornerstones of our research. In Section 4, we propose the architecture of our solution, and Section 5 describes the roadmap we envision as the next step. We conclude the paper in Section 6 and explain future work and exploitation plans.

2 Related work

Technology is constantly changing and becoming increasingly important under a wide range of circumstances. As a result of recent technological developments, organizations now have more options for communicating with their stakeholders. As students are a particularly distinctive type of stakeholder, such communication scenarios are more common in the service business and higher education environments. Most pupils are teenagers, particularly the members of the Millennial generation and Generation Z[8].

A virtual environment offers the user an immersive experience that replaces actual surroundings, enabling the user to engage with the virtual world in a manner that seems authentic and true[7,9]. When students practice and polish their talent in a virtual setting, they are more likely to succeed in the actual world[10]. Because of this, gamification (game-based learning) in education is gaining traction as a technique for encouraging students to learn while entrancing them[11,12].

The term gamification was introduced in the early 2000s[13] and gamification provides a complementary perspective to serious games. This approach uses game elements to enhance non-entertainment applications to foster behavioral change, engagement, motivation, and soliciting participation in activities[14–17]. Its further dissemination began in 2011, after the publication of several documents[18–21] gaining popularity and rapidly spreading in a wide range of domains that benefit from the increased engagement of their target users[22], such as health and environmental awareness[15,23–25], e-banking[26], software engineering[27], education and training[14,28–30], and everyday challenges[31,32].

There is a wide interest in adopting gamification solutions to support engagement in production with learning purposes, such as employees handling tedious tasks[14,33–36] or programmers learning specific technologies[37–40]. This interest is also testified by the availability of hundreds of gamification development platforms that offer pre-packaged templates to build gameful applications[2] and by commercial learning management systems that aim to improve educational and training experiences[3].

Learning may be enhanced through gamification, which adds an additional incentive to the process. For distant education, social VR platforms have been shown to be trustworthy solutions that can enable gamification methodologies. Various gamification techniques have been employed in informal education. Ludic learning was a key focus of research on games in training and development in the 1990s[41], however, in the 2000s, the focus shifted to more interactive forms of learning (e.g., online games). The use of gamification features in training has become more common as technology has become more accessible and affordable.

Teaching with the aid of technology seems simple now. Computers have become more common in schools in recent decades, thanks to advancements in computing technology. Computers and the Internet have made

[2]https://technologyadvice.com/gamification/

[3]https://elearningindustry.com/top-gamification-lms-software-learning-management-systems

information systems a vital part of the educational process, making them a necessity. Recent years have seen them gain prominence as the main source of obtaining information and as a means to develop professional skills; hence, computers and the Internet are used not only as a useful tool to support conventional educational techniques and methodologies but also as a main source.

Student engagement and self-directed learning are believed to be increased by gamifying remote learning, which led to the notion of gamifying distant learning. An exploratory study of social VR platforms indicated positive results, corroborating the findings of previous studies[42,43]. Participating in game creation and mastering as instructors or practitioners increases the complexity of training, making it less likely that these approaches will be widely adopted. Teachers must be able to plan to learn and change summative assessments in innovative ways for students to express their creativity.

Additionally, VR has already shown that technology can improve students' learning experience, in addition to helping them perform better on standardized tests[44]. VR may also aid in the development of manual capabilities and improved spatial awareness, which are important for increasingly complicated situations[45]. While searching for a significant and strategic hire, recruiters in the competitive graduate recruitment market have taken notice of gamification examples in the recruitment and training because of the novelty these examples bring. Incorporating game mechanics and elements of strategy and creativity, and using gamification elements (leveling up, competition, status, etc.), helps engage prospective hires and find the best individuals for critical positions within a company[46].

Gamification and VR are used in the creation of new educational settings and processes, making it easier for researchers to gather and evaluate data on students' feelings, motivations, and engagement[47]. Pressure is increasingly placed on educational techniques in general, and more specifically on some of the teaching methods used at the university level, which are increasingly threatened by new technologies that aim to provide better alternatives to help share knowledge and motivate the people and organizations involved (e.g., students, educators, enterprises)[48]. Consequently, learning how to spark students' interest in their topics may be advantageous not just to educational practice, but also to improve public goods and services.

3 Background

3.1 Digital twins

The concept of DTs was established as early as 1991[4]. However, it was officially launched a decade later, when its operationality and application aspects were first published. This term is typically used in various scientific and technological fields. The idea of using twin technological concepts was initially conceived during the process of the Apollo program developed by NASA. The engineers built and developed two identical forms of space vehicles. This action plan was to facilitate them in mirroring the space conditions of the vehicle in space while the other remained on Earth during their mission. DT is composed of various hierarchical concepts such as part and product twinning[49]. The current DT technology was introduced in 2002 by Michael Grieves[5]. However, the functional definition of DT was introduced by NASA in 2010 when it attempted to enhance their spacecraft simulation physical model[50]. The available evidence presents DT technology as a technique of virtually presenting physical processes and products. DT is specifically used to predict and understand the performance characteristics of physical counterparts. Therefore, this technology presents a digital replication of different physical objects and processes for the purpose of data collection and, in turn, predicting how they typically work or perform. Ideally, DT technology is a computerized program that

[4]https://www.nasa.gov/pdf/501625main_TA12-MSMSM-DRAFT-Nov2010-A.pdf
[5]https://scholar.google.com/citations?user=0gGMvgkAAAAJ&hl=en

utilizes real-time data to create simulations that reliably predict how the processes or a particular project performs. This technology is agile and can be successfully integrated with the internet of things, software analytics, and artificial intelligence to increase the output. Therefore, DT technological concepts have become the basic element of contemporary engineering activities. It works under the concept of constructing digital information in a particular physical system using different entities[4]. They can be used in different industries and areas of operation to improve performance and support innovation activities. In addition, the establishment of DT can facilitate other functions, including monitoring, undertaking analytical functions, and testing various services and products using its predictive abilities and competencies. The DTs of physical objects typically rely on a digital thread to ensure a high accuracy. Changing the product designs is possible using the engineering technique of changing orders. The operational life of a DT typically begins with data science or mathematics research. Therefore, it has a unique mathematical model that can stimulate the original. When being created, the DT is critically designed. The virtual model can receive data directly from sensors; the data is obtained or collected from real-world processes or situations. After the data from the real world has been received, the digital model can simulate and mimic what is happening in the original real-time version. This process creates reliable opportunities for gathering information regarding performance process and assessment of other dynamics, including possible problems. The DT can be complicated or simplified based on the needs or preferences of the user. This difference is created by the available data, which significantly influences how the real-world physical version is simulated.

DT technology in the modern world has many applications and uses in various fields. Current systems typically communicate effectively with other integrated components and boost operation efficiency. This technology can be used jointly with a prototype to provide feedback on a particular product during the development process. Alternatively, it can be used as a prototype to determine what is likely to happen to a physical model when created. Therefore, it is a multipurpose technology with many applications in different sectors. It is applicable in industries such as the automotive, power, healthcare, and education sectors. It can be used in different fields, where the technology is applicable. This helps improves performance and operational efficiency. Given its agility, other applications have been integrated with DTs to improve workflow and determine the relevant procedures for improvement. Therefore, DTs offer technological solutions for facilitating processes that are not limited to learning, manufacturing, and related functions, such as product development. Therefore, DTs can virtually showcase the problem of establishing specific solutions of technology uses. The integration of DT in education provides a pathway for resolving instruction and learning challenges, as well as enhancing the potential of accessing new skills and knowledge for students and teachers[51].

3.2 Virtual reality

VR is typically a computer-generated environment with objects and scenes that appear real. This technology can be used to simulate various engineering challenges. In this case, they can typically make users feel immersed and create a direct connection with the new environment in various settings[52]. Some VR applications are video games and other related graphical presentations. The available VR systems typically use multi-projected environments or even virtual reality headsets for the generation of sounds, videos, and other forms of sensations that directly simulate the physical presence of users in virtual environments. Simulation-oriented VR is common and helps effectively model an original environment. Different devices are typically used to receive VR signals, such as body suits, gloves, and headsets. VR technology has become commonly used in the education sector[53]. Ideally, VR in education usually opens more opportunities for knowledge acquisition and instruction. It provides learners with real experience concerning various real-life situations without necessarily being physically available. Therefore, by virtually projecting different activities and creative functions, learners can obtain advanced skills and increase the value of instructional processes. Therefore, VR provides tools and opportunities to leverage technology to perform various education-based activities that are valuable for their studies. This occurs by immersing new real worlds in the classroom and expanding learning opportunities. VR makes the process of learning more engaging and establishes experience-based knowledge acquisition through virtual trips. It can also enhance learning opportunities for students, because it supports distance learning. Mixed reality can be easily replicated to suit current needs.

3.3 Gamification

The term gamification, introduced in the early 2000s[13], provides a complementary perspective to serious games. This approach uses game elements to enhance non-entertainment applications to foster behavioral change, engagement, motivation, and soliciting participation in activities[14–17]. Its further dissemination began in 2011, after the publication of several documents[18–21], gaining popularity and rapidly spreading to a wide range of domains that benefit from the increased engagement of their target users[22], such as health and environmental awareness[15,23–25], e-banking[26], software engineering[27], education and training[14,28–31], and everyday challenges[32].

Motivation plays a central role in the learning setting; when students are motivated, they are engaged and achieve better results[54,55]. Educational settings usually lack the ability to attract students' full attention and motivation. This problem was exacerbated during the COVID-19 pandemic, in which online lessons and e-learning platforms were adopted to pursue learning paths. However, these platforms make education more accessible, allowing a vast number of students to access education[56]. Moreover, the same platforms experience high dropout rates[57] and low levels of user engagement and motivation[58], making the provision of quality learning difficult. Furthermore, students' lacking physical presence introduces a community-building problem. According to Brooks[59], the perception of community in educational settings are linked to students' persistence in school and learning outcomes.

Gamification[18] helps address the motivational problems that exist in the educational setting, primarily in online learning approaches[57,60,61]. According to Bai et al.[62], "gamification increases students' learning performance by promoting goal setting among learners, meeting learners' needs for recognition, and providing feedback on the performance of the individual learner". The application of gamification can also provide improvements in user motivation[16] and engagement[22], encouraging social interaction[63], and reducing dropout rates[64]. Furthermore, gamification can create a relaxed environment, encourage positive behaviors, and promoting attitude changes[56,65].

With respect to education and training, there is an extensive body of results available in the software modeling and engineering domains. Earlier articles explored issues related to accreditation, certification, collaborative learning environments (industry and academia), curriculum development, distance learning, establishing a body of knowledge standards, lifelong learning, professional education, and developing specific skills, such as metrics, programming languages, and visual formalisms. The use of game-based learning techniques (situated at the intersection of game development, education, and training topics) appeared over a decade ago[66]. Two IEEE Software theme issues addressing education and training topics include the state of software engineering education and training in the mid-1990s[67] and software engineering curriculum development in the mid-2000s[68]. More recently (i.e., 2017-2021), education and training articles have addressed a wide range of topics, including global software engineering environments, human factors and psychology, quality of service attributes (e.g., security), and bridging the gap between educational providers and industrial needs. An assessment framework for serious engineering games (situated at the intersection of game development, education, and training topics) has been reported[69].

4 The vision

DTs are becoming increasingly popular in various industries as a manner of managing complex systems[70–72]. As DTs become more sophisticated, the need for effective training and learning systems has become more important. VR and gamification can be powerful tools for training DT users. VR allows users to immerse themselves in realistic, simulated environments. This can be particularly useful for DTs, as it allows users to feel how a system works before using it in the real world. Gamification can also be used to make learning more enjoyable. By incorporating elements of game design into training, users are more likely to continue learning and retain what they learn. When combined, VR and gamification can create an immersive and enjoyable learning experience that helps DT users succeed.

Our vision is to design a more functional learning DT technology with more applications for facilitating training activities and improving education outcomes. The usual DT technology used for learning has various functional loopholes that, to a greater extent, limit learners' performance and academic knowledge development opportunities. In time, student, VR, and expert components will be combined with a more valuable DT mode that can create better functions and expand the opportunities of decision-making on educational activities using real-time data and accelerate student success using effective knowledge acquisition techniques. Therefore, the main concept in this new design involves the gamification of learning and enhancement of its performance through new VR competencies. It will be easy for learners to enjoy using technology more and create a positive attitude in a well-organized learning process. Model-based techniques and simulations can help create DTs to support performance[73].

There is substantial evidence that gaming and VR are reliable components that can be used for learning and training purposes[44]. Given that VR can facilitate a high level of engagement, it can create substantial value in the learning process[74]. DT with other integrated technological concepts, such as VR, provides a viable solution that facilitates decision-making in routine operations[75].

In the following sections, we describe our vision in realizing a gamified approach to train DT users in a virtual environment. Figure 1 illustrates the set of components of the envisioned architecture that collaborate to realize the learning/training we envision. We explain each component, their relations, and how different stakeholders are involved in performing specific activities.

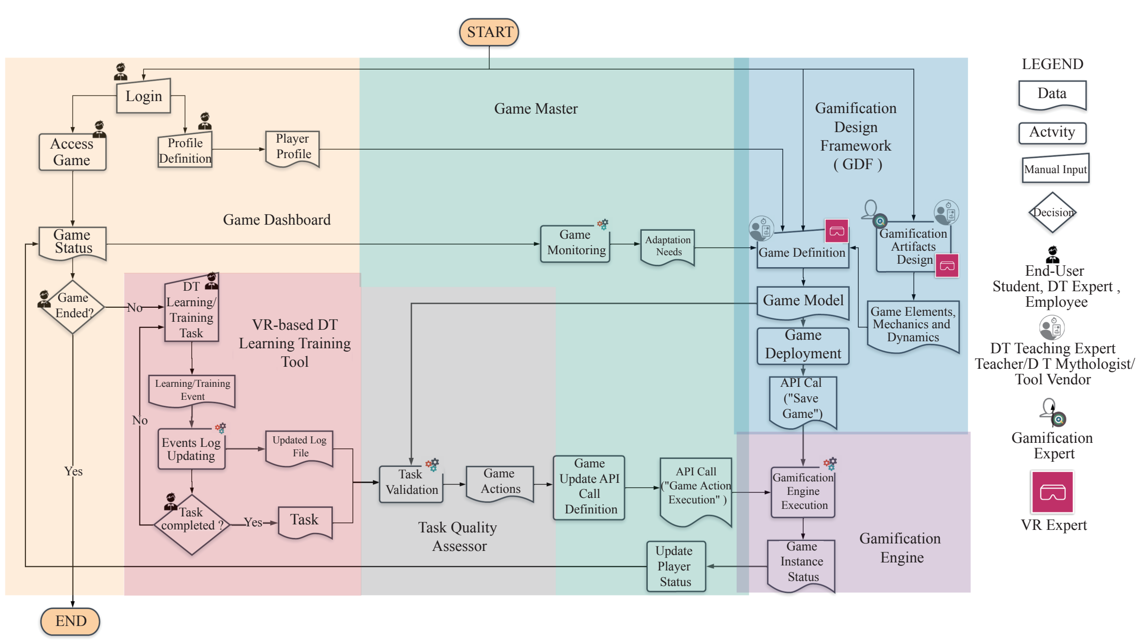

Figure 1 Our envisioned architecture, components, and stakeholders.

4.1 Envisioned stakeholders and related concerns

Our approach caters to four principal stakeholders: (1) a Gamification Expert, who designs and develops appropriate gamification artifacts (i.e., game elements, mechanics, and dynamics) in line with generic learning goals; (2) a DT Teaching Expert (e.g., teacher, methodologist, or tool Vendor) that, in collaboration with the gamification expert, defines the game including the expected pedagogical principles, global learning goals, and suitable progression of learning steps with their intermediate learning goals; (3) a VR Expert that implements multifaceted, immersive VR tools that can run on the web and various native platforms to execute the defined games; and (4) End-Users (i.e., student or employee) who use the VR-based DT learning/training tool to learn/train with specific tasks and enhance their competencies/skills. The experts are responsible for creating simulated worlds and making them look realistic for DT learning/training purposes.

4.2 Software components

The *Game Dashboard* component is the end-user entry point in the proposed learning/training environment. Through this component, one can *log in* to the game framework, *access* the various available games, and check their *game status* (i.e., history, achievements, and progress). It also enables end-users to personalize their *player profile* with new avatars, expertise levels, etc. This information may be used by the *Game Master* component to dynamically adapt game scenarios or difficulties to end-user features and experiences.

When a game begins, the end user must use the *VR-based DT learning/training tool* to achieve a goal, as prescribed by the game rules. Every time a player (e.g., student/employee) uses this tool to execute and assign learning/training tasks, the events related to task execution are captured and sent to the *Task Quality Assessor* component for validation and transformation into specific game actions. Task execution events, with the finalized task, are received by the *Task Quality Assessor*, which triggers predefined quality assessment algorithms. The output of these algorithms is then translated into new game actions, which are transferred to the gamification engine for execution.

The *Task Quality Assessor* component provides two services. First, it assesses whether the end user has satisfied the goal of the game. This is achieved by comparing the task performed by the student/employee with a reference result defined by the teacher. If they match, the game is won; otherwise, it is lost. In some specific cases (games), the comparison may not be binary (i.e., won or lost). A given task may be solved by different, equally good solutions. In other cases, some solutions are better than others. Therefore, the *Task Quality Assessor* should be able to measure the quality of a task solution such that, depending on the quality level, the player will gain more or fewer points. The second service provided by this component involves game progression; the Game Master may need to know the status of the game to monitor the player's progress and decide whether, for example, to help the player or modify the game to better match a player profile.

As is typical for role-playing games, the proposed gamified system has a specific component dedicated to *monitoring* the game execution called the *Game Master*. The latter receives notifications from both the *VR-based DT learning/training tool* and *Task Quality Assessor* components, enabling it to track user's *game actions* and *status*. Consequently, depending on the game strategy, gamer experience, and possibly other external factors, the *Game Master* can decide to adapt the game scenario (e.g., to speed-up or slow down the game dynamics) or even assist the gamer with achieving game goals.

The *Gamification Engine* (GE) component oversees launching games, executing their logic, advancing the *Game Status* for all players in all executing games, and persisting each game state. The GE adopts reactive computing models, as advocated in [76], and the logic of a game is typically expressed as a set of rules that predicate on players' current state and are fired in response to incoming events, that is, gamifiable actions. Rules can modify the game state and fire additional events that may trigger chains of further game rules.

The GE is also responsible for providing access to the *Player Game Status* and presenting an interface (i.e., REST API) to retrieve the various elements composing the game state of the players. This information is intended to be used by the *Game Dashboard* component to update the specific player game state and present the results to end-users. To this end, the GE encapsulates state-of-the-art rule engine technology (that is, the open-source DROOLS rule engine[6]).

Gamified systems are typically exploited to maintain users' involvement in certain activities or modify their initial behavior through game-like elements, such as awarding points, submitting challenges, fostering competition, and enabling cooperation with other players. *Gamification mechanisms* are well defined and composed of different ingredients that must be correctly amalgamated; among these, we find single/multi-player challenges targeted to reach a certain goal and provide an adequate award for compensation. A *gamified solution* is the result of combining these ingredients to obtain and maintain the motivation of the intended target players. When the game increases in complexity, keeping track of all mechanisms and maintaining the implementation can become error-prone and tedious. To address this issue, the development of gameful systems requires a software engineering approach[77] that can raise the level of abstraction of gamification mechanisms and provide a domain-independent solution for the design and development of gamified applications. Consequently, the *Gamification Design Framework* (GDF) component provides a modular approach that can be customized for different gameful systems and reflects a specific gamification process. Through this, game experts (in collaboration with modeling experts) can define the main components of a game (i.e., actions, points, levels, etc.) and its behavioral details (i.e., game rules). Moreover, it should provide support for deploying games in the target gamification engine. This is accomplished using a domain-specific language (DSL) called *GaML* (see [78] for details), which supports modeling experts in defining a certain concrete game (i.e., the *Game Definition* input of Figure 1). The DSL relies on game mechanics and allows the game designer to specify concrete games. In particular, they can specify in more detail how the game components are assembled to create a gamification application (i.e., the learning *Game Elements*, *Mechanics*, and *Dynamics*) and generate the respective *Game Model*. The DSL also enables *Game Deployment* in a target gamification engine. This part is performed automatically by an appropriate generator that can create appropriate calls for specific APIs (i.e., *Save Game* data in Figure 1).

4.3 Implementation requirements

DTs are becoming increasingly popular in various industries, from manufacturing to healthcare. To take full advantage of the potential of DTs, obtaining a comprehensive understanding of how to implement learning/training systems for these applications is important. There are a few key requirements that must be satisfied to successfully implement the architecture described in Figure 1. First, having a clear vision for how the system will be used and what objectives it should achieve is important. Without a clear vision, determining the necessary features and functionality of the system will be difficult. In addition, having a detailed understanding of the DT platform that will be used is important. This includes knowing how to configure and operate the platform, as well as understanding its capabilities and limitations. Without this knowledge, designing an effective training system will be difficult. Finally, having access to expert resources who can help with the development and implementation of the learning/training system is important. These experts can provide valuable guidance and support throughout the process, ensuring that the system is developed correctly and satisfied all required objectives.

The following are some points to consider when designing training programs for DTs:

(1) It is important to have a clear vision of how to use DTs in training programs. What goals do you hope to

[6]https://www.drools.org/

achieve? What processes do you want to simulate? What type of feedback do you want to provide?

(2) Ensure that the team responsible for developing the training program has the necessary expertise. This includes experts in gamification, VR, and DT technology.

(3) Awareness of the potential risks associated with using digital twins in training programs. For example, users may accidentally make changes to a digital twin that could impact production operations.

(4) Ensure that there is a clear process for monitoring and evaluating the performance of DT learning and training programs. This helps determine whether the programs are achieving their desired results.

4.4 Costs

According to extensive research and considering the implementation requirements of the vision presented in this article, there is a requirement for significant investment, as it will be the basis of the actual setup. This will help in setting up a pilot program, resulting in feasibility analysis in a specific teaching/training domain, which is typically the first step before setting up the full-fledged platform[79,80]. However, after the initial pilot study and program, the establishment of a full-fledged VR and gamification platform requires an even larger investment because it includes viewing systems, tracking systems, interactive elements, artistic inclinations, and a sensory management system, which impacts the overall budget by approximately 64%. The components that will significantly impact the costing structure include the outlining of the learning objectives[79,80]; therefore, the cost varies based on these specific factors. The development of the gamification elements and rules related to the specific learning/training objectives and pilots will also significantly impact the overall expense. Furthermore, mapping VR interactions and identifying the major matrix of the system and platform directly impacts increase and decreases in the overall expense[81,82]. Moreover, further budget and costing are also allocated for the continuous management and maintenance of the system, which will be required at least every three months. Continuously improving and updating the system with respect to the market and customer demand are also the factors that the budget must address.

4.5 Risks

There are various risks associated with establishing the proposed solution; however, the most important risks include the expensive nature of development. The expense related with the development of this type of platform significantly adds to the level of risk for this platform. A huge investment also means a huge loss may occur if the idea or platform fails in any aspect[83]. Furthermore, another important risk associated with this includes diminished value, which can be observed over time; such platforms are at a risk of losing value over a period of time[80,81]. The platform may not provide as much value as the money invested at a specific time; thus, diminished value can significantly and negatively impact the overall idea behind establishing the platform[84].

4.6 Ethics

Ethical considerations are also important while realizing this vision. These can include ensuring that gamification practices are not unfairly or unequally taking advantage of workers/students. This may include any type of exploitation[80,81]. Furthermore, no infringes may occur, and all workers and customers involved must have a significant level of autonomy, thereby satisfying ethical considerations. Furthermore, it is also important to consider that, unintentionally or intentionally, any worker/student or involved parties are not hurt, and ethical considerations include considering any type of negative impact on the moral or physical character of the parties involved[80,81].

5 Research challenges

The agenda we envision involves concretely implementing the introduced architecture and using it for actual learning/training activities. Once implemented, the proposed framework enables students/employees to directly experience a VR setting with 3D models and learn complex systems and industrial processes via DTs and gamified activities. We must instantiate a learning/training environment that is self-regulated and can be personalized for different learning needs and contexts. This project focuses on integrating VR technology concepts to create more opportunities for learning. The technology integrates gamification to motivate users and support learning processes. Therefore, this new technological concept will be a reliable indicator of proficiency in learning and training processes. The use of data can be a reliable means for enhancing and establishing proactive education programs. Using technology integration concepts can be a differentiating strategy for education quality, which has been deteriorating in different learning environments for most situations in terms of quality.

The remainder of this section describes a set of future challenges we consider critical to enabling a more effective education/training approach.

5.1 Repository of learning experiences

The design quality of learning activities is a critical element for the success of any educational strategy. In this respect, we believe that the community of interested educators would benefit from a shared repository of exercises and problems, with their intended learning objectives. Therefore, we plan to promote the creation of public repositories where educators can upload and share games they have used and lessons learned from applying them in a teaching/training context. A specialized infrastructure for managing game models may be proposed, including game designs, and accompanying artifacts such as DT models. We also foresee an interesting potential in sharing students' artifacts to both identify typical challenges encountered by the students and also provide automated mechanisms for artifact evaluation.

5.2 Adaptive and personalized feedback

Feedback is crucial to learning and training. Lack of feedback is a determining factor for student dropouts[57]. A report of students′ work is considered a key element of quality in teaching[85]. In traditional educational settings, teachers provide feedback to students on their strengths and weaknesses.

However, this feedback process seems complicated to students. According to [85], students have different perspectives on feedback processes, which makes providing accurate feedback on their performance in traditional classrooms difficult. According to [57], in e-learning and gamification, tailoring feedback that fits individual preferences is possible. Therefore, future research activities should target personalized and adaptive feedback to provide adequate reports on students' work and help enhance their performance and engagement levels.

5.3 Personalized and cooperative learning

Gamification principles have proven to be effective in motivating target users to engage with everyday challenges, including dedication to education, use of public transportation, and adoption of healthy habits. School closures due to the COVID-19 pandemic led to the need for a change in approach to managing students′ educational pathways. This uncovered the need for methods and digital systems that can support teachers in defining educational content and objectives for their classrooms and keep students engaged in their training paths.

Therefore, future investigations should focus on approaches, techniques, and tools to design and release educational digital systems for personalized and cooperative learning paths. Cooperative learning can be useful in introducing a sense of community, making gamification more effective despite individual differences and enabling the inclusion of marginalized students. Our intention is to first introduce group exercises and then class competitions. These approaches are expected to leverage AI techniques for adaptive gamification to support teachers in defining and monitoring dedicated learning paths for their students. By generating dedicated learning paths and personalized feedback, these solutions are expected to facilitate learning, encourage motivation and engagement, improve student participation and cooperation, and stimulate students to expand their knowledge.

6 Conclusions

This study proposes the integration of VR and gamification mechanisms to enable DT students and employees to experience quality learning and training experiences. This technology will be multi-purpose and suitable for different uses, including lesson planning and instruction. The gamification element will enhance learner motivation and make the entire experience more enjoyable. This benefits the learning process by enabling learners to acquire knowledge and create a favorable learning environment. We discussed the required components and necessary interconnections to adequately assemble and obtain the resulting gamified modeling tool. We highlighted some relevant issues that should be addressed in future research: the definition of a repository for learning experiences, the realization of techniques required to adapt and personalize user feedback, and the implementation of approaches for personalized and cooperative learning in the DT domain.

Declaration of competing interest

We declare that we have no conflict of interest.

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