Applications of Virtual and Augmented Reality for Practical Application Learning with Gamification Elements

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Abstract. Virtual reality and augmented reality have the potential to enhance and widespread practical learning environments in professional courses efficiently in a cost-efficient manner by limiting the costs of real resources substituting them with fixed costs from.VR/AR applications with virtual resources. There are advantages in the learning process, as practical, active and visual learning methods are more efficient and virtual and augmented reality can digitalize these procedures and replicate them at scale with different degrees of virtualization. In this work we aim to provide a framework that allows the creation of VR and AR experiences for learning or training proposes in a serious environment adding gamification elements to keep user engaged in the learning/training process. In the process gamification adaptation to VR/AR environment is demonstrated in real applications. The learning tasks in this approach are not necessarily changed or take advantage of new forms of interactions and guidance but aim to be replicated in a blend between virtual and real environments. In this regard, we hope to advance gamification application to account for more elements, such as VR/AR interaction, digital twins and digital aids in a learning application. In this article we detail possible scenarios for the application of virtual reality and augmented reality combined with machine learning in serious games and learning scenarios.

Keywords: Gamification, Virtual Reality, Augmented Reality.

1 Introduction

Contemporary society is featured by instability, fluidity, globalization, rapid changes and growing inter-linkages between human life and technology. Smartphones, tablets, and computers are common in daily lives and play a central role in individuals' social adjustment.

As a consequence of technology being entangled in the current society, children have been labelled native-digitals [1]. This means that the use of technology is getting more natural and intuitive in our lives, whereby its potential to sustain individuals' learning and development needs to be acknowledged. For example, a number of studies have suggested technology's advantages in children's curiosity, multicultural awareness, self-esteem, creativity, and exploration [2],[3],[4].

However, technology's disadvantages have been also considered. Concerns regarding dependency from technology, Internet addiction, cyber-bullying or technology's potentially negative impact on individuals' social skills, interpersonal relationships, pro-social behaviour, and emotional competence have been disseminated [5].

Gamification consists of applying game principles to an everyday activity. These principles appeal to natural instincts so as to influence human behaviour [6]. It does not need to be connected to the computer science definition of game, but it's a fact that most of its implementations are based on computer-based game elements.

The application of this concept has increased in the last decade and has also been applied in diversified areas. From the incentive to reduce the energy impact, allowing to improve the sustainability of the planet, as is the case of the platform PHESS [7] to the incentive to increase sports practices to improve health and quality of life, such as the Nike Fuel punctuation system [8] that has a public/private ranking and rewards participants for practicing sports. On one hand encourages the continued practice of sport at an individual level, and on the other hand, keeps public rankings that increase the competitiveness among the users, again translating into an incentive for practicing sports. Gamification has proven to be a very powerful tool to help engaged people in a world of possibilities.

On a learning perspective, gamification has been successfully implemented over several platforms mostly in its traditional form accounting for basic game elements such as points, levels, badges and achievements. However currently technology can portray more game elements from computer technology such as avatars, digital objects of virtual and real interactions within a mixed reality environment. VR and AR are technologies made to substitute or complement the real world and therefore present an opportunity to a specific subset of learning such as practical learning in professional courses.

Apart from the initial education courses such as technicians in mechanic, electronics, carpentry, hospitality, culinary and other also provide important opportunities to re-education and enlarge people skillsets. This works aims to demonstrate the benefits of applying virtual reality and augmented reality to these courses in a gamified learning system while presenting solutions to the application of gamification theory targeting these domains.

2 Related Work

In this section relevant works and research fields are presented. Hence, a discussion of topics such gamification, virtual reality, augmented reality, machine learning models and means to assess these experiences are addressed.

2.1. Gamification

Gamification seems to be advancing in the alignment between the primordial purpose of technology and the contemporary needs. Gamification requires and aggregates knowledge from multiple fields besides computer engineering, such as public psychology, and sociology. It can be conceived of the use of game and interactive mechanisms to foster individuals' motivation in non-game settings [9]. It triggers psychophysiological reactions similar to those experienced when one is playing a video game in order to increase motivation and help change risk behaviours [10]. By promoting fun, joyful, ludic and flow experiences, gamification is believed to motivate individuals to perform a given activity. At a practical level, gamification can be used in political, educational, work, marketing, touristic training and learning [9].
For example, gamification might be useful to cheer and motivate people to walk and work out more often as well as to reduce environmental unfriendly habits by challenging drivers to minimize fuel consumption and, thus, reduce carbon emissions. Gamification offers, therefore, the potential to engage individuals in civic matters and jointly solve common social problems [11].

In the specific case of learning systems there are identified 5 dimensions on a gamification taxonomy [12]:

- Performance – associated with the assessment of a players performance and can include traditional game elements such as points, levels, progress report, player stats and achievements;
- Personal – related to the design and experience of the player through the objective, sensation, puzzle and novelty of experience;
- Social – includes the psychological attributes such as reputation, social pressure, competition versus cooperation design in the gamification experience;
- Ecological – design real experiences through implementation of world rules and restriction such rarity of resources, economical conditions, time pressure and conditioned choices either by time pressure or chance;
- Fictional – the use story telling or game narratives to direct the player through the gamification experience.

In this rich taxonomy, a gamification implementation considers and mixes not only traditional elements but also newer approaches that mimic real world events and restrictions, psychological factors and virtual elements. Moreover, game elements can also cover multiple dimensions, depending on how they are implemented in the system.

Although gamification implementations in the learning domains are generally common, the use of immersive implementations of gamification is less frequent [13]. This presents an opportunity to further enhance gamification application with more immersive applications making use of immersive technologies such as VR and AR. In fact, the application of gamification in VR/AR is still an emerging trend, as VR/AR itself is also an emergent technology as well. This provides opportunities to develop new and innovative system that aim specifically for these applications and develop solutions to join these two fields. In area of learning application VR/AR have been touted has revolutionary technologies, and they enable the mimic of real environment in computer generated environments that the user is himself transported to. To best of the authors ability, no generic framework for the application of gamification in the learning space was presented specifically targeting and solving the problem of its application to VR/AR.

The dynamics of gamification are not static in nature. To demonstrate, authors have provided different models for the dynamics of gamification such as Mechanics, Dynamics and Emotions (MDE) model [14], which tries to build upon the Self-Determination Theory (SDT) [15], which states that intrinsic motivation is better than extrinsic motivation. The MDE model describes the continuous dynamics that a gamification implementation should target to develop extrinsic motivation and increase players performance. It is also key to consider the characteristics and emotions of the players. Knowing the population of players in a gamification implementation should lead to different results in different populations. The intrinsic motivations of players can be different in a heterogenous population or change entirely between populations. Recognising player types can be achieved using models such as Marczewski's Gamification User Types Hexad [16] or Bartley Player taxonomy [17]. The design of the gamification experience should, therefore, attend the specific needs of each player in order to be successful. For reference, some studies have proposed the use of certain game elements to target specific player types [18]. Often, game elements can target many extrinsic and intrinsic element of motivation, as well as user types as demonstrated by table 1.

Table 1. Rewards by user types, adapted from [18].

User Type	Extrinsic Elements	Intrinsic Elements
Networkers	Virtual goods, Badges, Points	Social Status, Social Connections
Exploiters	Visible Status, Virtual Goods Badges Points	-
Consumers	Virtual goods	-
Self-Seekers	Virtual goods, Badges, Points Leader Boards, Exclusive content	-
Socializers	-	Social status, social connections
Free Spirits	Unlockable Content	Customization
Achievers	Visible Status, Exclusive Content	Quests, Levels
Philanthropists	-	Social Status, Giving

The Octalysis framework [19], can provide yet another design to implement gamification experiences. It is based on 8 general principles as demonstrated in figure 1. As similar frameworks, it aims to develop gamification experiences that cater to the population of players it is being used and make use of a combination of game elements not only to apply gamification but also to motivate and engage user based on their sensations, experiences, and motivations.

Until this point, gamification has been presented as a mature field of work with several application and methodologies associated. However, to the best of authors ability, the application of gamification in VR/AR environment is not a mature field of application. It presents several challenges and opportunities that unique to this problem. In this article we tackle the application of gamification elements for the task of practical learning. VR/AR provide innovations such as virtualization of environments, assets, and resources, but it comes with challenges such as detection of interactions, synchronization between the virtual and real worlds, conditional triggering of rules and points as well as the sensation and motivation of players. These areas will be developed in course of development of this work in section 3 and 4.

Fig. 1. Octalysis framework, adapted from [19]

2.2 Virtual Reality (VR)

Virtual Reality as defined according to Kalawsky, R. [20] "*Virtual Reality is a synthetic sensory experience that may one day be indistinguishable from the real physical world*". It was in 70's that the first virtual reality equipment appeared, at the time called artificial reality, at that time some studies were carried out that combined computers and video systems.

Virtual reality consists of several components, two of the most important are presence and immersion in the virtual environment. For immersion to exist, interaction between the user and the created environment is necessary, such as a movement of the user's head, there must be immediate feedback from the side of the environment. In relation to presence, this is a psychological state of a subjective experience of being in a different place than reality [21]. The presence in virtual reality can be in three ways:

- Personal presence, in which the user feels that he is in that same created environment.
- Social presence in which the user feels that other beings also exist in the environment.
- Environmental presence, in which the environment and the user react with each other.

For there to be a strong presence in the environment, there are certain factors that contribute, such as sensory factors, factors at the level of user controls in the environment, factors at the level of reality used in the environment, and finally factors of distraction, attempted that the user keeps the greatest attention to the created environment. When all these factors are used, it is possible to keep the user as immersed in the virtual environment as possible, thus making the user's behaviour in the virtual environment as identical as possible with reality.

These two components are related to each other, the better the immersion created by the environment, the better the user's presence in it, making it possible to remove the user as much as possible from reality [21].

2.3 Augmented Reality (AR)

Augmented Reality has had several definitions over the years, for example *in Milgram's Reality-Virtuality Continuum* [22], the authors define Mixed Reality as a mixture of the real and virtual world. In the context of Mixed Reality, the authors refer to Augmented Reality as "any case in which an otherwise real environment is augmented through virtual objects (computational charts)". In 1997, in the article "*A Survey of Augmented Reality*" [23], the authors conclude the same observations as *Milgram* and *Kishino*, but defines AR comprehensively: "Augmented Reality (AR) is a variation of Virtual Environments (VE), or Virtual Reality. VE technologies completely immerse the user in a synthetic environment. While immersed, the user cannot see the real world around them. In contrast, AR allows the user to see the real world, with virtual objects overlapping or composed with the real world" [23]. Four years later, Azuma [24] stated that AR "combines real and virtual objects in a real environment; wheel interactively and in real time; and records (aligns) real and virtual objects with each other." This is a widely accepted definition that is also used in current works such as Javornik [25] and Billinghurst, Clark and Lee [26].

On the other hand, Augmented Reality. according to Klopfer [27] should not be defined with a restricted definition, but more comprehensive to all technology that combines real virtual information in a meaningful way for the user. The most concrete definition is that Augmented Reality is a situation in which the context of the real world is dynamically superimposed with a location coherent to the context of virtual information [28].

The quality of AR technology is linked to the technology, such as the combination of virtual images with real ones, interactivity in real time and 3D interaction. For these components to be present in technology, there are operations that must be respected to the best effort possible, such as object detection, depth estimation and plan detection. Other operations, such as the synchronization of virtual elements with the real elements are achieved through registration and tracking algorithms. These are responsible for positioning the virtual object in the real world, thus managing to give the user a sense of reality to the scene viewed by the user.

2.4 Computer Vision and Machine Learning Models

Applications based on VR and AR are not possible without contributions from other areas. Namely, the field of computer vision is important as it addresses the theoretical background for many structures used in these applications. In the case of AR, computer vision models and machine learning algorithms are determinant for the end result.

The developed of real-world applications based on real objects requires the digitalization of physical objects. It is also true that we can achieve some results by simply using dedicated machinery such as 3D sensors, but the point cloud from the digitalized item may require further processing and optimization. Other cases, it may be impractical to use such devices. However, there are alternatives modelling options relying on expert combination of photos and videos taken from a subject and is known as photogrammetry. One of its applications is to provide means to create rich VR and AR realistic elements [29].

The processing of digital assets such video and photos, by dedicated algorithms can also yield further results. For instance, the location and identification of specific objects can also be made using simple computer vision algorithms such as template matching [30]. These are a group of techniques that can help identify certain details of interest in images or video frames. Different implementation and variations do exist, however recently, the field of deep learning has provided great competition to these classifiers.

From 2010, increasingly efficient and precise models have been proposed fuelled by the ImageNet Large Scale Visual Recognition Challenge[1]. During this time algorithm proposals for generic object recognition models included R-CNN [31], FAST R-CNN [32], Faster R-CNN [33], YOLO [34][35][36] and SSD . The common characteristic from these models is their use of algorithms based on deep learning and neural networks. Not only object recognition, but also other areas such as speech recognition [37], pose estimation [38], body segmentation [39], and other topics of detection have been increased in recent years. It is these advancements that allow the creation of rich experiences in VR and AR.

In the scope of this article, we are particularly interested in algorithms to detect objects and tasks completion with precision. The specific value for precision in the detection algorithms is often linked to the training data and to the tolerance of the task at hand. In the case of lack of training samples relevant to the detection task at hand, there are also procedures for transfer learning, in which, an improvement of the selected model can be achieved by re-training the original model with additional annotated samples relevant for the detection problem. This procedures, allows the object detection algorithm to adapt to new contexts quicker than retraining the whole model from scratch preserving the origin model strengths [40], [41].

[1] https://www.image-net.org/challenges - Object detection and image classification at large scale competition that ran from 2010 to 2017 based on the imagenet dataset.

2.5 Evaluation of VR and AR experiences

The evaluation of VR and AR is also an evaluation of perceptions and therefore complex to achieve through only analytic or numeric benchmarking methods. A VR experience is intended to mimic and substitute reality with an alternative computer-generated environment that should be realist to the user. This means that the virtual reality, objects, and interaction should be accepted as natural and real by the user. An AR experience intended to blend virtual assets in the real world in a believable format that the user accepts naturally. This should make the presence and interaction of virtual assets with the physical world believable and natural for the user.

In the literature, researcher seems to indicate that the preferred method to evaluate VR and AR experiences is with questionnaires to the users of such experiences. Of course, these questionnaires are not only open-ended questions to the user but calibrated and research validated questions to assess categories for each experience according to its specificities.

In the case of VR the questionnaire "*Measuring Presence in Virtual Environments: A Presence Questionnaire*"[42], presents questions to the user in order to assess categories: *Control Factors* (CF), *Sensorial Factors* (SF), *Distraction Factors* (DF) and *Realism Factors* (RF). The answers to this questionnaire are provided in a Likert scale from 1 to 8 and the value of each question is added to the respective categories using a weighted factor which determines the relevance of the question to that category.

annoying	o o o o o o o	enjoyable	1
not understandable	o o o o o o o	understandable	2
creative	o o o o o o o	dull	3
easy to learn	o o o o o o o	difficult to learn	4
valuable	o o o o o o o	inferior	5
boring	o o o o o o o	exciting	6
not interesting	o o o o o o o	interesting	7
unpredictable	o o o o o o o	predictable	8
fast	o o o o o o o	slow	9
inventive	o o o o o o o	conventional	10
obstructive	o o o o o o o	supportive	11
good	o o o o o o o	bad	12
complicated	o o o o o o o	easy	13
unlikable	o o o o o o o	pleasing	14
usual	o o o o o o o	leading edge	15
unpleasant	o o o o o o o	pleasant	16
secure	o o o o o o o	not secure	17
motivating	o o o o o o o	demotivating	18
meets expectations	o o o o o o o	does not meet expectations	19
inefficient	o o o o o o o	efficient	20
clear	o o o o o o o	confusing	21
impractical	o o o o o o o	practical	22
organized	o o o o o o o	cluttered	23
attractive	o o o o o o o	unattractive	24
friendly	o o o o o o o	unfriendly	25
conservative	o o o o o o o	innovative	26

Fig. 2. UEQ Questionnaire in English

In the case of AR, the UEQ questionnaire based on the article "*User Experience Design With Augmented Reality (AR)*" [43] was used. The main objective is to enable a quick and immediate measurement of the user experience. The UEQ considers aspects of pragmatic and hedonic quality. The original German version of UEQ was created in 2005 by an analytical approach to data to ensure the practical relevance of the scales constructed, which correspond to different aspects of quality. In Fig. 2 you can observe the UEQ questionnaire in English.

The user experience questionnaire thus contains 6 dimensions with 26 items:´

- Attractiveness: General printing of the product. Do users like it or don't like it? Items: nice/annoying, good/bad, nice/nasty, unattractive/attractive, friendly/hostile.
- Perspicuity: Is it easy to familiarize yourself with the product? Items: not understandable/understandable, easy to learn/difficult to learn, easy/complicated, clear/confusing.
- Efficiency: Can users solve their tasks with the product without unnecessary effort? Items: fast/slow, efficient/inefficient, practical/impractical, organized/disorganized.
- Reliability: Does the user feel in control in the interaction? Items: unpredictable/predictable, auxiliary/obstructive, safe/unsafe, meets expectations/does not meet expectations.
- Stimulation: Is it exciting and motivating to use the product? Items: valuable/inferior, boring/exciting, not interesting/interesting, motivating/demotivating.
- Novelty: Is the product innovative and creative? Items: creative/dull, inventive/conventional, cutting-edge/usual, innovative/conservative.

According to the original questionnaire the user answers the items/questions on a scale of -3 to 3, in which -3 is the fully agreed negative term and 3 positive term fully agreed. However, to facilitate the normalization and interpretation of the data, a scale from 1 to 7 was used, in which 1 is the fully agreed negative term and 7 positive term fully agreed.

Due to the relevance of these two questionnaire and broad usage in the field, both will be used in this work to address the evaluation of VR and AR experiences for practical learning scenarios. These questionnaires will also be used to assess the quality of gamification fictional and personal dimensions through the assessment of VR/AR experiences. Traditional approaches from performance and ecological dimensions will be added to the design of VR/AR experiences through techniques related to both VR/AR such as raycasting, collision detection, anchors and interpretation of the virtual and real environment. These techniques will be used adapted to each reality to detect interactions, simulate movement and practical actions such as assembling, distribution or separation in open lesson plan that are graded by the efficiency and correct order of tasks. The points levels and progress of the player will be embedded in the VR/AR experience in elements that mimic real environments.

3 Application of Gamification and Mixed Realities for Practical Learning Applications

In this section the framework for the application of VR and AR in the context of practical learning scenarios is presented. The intention is to support the learning tasks with the development of gamified architecture that can combine different lessons both on virtual and augmented reality according to proficiency of the student/trainee and apply gamification elements to motivate self-learning and continuous improvement.

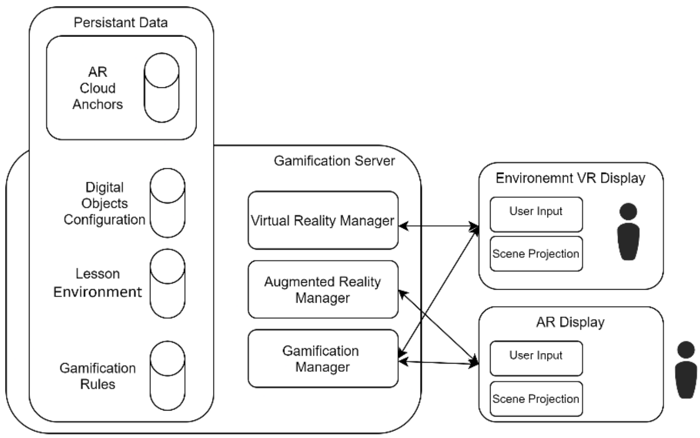

Fig. 3. Augmented Gamification System for Learning tasks

The architecture proposed (Fig. 3) after the proof-of-concept experiments contemplates a server application which should store the definition of the learning lessons, and a list of interactable objects both on VR and AR. The base lesson should be implemented either by Virtual Reality Manager (VRM) or Augmented Reality Manager (ARM) to correctly load assets belonging to each version. A Gamification Manager (GM) should interact with both VRM and ARM, through event triggers which notify the GM of interaction and events of interest according to gamification rules. The framework is built around the unity engine for client application while the server provides the necessary assets and rules for the experience.

On the client side, specific hardware is necessary to run the experiments in the case of VR, ideally a Head Mounted Display (HMD) or specialized device. In the case of AR, although the framework used support export for HMD devices, modern mobile devices with support for modern VR and AR computer libraires are sufficient.

3.1 Gamification Elements

This approach uses gamification as base context for student motivation. However, the use of virtual reality and augmented reality are explored to create an immersive environment for learning task enhancing student motivation specially on practical lessons.

In this approach the traditional assessment and grading is substituted by gamification elements which introduce different approaches to the learning tasks. Elements such as points allow a direct reward from each task and a level represents a threshold towards different proficiencies or task completion. Finally, achievements rewards users which mastery over a single aspect of a specific task or a combined event in the platform (Table 2).

Table 2. Gamification Elements present on Virtual Reality or Augmented Reality approach.

Element	Description	Virtual Reality	Augmented Reality
Points	Collection of points for each instruction followed	X	X
Level	Levels are divided according to the accumulated experience	X	X
Achievement	Certificates of task completion with minimal, optimal or excellent performance	X	X
Digital Objects	Introduce digital objects such as avatars and tools	X	X
Physical Objects	Capture interactions with real world objects through machine learning object detection algorithms	-	X

Considering the learning tasks on inherently practical fields such as man craft, cooking, an innovative aspect is that gamification elements only offer a reward after physical tasks are validated. Virtual Reality and Augmented reality change this notion by immersing the student in virtual world shielding him from the natural world where interactions must be replicated and can be easily conferred automatically. On the other hand, Augmented Reality links both virtual and real elements through a passthrough display. This approach links the physical setting with virtual elements displayed over the scene taking into consideration the physical structure of the environment and reproducing physical rules appropriately.

The main challenge is to monitor and acquire relevant information from user interactions and movement to be able to detect the activation game elements and award the user with positive reinforcement or if enabled negative reinforcement as well. Both in VR and AR systems, the framework can acquire information regarding user gaze, recognition of player tasks, task completion, user state, movement, collisions, number of attempts. More analytics are derived from temporal data on a player uses the gamification experience. These analytics are commonly referred as gamification analytics and cover not only VR/AR analytics but also how the user engages with the platform [44].

In the case of AR application, more considerations are needed. The implementation of gamification elements is dependent on the interpretation of both the real and virtual environment and assets. It is harder because the combination of the two can generate unknown variables if not properly controlled. In this case, we focus our attention on the application of state of the art components from computer vision to place virtual assets in a real environment which also needs to be understood by the system. So, in order to replicate the same components from VR, it also needed plane and scene detection and enforce bounds for virtual interactions with real objects. Only then, can rules defined in the gamification experience be triggered and monitored through gamification analytics.

The application of gamification according to the gamification taxonomy in [12], yields so far the performance dimension but others are also considered such ecological by the implementation and restriction of possible interactions, impose environment bounds, fixed number of resources that make the game mechanic. Personal dimension is target by the experience of the user and the immersion sensation of each experience, the novelty puzzle solving problems in practical scenarios targeted to learning processes, and objective driven design. Fictional dimension is also embedded into the VR/AR experience, as a number of fictional, game like elements is presented as part of the environment and managed by the system. These include monitor, progress information, feedback loops by unlocking content and visual cues. The last dimension, social is target by the support system where players are ranked and compared according to their gamification analytics and rankings in public leader boards. Cooperation experiences are not yet implemented but are identified as a future opportunity to further develop the system.

The challenge presented by VR/AR is not negligible and requires effort and detail to implement different mechanics. Unlike traditional computer programs, VR/AR present additional points of concern when applying gamification theory, specially in the case of AR which is very dependent on the quality of algorithms, devices and AR frameworks used.

3.2 Virtual Reality

The implementation of the techniques used for the task learning were implemented using the VRTK, Virtual Reality Toolkit. With the help of this toolkit, it was possible to implement the features such as Ray-Casting for selection of virtual objects and the Hand-Centered, Object, Manipulation Extending Ray-Casting (HOMER) [45]. This technique uses the size of the objects at the scale of the environment, which makes manipulation more realistic. Along with this manipulation technique, Snap Drop Zones in the VRTK framework or simple sockets in the unity XR framework are another technique to define areas where objects should be placed or removed for a detailed precise interaction. These techniques are used to simulate user interaction in a virtual environment.

The navigation inside an environment is made defining a camera rig for the user, getting him to be as integrated as possible in the environment and tasks performed, detecting collisions and interactions with other objects in the space. The navigation paths are based on the environment modelled.

Objects placed inside the simulation lesson should be retrieved through the gamification server and applied in the VR scene. The objects used should be the most identical to reality, to facilitate their recognition and interaction. All objects used, should be influenced by physical rules such as gravity and collisions. In terms of feedback, visual and sound effects were used attached either to object interaction or the environment itself.

Gamification events are captured from object interactions, and simulation events which should be sent to the gamification server to categorize events and interactions according to gamification rules present in the gamification manager. In turn the gamification manager should update the user's profile accordingly. This synchronization could be done in real time or at the end of a lesson.

The realization of lesson plan in virtual reality is realized by the design of a scene in the unity engine that applies all the physic rules of the practical learning lesson. The scene may use a collection of digital objects, or template object with configured interactions zones (snap drop zones), colliders and trigger behaviours to actions actionable by a player with techniques such as raycasting, collision, gaze or pointing. The VR experience is then stored in a database which is used to load the experience on the student device when he desires to initiate the experience. The unity scene also uses a standard communication library to report the players analytics in real time to the central system which than saves user progress and grading.

3.3 Augmented Reality

To implement the AR lesson the ARFoundation library from the unity game engine was used. With ARCore it is possible to have a set of behaviours and APIs that allow to realize functionalities such as, position and orientation of the device in relation to the physical space, detection of planes and representation of 3D objects at scale. These functionalities complement the functionalities already existent on a traditional VR approach.

Image Detection models with location aware clues are used with the AR Track Image component. This is useful to identify a workstation or environment from clues such as QR codes or labels present in the real environment.

The positioning of virtual objects in a real environment at scale and integrated with real objects is a complex task which should be handled by a combination of techniques such as plane detection and AR Raycast. The device's camera works as the user's vision, that we can use to apply algorithms to detect the planes of the physical space that surrounds us, as well as the distance to those planes.

Cloud Anchors makes it possible to save the position of virtual objects inside a real environment. This takes into consideration the properties of the virtual object retrieved from the gamification server, but also planes and physical objects nearby. This technique was used to store virtual objects that complement real objects during a student's lesson. When the student launches the lesson, it should load not only gamification rules for the lesson, but also recognize the physical environment and reload all virtual objects.

Other machine learning tasks are also used to process the camera feed to perform Object Recognition in the physical worlds. Algorithms such as Single Shot MultiBox Detector (SSD) [46], can be used to identify and delimit, inside the feed, the position of known classes of physical objects. Other machine learning models currently available in this framework are detailed in table 3. The models used in this framework are publicly available from the tensorflow library.

Table 3.

Requirement	Machine Learning Model
Hand Tracking	Hand Tracking
Body Pose Estimation	PoseNet
Head Tracking	Blaze Face
Object Classification	SSD Object Detection

Gamification elements are applied in a similar strategy as in a VR environment albeit, in this approach they are only visible through the AR device screen as they are also virtualized.

The implementation of these experiences follows the same rule as in the section 3.2. The digital assets used for learning are stored in a database as resources which are then imported to a scene in the unity AR engine. The scene in VR should use a device such as AR headset or a AR enabled smartphone to process computer vision algorithms and AR frameworks such as AR core in the device. The unity scene, shares a communication library to report user analytics and interaction back to the system to provide a centralized source of data which stores user progress and grades.

4 Practical Learning Experiences

For the demonstration of the application of virtual reality and augmented reality, two practical learning tasks in which gamification elements are deployed to control the flow of actions are described here. Over these tasks we assessed the use of gamification elements both in a virtual reality and augmented reality setting to have the user learn how to perform practical tasks obtaining direct feedback from its performance using gamification elements. In the first phase, the simulator appears as part of a hotel business or catering course to replace student training over culinary lessons or the preparations of new catering products. In the second phase, the simulator demonstrates an application of AR to address the montage of furniture from in a real environment.

4.1 VR Practical Lesson

In the first iteration a demonstration utilizing virtual reality as a catalyst for learning simulation under real conditions was developed [47]. A simulator to avoid the costs that these trainings involve was developed for beginner students. It simulates with the best possible effort, and students have the same training with relative low cost derived from being able to train in the simulator without having to spend physical resources.

Gamification elements are spread inside the VR simulation, as observed in fig.4, to direct the user to the most important tasks using point rules and level change for each milestone inside the lesson. The application of gamification was correctly identified from test subjects and the grading system based on levels was deemed adequate and motivating. The most important tasks are signalled by rewarding more points to the user which can make the instruction in the correct order in the optimal time.

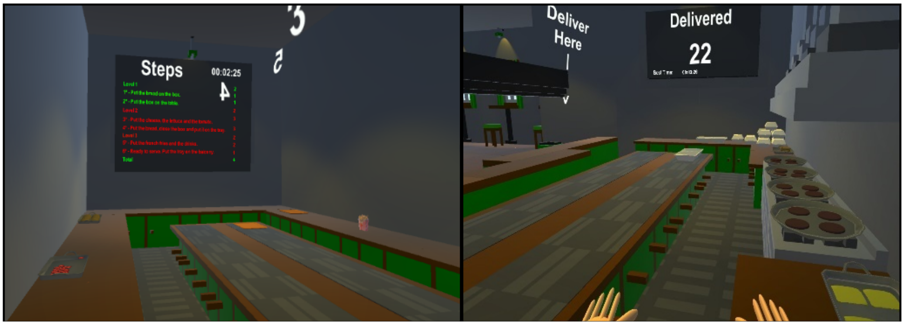

Fig. 4. VR gamified task with list of objectives and points (left) and current status of the simulated lesson (right)

To perform the evaluation of a virtual reality application there are some ways to measure in terms of presence as well as in terms of immersion. In this work the evaluation questionnaire created by Witmer and Singer in [48] to assess presence and immersion during the simulation was used. The virtual reality experience was assessed in the categories: Control Factors (CF), Sensory Factors (SF), Distraction Factors (DF) and Realism Factors (RF). The results from the assessment are summarized in Table **4**4

Table 4. Immersion assessment of virtual reality-based gamification.

Assessment Criteria	Score	%
Sensory Factors (SF)	25.83	78%
Control Factors (CF)	33.99	81%
Distraction Factors (DF)	7.84	68%
Realism Factors (RF)	12.81	80%

The best categories assessed were SF, CF and RF. this was due to our concern with making the proof of concept virtual environmental modifiable through interaction with objects and scene realism reproducing the virtual space that is identical to reality. Of course, the assessment of the simulated environment is not perfect, but an assessment based at 80% of the maximum is satisfiable for the team as a proof-of-concept at this stage. The last category, DF has a lower score, due to the imperfect nature of the simulation, and the lack of physical movement during the simulation as well as the lack of specialized input hardware and the need to use more generic controls which will make user's more distracted as they coordinate the task through unnatural movements.

4.2 AR Practical Lesson

With regard to the results of the second part of the article, an application was made capable of providing the user with informative and training components, in order to accompany these employees in the assembly of furniture in a real setting.

The assembly is done after recognizing the 3D space surrounding the user and finding a suitable and physically possible location. After the user is inquired to which pieces he should build next, as well as the final position for assembly. If the user requires, a help section can provide a guided approach in which the user is guided though all the steps of assembly, fig. 5.

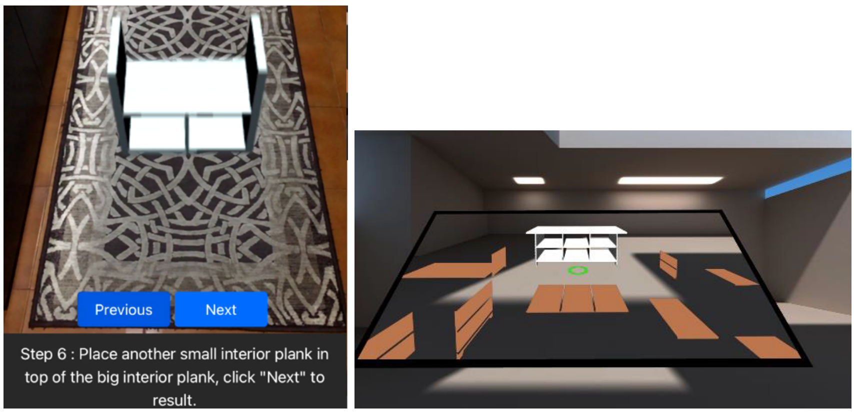

Fig. 5. –Augmented reality implementation for furniture assembly in a real setting in a assisted context (left) and gamified context (right)

The experience was assessed using the UEQ questionnaire mentioned in section 3.5. The results answered by users succinctly are observable in Table 5. Attractiveness is a dimension of subjectivity; this dimension represents the overall impression that the user has extracted from the AR experience. An average result of 61% was achieved which means that users had a slightly reasonable overall impression of the AR experience. Efficiency, perspicuity and reliability are dimensions of pragmatic quality, these describe qualities of interactivity that are related to the tasks or objectives that the user intends to achieve with experience. In efficiency it had an average result of 79%, which represents that the experience proved to be good in aspects such as being fast, efficient, practical and organized. The dimension of perspicuity assesses whether an experience is intuitive, easy and clear in that users had an average result of 88%, which suggests that the experience is very good in this dimension. The reliability dimension assesses whether an experience is predictable, auxiliary, safe in which users had an average result of 38%, which suggests that the experience is bad in this dimension.

Table 5. UEQ results from the AR experience.

Assessment Criteria	User 1	User 2	User 3	Mean
Attractiveness	0,61	0,53	0,83	0,61
Efficiency	0,88	0,71	0,79	0,79
Perspicuity	0,96	0,88	0,79	0,88
Dependability	0,38	0,38	0,38	0,38
Stimulation	0,33	0,21	0,50	0,33
Novelty	0,13	0,08	0,33	0,13
Total	0,55	0,47	0,62	0,55

Stimulation and Novelty are dimensions of hedonic quality, which do not relate to tasks and objectives, but describe aspects related to the pleasure or fun of the AR experience. The increased experience in the stimulation dimension reached an average rate of 33% and in the novelty dimension an average rate of 13%. This means that the AR experience performed poorly in the aspects of pleasure and fun during the experience.

4.3 Gamification integrated in Virtual and Augmented Reality

Gamification is the commonly defined as the application of game elements to serious tasks. In this paper we provide tools and a system design to demonstrate the application gamification elements in realistic scenarios such as practical learning and skill development.

In this specific scenario, gamification is used to increase user engagement, motivation, productivity, feedback and interaction. The final objective is not to design a game but to make people acquire expert knowledge of a given field while using realistic technology. In this sense, the usability study presented in section 4.1 and 4.2 should be interpreted as a means to demonstrate the efforts of replicating a real world inside a computer system to which the user is transported. Of course, the same rules and gamification elements could be implemented in a real setup, with simpler systems, but the innovation of this work is to portrait the advantages of VR/AR experiences in reach, accessibility and cost while not being detrimental to the application gamification in the learning process.

Gamification needs the identification of user and environment condition to activate game elements such as rules or achievements as an example. VR and AR. The tasks in the learning process require the process and following complex interconnected steps and strict movement monitoring. While at a first stage, the system is limited by the precision of controllers and headset for tracking gestures and movements, at a second stage there is the problem to translate those to actions in a virtual environment and coordinate with portions of the real environment. This makes the application of gamification models not as simple as following a set of steps in a gamification framework, but to actually solve and develop strategies to monitor gamification elements in VR/AR environments.

In our approach we mapped some of the most relevant technologies to elements implemented in the system so far. An ongoing effort is being conducted in order to increase the number of dimensions ported to VR/AR applications. In table 6, the current state of techniques being used is displayed.

Table 6. Gamification Elements present on Virtual Reality or Augmented Reality approach.

Virtual Reality Techniques	Augmented Reality Techniques	Gamification Elements by Gamification Taxonomy [12]
Collider detection	Colliders detection	Performance (Points, Achievements,) Ecological (Imposed Choice, Chance, Economy) Personal (Sensation, Puzzle)
Raycasting	AR Raycasting	Performance (Points, Achievements,) Ecological (Rarity, Economy, Imposed Choice) Personal (Objective, Novelty, Puzzle)
Anchors	Plane Detection + Anchors Environment Detection + Cloud Anchors	Performance (Points, Achievements,) Ecological (Imposed Choice, Chance, Economy) Fictional(Narrative, Storytelling) Social(Competition)

The social dimension is argued one dimension sub represented in table 6 due to the fact that its implementation is not directly an effect of these techniques but rather player recognition of its standing and ranking. For this effect, a ranking board is stored and displayed in the system but more work is needed to make use of complex social interactions. For such implementation, multiplayer mode in VR/AR experiences is being assessed and planed for future development to make the experiences more dynamic.

An interesting side effect of the usability questionnaires from VR/AR experiences is also the partial validation of gamification elements in the personal dimension such novelty and sensation. These questionnaires may be used in the future as possible gamification analytical tools to assess experiences in VR/AR Their use in this work yield valid result and direction to further improve gamification experiences in accordance in MDE model [14].

Considering the work presented and capabilities of our system, it is the authors belief that our system can successfully target different player types [18], with special emphasis on exploiters, consumers, self-seekers, free spirits and achievers. The results may vary from experience to experience and, updated in accordance to player feedback. Notably player types such as networks, socializers, and philanthropists require the development of multiplayer functionalities, in order to enhance the experience of player targeting these objectives. Albeit not particularly, a requirement for a learning system, it is identified as a strong opportunity to improve the system in the future.

5 Conclusions and Future Work

Remote and assisted practical learning is an area which is poised to grow as technology enable more rich experiences. Guided by the advances on VR and AR technology, algorithms and devices it is increasingly affordable, easier and faster. Coupled with gamification, one motivational tool for serious activities such as the case of learning, this platform aims to engage user in the learning tasks it provides. This article presents a proof-of-concept architecture drawn from the proof-of-concept experiments presented.

The application has room for improvement, during both a VR and AR implementations. Although satisfactory, the experience is not yet at the level of a real environment. Nevertheless, gamification elements allow the users to stay motivated while completing the tasks. There are differences perceived from a VR or AR experiments with the former being less realistic which was of concern to learning tasks. While VR is deemed appropriate to learn basic operation, AR seems more suitable for gaining proficiency over a task as it can guide the students while performing tasks in a real setting prior to acquiring basic knowledge. This gap is largely, due to the problems in the VR experience probably related with imperfect simulation of reality and the presence of DF as pointed from the presented study. Assessing the presence of gamification elements, in both experiments, users were able to recognize the game mechanics and improve upon the task given by repeating tasks that although completed were not fully perfected. This motivates the user to perform better. Gamification elements such ranking, leader boards and select information diffusion to motivate positive reinforcement and generate healthy competition while acquiring mastery over the presented lessons should be included. Moreover, validation of certain gamification dimensions such the personal dimension was demonstrated using usability questionnaires from VR/AR experiences which help diagnose strengths and weakness in each lesson plan. Theory from player types, gamification elements and VR/AR techniques presented through the development and results from the implementation of this system, demonstrate the application of specific techniques from VR/AR and their translation in gamification elements from different dimensions.

Although satisfactory results regarding presence and immersion in VR and virtual and physical interaction in AR, the work presented has improvement opportunities that will be addressed in future iterations. First the categorization of events occurring in the scene and linkage to gamification elements. Although already implemented to a degree, an improved interaction schemes and categorization of events detected via machine learning software will enable finer point systems and achievement generation. New machine learning for object detection can also improve the quality of the presented lessons. An extension for custom built model tailored to objects from a domain should also increase the quality of the system specially in the case of AR based lessons. These improvements would also prepare the system to make a generic platform for multiple domains of practical learning and gamified classes.

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