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An Approach to Improve Technical Drawing using VR and AR Tools

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Abstract. In this paper, the authors present the development of 3D interactive AR/VR teaching system from a design-based method to help engineering and product design students improve on critical and complex topics related to TD skills according to an international survey and as part of a broader European funded research project. This work shows that human-centred approaches can improve the understanding of students needs and facilitate the development of AR/VR technology applications for T&L within an international and multidisciplinary team.

Keywords: Virtual Reality, Augmented Reality, Technical Drawings, Teaching and Learning.
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1 INTRODUCTION

There are concerns from Higher Education (HE) institutions and industry about the decline in standards of Technical Drawings (TD) due to the lack of understanding of basic principles and conventions that underpin the best practices [28],[35]. There is growing evidence that simulations/animations along with augmented and virtual reality (AR/VR) technologies can improve learners' engagement, competence and skills; especially when compared to traditional didactic methods. The purpose of this work is to develop and examine the overall effect as well as the impact of virtual and augmented reality-based methods and tools on the teaching and learning experience. In this paper the focus is on technical drawing principles in the context of higher education settings. The development of tools and methods is based on the findings of a previous international study covering the perception of TD education, assessing of TD knowledge and ability, and expectations of TD education.

TD's have always been an essential component in the formative education of new engineers and product designers (E&D). They play an important role in communicating the technical product specifications (TPS) (i.e. material, size, shape, tolerances) for manufacturing during the new product development process. The decline in standards due to the lack of understanding of basic principles and the conventions of drafting skills that underpin these practices represent a challenge for HE institutions and traditional teaching strategies [61]. Despite product design students being known to prefer visual, sensing, inductive, and active learning styles; most engineering education and in particular the teaching of technical drawing skills has relied on auditory, abstract, deductive, passive, and sequential teaching styles [24].

There have been a number of teaching and learning (T&L) approaches trialled, practiced and then modified over the years. These varied teaching styles can be categorised into modern or traditional methods. Traditional methods consist of a conventional lecture followed by tutorial/ laboratory sessions. These pedagogical typologies are usually isolated from each other [42]. Engineering students cannot sustain their attention levels throughout a whole lecture; with active learning thought to improve learning and attention spans for the students [51]. Traditional methods lack adequate interaction between the academic staff and the students, especially when students are passive learners [42],[58]. Conversely, contemporary teaching strategies based on cognitive science methods aid students in constructing knowledge rather than compiling it when disseminated [16],[17]. Newer strategies in engineering and design education incorporate real life concepts, experiences, technologies [14],[39] and project-based work [42] as an integrated learning approach.

The main focus of Virtual Reality (VR) and its application has been towards training for medical scenarios [47]. There has been an increase in the use of VR for construction engineering [64], reflecting the popularity of VR and its current cost effectiveness [2]. Burdea (2004) found that lecturers lack experience using VR, laboratories were not equipped to deal with VR, and textbooks could not support VR courses or lectures [11]. Recent research outcomes have tried to recommend teaching methodologies with the use of VR in engineering education; but there are still uncertainties over how to implement VR into engineering education [28].

2 THE CHALLENGES IN ENGINEERING AND DESIGN EDUCATION

Student numbers are decreasing in Engineering, Mathematics, Physics and Chemistry throughout the UK [31]. Similarly, in Europe young people do not choose to study Science, Engineering and Technology subjects. Many studies have shown that students experience difficulties learning complex technical subjects therefore new, innovative engaging methods and technologies are needed. Students prefer to learn in interactive ways rather than the traditional teaching methods and are less interested in studying subjects that are perceived as boring or less challenging [53].

2.1 AR/VR in Technical Drawing Education

In engineering and product design, TD play an important role in communicating the technical product specifications for manufacturing. These specifications can include: material, size, shape, and tolerances. Along with student ability, appropriate and innovative teaching strategies are determinant in enhancing student's learning [30]. There is growing evidence that simulations/animations along with AR and VR technologies can improve learners' engagement, competence, and skills; especially when compared to traditional didactic methods [61]. AR/VR offers an efficient way to present complex and difficult theories/concepts to design and engineering students, whereas animations have shown to stimulate more enthusiasm for the learning activity, better performance in understanding the appearances and features of objects and improve the spatial visualisation capabilities of the learner [43]. Furthermore, the use of technology allow students to learn through interaction during class activities [39],[49] and to visualize real world situations using their existing knowledge to enhance their understanding about the problem and its context [50]. With technology growing; the E&D world is now looking at how mixed reality can improve the usage of TD.

Research done by Murad et al, (2011) proposed a 3D virtual world environment within a "second life environment" for teaching TD as a way to improve the students understanding of orthogonal projections and the relationships between the real 3D objects and their 2D representations [41]. The representation of these real 3D objects on a 2D medium has been proven the most challenging area. Hence, VR could facilitate the transition and movement between 3D and 2D spaces to explore the models students are designing.

Technology has been shown to have a positive and measurable effect on T&L styles [48], [52]. However, it is important to recognize that its use to complement traditional forms of T&L is generally affected by certain barriers [6],[30], and its use requires time and confidence from the teacher's perspective. Technology in education can enhance the student learning experience and engagement in lectures, resulting in a better understanding of complex concepts and a greater collaboration amongst students [27],[43]. Furthermore, the appropriate use of technology involves real-world problems, current informational resources, simulations of concepts, and communication with professionals in the field [56]. On the contrary, previous research has pointed out that technology could foster a passive learning process if critical thinking, meaning-making or metacognition are not promoted [20]. Current research highlights that the educational sector will benefit most from improved accessibility and affordability of virtual reality as a teaching tool [38].

VR has been generally defined as an interactive computer simulation technology that uses the user's position and actions, to replace or to augment the user feedback through one or more senses, thereby giving the user a mentally immersive experience (a virtual world experience) [57]. VR is an attractive T&L alternative for HE institutions [25]. In engineering and design for example, physical prototypes or models play an important role to analyse and modify design weaknesses during the design phase. However, these are time consuming and costly to produce. Therefore, VR is advantageous because it speeds up the decision making process through the virtual analysis of the design [3]. Moreover, VR technology provides realism and interactivity to provide reality-like perception of conceived/designed products/components and significantly enhance the T&L experience.

Engineering is a practice-based profession. Practical laboratories, which aim to familiarise students with industry standards, have been a crucial element of undergraduate curricula from the outset of engineering education [22]. Recent research has investigated the use of immersive technology in laboratories to improve engineering courses at undergraduate level [12]. Furthermore, AR has had a lot more development over the years. A breakthrough for virtual learning was The Magic Book where 3D models are visible on the pages of a book when scanning a marker [8]. This kick-started the recognition that AR could be useful for T&L also.

AR brings virtual objects into the real world, allowing the user to explore enriched and attractive real-world scenarios in order to enhance the user's perception and interaction with the real world [32]. These virtual objects can include sounds and music, sensations, or digitally generated images. Since its introduction, AR has shown good potential for education applications as it makes the learning process more active, effective and meaningful. Unlike VR, AR does not create a simulated reality. Instead, it takes a real object or space and uses technologies to add contextual data to deepen students' understanding. The use of AR systems for educational purposes has increased as it fosters knowledge and understanding of difficult and complex subjects through the active engagement of students, motivating them to learn by doing, and taking into account specific contexts. For example, in engineering and design, AR has been used as process of getting digital output that represent the imagined model of a component or system to be constructed during the design process [33]. A promising application for difficult subjects (i.e. technical drawing), is the immersive and interactive AR book, also called "pop-up book" [8]. On this type of application, features such as: 3D objects, sounds, animations, textual explanations, videos and other interactive elements are added to a physical book making students' interest more active, motivating them to explore the issues raised and improving the overall learning experience. Consequently, VR/AR technologies along with animations provide the natural and interactive answer to overcome the technical gap in the iterative design process by evolving from traditional computer aided design process to mixed reality aided design space [1], where skills and knowledge of TD can be improved efficiently in HE with the use of AR/VR to tackle the teaching of complex theories, principles and system mechanisms/machinery [4],[14],[33].

This paper presents the multidisciplinary development and preliminary evaluation of a 3D interactive AR/VR system to improve T&L of critical and complex TD topics. This development will support the teaching and learning of TD topics covering the critical subjects raised by HE institutions and industry through an international survey of engineers and designers [35]. The paper identifies the importance of human-centred approaches and design-based methods in improving understanding for students. Additionally, the paper presents a method for development of T&L tailored AR/VR applications which could be adapted to the educational requirements and restrictions involved in the delivery of surrounding subjects. An attempt has also been made to highlight advantages, as well as identify areas of further improvement in the development of these kind of applications for such subjects.

2.2 Design Approach to AR/VR Development

Current research and other AR/VR developments reviewed have shown that most developments are technology-driven, and therefore incrementally improve the efficiency and applications of interactive tools but do not have the user (i.e. student and lecturer) at the core of the development. Traditionally, many research methodologies have been applied in the development of T&L materials, design of subjects, information technology, and AR/VR applications for engineering and design (see Figure 1).

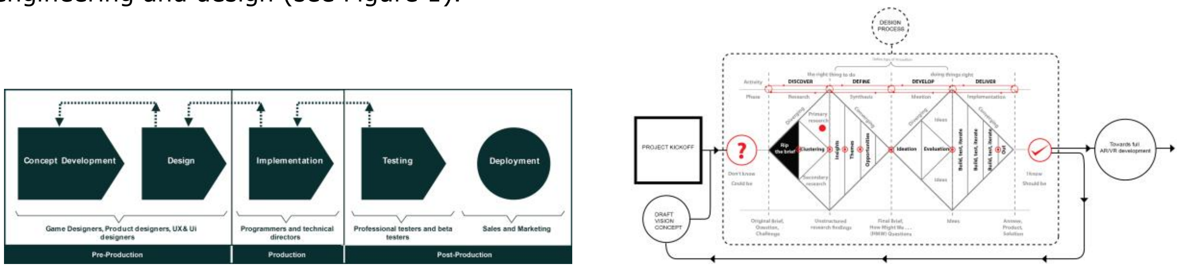

Figure 1: (a) AR/VR development process, (b) Design Centric Hybrid (DeCH) method**.**

This European funded research project combines pedagogy and technology to approach TDs education problems; to develop an AR/VR education solution that addresses such learning difficulties. Due to the multidisciplinary and international reach of this research project, several traditional research and other AR/VR development methods such as: design science [62], the Design Council double diamond [15], and design thinking [10], were analysed.

The project followed a multi-disciplinary user-centred research methodology to approach the design, development and testing of the AR and VR applications. In this research, users were at the core of the development process, which followed the proposed Design Centric Hybrid (DeCH) method for immersive education technology developments (see Figure 1 (b)).

In this method "design research" was used as the process of knowledge production that occurs through the act of design [62]. This also considered the similarities that distinct practices could have during the design phase to set common phases, terminology, requirements and boundaries within the tasks to be developed. As shown in Figure 1 (b), a very iterative process has been followed across four distinct phases: "Discover", "Define", "Develop" and "Deliver", where divergent and convergent thinking were used respectively. In this process, the consideration of possible futures through "abductive reasoning" [34] allowed the research team to envision "the effect or impact" of decisions taken and to form hypotheses (or "best guesses") that were subsequently tested through experimentation and development. Consequently, the abductive based activities derived from this process were rooted in the user experience [24]. Therefore, allowing knowledge discovery and creation from an empirically-oriented and "applied" approach.

Human centred design was applied to the creation of the methods and tools that use AR/VR, with students at the core of the design [45],[58] to make the T&L experience more interactive, productive and engaging [35]. Three main circles of interaction were considered when designing the AR/VR applications [18]. The first circle of interaction incorporates personal limitations, for example cognitive load and a student's prior experiences. The second circle looks into numerous users collaborating with one another by measuring usability. The smoothness of turn taking quality of conversations and the richness of deictic gestures all factor into measuring usability. The third circle of usability considers real-time management of a multi-plane educational scheme, where the lecturer conducts learning activities (i.e. Vygotsky's social development theory) [63].

3 DESIGN AND DEVELOPMENT OF AR/VR TRAINING MATERIALS

This section addresses the design and development of the aforementioned AR/VR tools with the support of animation and simulation, based on findings from an international survey previously published [35]. The team recognised that users would need a variety of options when learning technical content. For example, individual students could require different levels of support commensurate with their levels of concentration, their abilities, personal circumstances, learning environment, existing knowledge or age. To test this hypothesis, the aforementioned international survey was conducted and the results used to identify aspects of TD that would benefit from AR/VR support.

3.1 Research and Data Collection

The process of "needs analysis" was used to demonstrate the difference between the current and the desired situation for the training program and material development. In TD education four stages covering preparation, information collecting, analysis and reporting were planned. The survey was conducted with 320 people from UK, Bulgaria and Turkey with different educational backgrounds (engineering/design, student, instructor/lecturer, manufacturing sector employee, college/high school/university student, and teacher/trainer). The survey included 25 five-point Likert-type scale and 5 open ended questions. The questions were aimed to analyse participants' TD perception, to explore knowledge and skill levels, and to find out the expectations of TD education [5]. From this survey, six major aspects of TD were identified for developing AR/VR content and animations:

- Dimensioning and Tolerances
- Sectioning, Projections and Perspective Drawings
- Dimensional Tolerances, Edge Tolerances, Shaft and Hole Tolerances
- Geometric Tolerance/Form-Position Tolerances
- Surface Treatment Markings/Surface Roughness
- Production and Assembly Drawings

The survey helped identify stakeholders: students, instructors, Universities, and colleges, industry (manufacturing and design companies), workers. The questions used helped to determine the stakeholder's requirements in the following areas: users of TD, operators and managers; benefits gained from the TD education offered by the institutions; and affected parties by the TD education. Analysis of the information showed that there were differences between observed and expected success levels particularly between the expected skill level and the current skills. The sample data showed an important deficit between the skills required and the level of competence attained across all groups using current TD learning materials. The differences observed were attributed to several factors, such as the type of training material used, the amount of time spent during training and the lack of a continuous training plan. These factors have been used as design guidelines in this work to assist closing the skills gap through the development of AR/VR TD content. More details have been discussed elsewhere [35].

3.2 Design, Visualisation and Interactive Content Development

T&L is a complex task, and purely technology driven developments do not foster student's learning [23]. Learning of TD is reasonably understood as an interactive knowledge construction process where dialog and co-operation between lecturer and students occur in a variety of media types, forms of interaction and contexts. Consequently, software-technologically driven developments do not provide an opportunity to represent and discuss details of human learning [23],[40]. Therefore, a human-centred approach provided a better consideration for T&L processes.

A storyboard is a short graphical depiction of a narrative. Storyboarding is a common technique used in Human Computer Interaction (HCI) and Human Centred Design (HCD) for demonstrating system interfaces and contexts of use [29]. In this project, storyboarding was used for didactic design. Its use aimed at anticipating a variety of T&L experiences for the different users considering their goals and different context conditions.

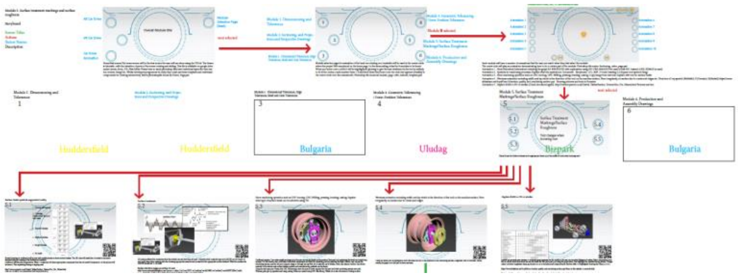

Figure 2: Storyboarding.

During the early development of this project, the current practices of users (i.e. students and lecturers) were identified in order to generate problem scenarios (e.g. pedagogy and technology) through storyboarding (see Figure 2). During this phase, these possible scenarios were actively used to understand how to best meet the user's requirements through the proposed system. These scenarios were then used to create the specifications for content development and the interactions that would help users perceive, interpret and understand the proposed content. Once the content and experience specifications were defined through storyboarding, the content and applications were developed using the following AR/VR design and development process (see Figure 3).

After the user, design and development are probably the second most important elements in AR/VR application developments. Design plays an important role in visualization and communication; specially when it is about complex information. For example, user interface design and aesthetics have been found to be important for users' acceptance of technology [21],[59],[60]. Design elements including colour, font style, images, layout, shape the experience the users go through [55]. Therefore, linking the students' perceived attractiveness of the AR/VR application to a perceived usefulness, ease of use, and enjoyment. For this development, some design elements were decided during the storyboarding phase, while others were selected and applied throughout the development process and following an iterative design-develop-test cycle through initial pilot tests.

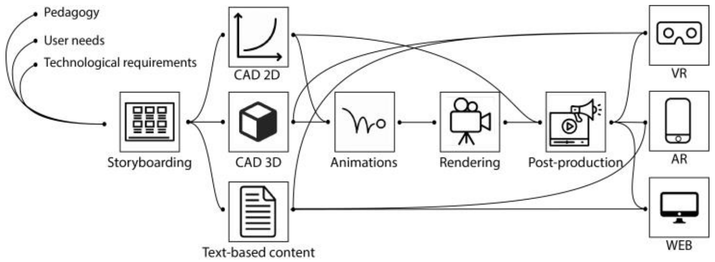

Figure 3: AR/VR design & development process.

The development of AR/VR and animation requires hardware considerations before the development phase. The considerations for the student/teacher for this project were:

- VR headset (HTC Vive and Samsung Gear)
- Competency of modelling SolidWorks or equivalent
- Design for manufacture experience, experience in TD details
- Some experience using AR and VR
- Mobile Phone (Android 7.0+)
- Powerful computer

For the content development, it was decided to use a Formula Student Race Car as the centrepiece of the project (Figure 4). This car, which has been designed (i.e. CAD) and physically manufactured by the engineering students at the Technical University of Sofia gave a wide range of different components to be used within AR/VR and animation (see

Table 1). Context/environment for each part was assigned in AR/VR along with animations to help the student understand the component and to give a more real-world content and user experience.

TD topic	*Car part*	*Approach*
Sketching and Dimensioning	Steering wheel and wheel	Introductory panoramic videos with animations used within an AR and VR app environment as well as a standalone video platform. AR/VR based content included some complementary video materials embedded within the app. Some selected videos are used as well as a standalone platform that can be accessed online. Voice-over, sound effects and music was used only to complement information and guide the user through the T&L experience.
Projections and Sectioning	Wheel and car body	
Shaft and Hole Tolerances	Wheel	
Geometric Dimensioning and Tolerancing	Steering wheel	
Surface Roughness	Steering wheel	
Assembly Drawings	Steering wheel	

Table 1: Summary of TD topics and corresponding car parts used.

Several software packages were used for content development including the Adobe suite (Photoshop, Illustrator, and InDesign) to create the storyboards, and graphics. For 3D and 2D content generation, SolidWorks was used while 3D Studio Max was used for mapping and animation. Low polygonal data (low for AR/VR and high for animation) with the appropriate textures were used along with various animation methods to prepare the content for final rendering and post-production process.

Figure 4: (a) 3D Modelling of Formula Student Race Car, (b) Mobile AR Applications, and (c) sample AR training simulation.

Unity was used to create interactive AR/VR applications with ARCore for building the AR experience that would be visually rich and engaging. Interactivity was crucial when creating an engaging experience. Not only should the user be able to look around the environment, but also they should be able to interact with components and complete tasks/objectives. For example, several AR applications have been developed for improving student understanding of tolerances. Currently, form (straightness, flatness, circularity and cylindricity), orientation (angularity, perpendicularity and parallelism), location (position and concentricity) and runout tolerances (symmetry, circular runout and total runout) have been covered. Figure 4 (b) and (c) show AR applications where tolerances and surface parameters are covered. Also shown is an AR game where a car can be driven using the on-screen controls on a floor defined in AR environment.

VR development included the creation of 3D content and the programming of interaction (see Figure 5). Depending on the desired level of both realism and interactivity, either high-level programming languages may be used; but these required extensive knowledge of programming or game engines such as Unity, Unreal or similar. The vehicle has been rendered with panoramic and stereoscopic cameras to be viewed in a Samsung Gear headset. This VR device enables a sufficiently wide field of view and good head tracking due to the sensors. The controller can be used to navigate and interact with the scene. The disadvantage of this device is that it only works with the latest Samsung phones and has a relatively low level of immersion, which would be adequate for this type of T&L activity.

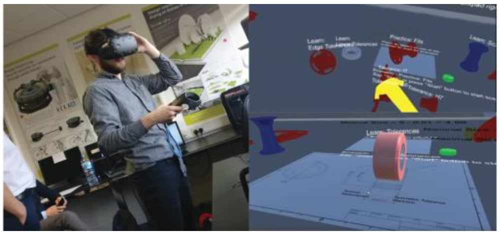

Figure 5: VR Application and training.

3.3 Future Evaluations

Based on regular feedback from academics and developers, the AR/VR application was continuously improved over the course of 12 months. Some of the details of these improvements have been mentioned in the previous sections. A pilot testing program has been recently completed with a focus group of 12 teachers/lecturers from 3 different EU countries and with selected undergraduate students. This focus group was used as an early evaluation tool to gather information regarding the usability and content appropriateness for the different materials developed (see
Table 2). Listening and observing the interactions with the developed system helped appreciate participants' experience.

TD Topic	*Feedback*
Sketching and Dimensioning	Participants reported satisfaction and appropriateness of content. Participants discussed the importance of graphic & editorial design for better reading and assimilation of contents, and there where instances where the animations worked better for this topic. Some suggestions made included the timing for text-based information and colour changes.
Projections and Sectioning	Participants discussed the appropriate choice of a wheel for the sectioning topic, as it is a well recognisable part with different simple and complex parts and materials that offered a variety of options for the selected topic. A combination of AR and animations was preferred across the participant for these topics. There were instances where participants were more open to sharing among the group their thoughts as a collaborative learning experience when using AR and animations. Turn-taking was smooth and participants help each other using the App.
Shaft and Hole Tolerances	Participants discussed a variety of factors related to these topics. The

	selection of the wheel as central part for these topics was well perceived as it included all type of tolerances within the same part making the move from one topic to other seamless. It was discussed the possible improvement of the T&L experience by using mixed VR to get tactile or haptic feedback.
Geometric Dimensioning and Tolerancing	Participants raised concerns about the complexity of these topics. The division of topics in basic, mid and advanced level was seen as more appropriate. Among other concerns raised, the level of previous knowledge and transferability of knowledge acquired to other applications or components was discussed. AR and animations were perceived as more appropriate for the topic that VR.
Surface Roughness	The use of AR animations to explain the principle by showing the machining and surface measuring process was well perceived and participants were deeply engaged with the activity. Some suggestions were made regarding the text-based information in order to improve the T&L experience.
Assembly Drawings	Participants struggled at first to get around the VR instructions and extra support from the group was needed. Long turn taking or perceived difficult tasks put participants off from trying the App or continue using it.

Table 2: Summary of received feedback during focus group.

An extensive study is planned for further testing. This will include 200 participants in educational and industrial settings. Sample groups will be trained using the AR/VR applications developed. A number of TD exercises/tasks for engineering curricula will be designed and then presented to different sample groups. One sample group will be kept unexposed to the VR/AR applications, and only current and traditional training materials used for TD teaching will be used. This group will be kept as control for comparison purposes. The main objective of this further study will be to assess the usability and potential effect the current AR/VR application has on engineering and product design students.

4 CONCLUSIONS, LIMITATIONS AND SUGGESTIONS

This research showed that the use of AR/VR applications and animations for teaching and learning TD has an overall positive impact. Across the focus group, participants reported a positive experience with the use of the materials developed in which they felt immersed and engaged with the activities. It was observed that students' motivation and understanding on related TD topics could be improved, and hence the developed AR/VR application could be used as an effective tool to aid in the teaching and learning of TD skills for engineering and product design students. AR/VR has been used in different areas such as: design, aerospace and medical applications [1] [44]. However, it is in education where it can have the most positive impact as it stimulates learning and comprehension, because it provides a tight coupling between symbolic and experiential information [9]. Furthermore, it aids complex conceptual learning [54], improves spatial knowledge development [19] and provides new forms and methods of visualization. It requires interaction and encourages active rather than passive participation, and can be used outside regular class schedules and over a flexible period of time [46].

Our pilot tests carried out through the design and development of this AR/VR application has shown that there are many aspects of AR/VR technology that still need to be explored in this relatively new area. The number of limitations found during this study regarding the use of this technology can be divided in technology, pedagogic and design and user experience limitations. Many studies concern the application of technology, but pedagogy and user experience still requires further research in the near future as technology will continue to mature and little knowledge on user experience and pedagogy influence is available.

As this development included a multidisciplinary background from four different industrial and academic partners (e.g. lecturers, UG students, PG students, software and web developers, 3D modellers, or animators.) we found that the access to vital information and background experience regarding best practices for T&L and specific workflows is vital for the proper communication and assignment of activities related to every development stage. Therefore, the use of a unified method and common workflow has facilitated the design and development process.

The use of storyboarding as a tool for understanding and translating users (i.e. students and lecturers) needs into practical design and development insights has eased the development and improved the overall T&L experience. Furthermore, the use of design elements (i.e. aesthetic considerations) helped in creating an improved user experience as these were perceived as usefulness, ease of use, and enjoyment. Likewise, the use of storyboarding provided a path that was easy to follow among a multidisciplinary team as it was used as communication tool. Therefore, the designer's role should be considered and defined in the development process. It is the view of the authors that new AR/VR applications for educational purposes should be developed from an approach where technology, pedagogy and user experience result in a holistic, well balanced methodology.

TD abstract knowledge is best suited for a virtual learning environment. However, AR is probably the best alternative as some technology limitations for VR could arise within the classroom environment. Generally, VR was not completely ideal, for visualizing and covering TD abstract and complex topics and cognitive processes. The technical difficulties related to setting up the equipment within a classroom environment and the individual learning style VR use fosters, makes the technology useful under very specific conditions and applications. VR users were deeply immersed in a virtual reality system, and carried off to an environment of TD content that they could see, hear and touch. However, the sensation of immersion could be so strong, and difficult to follow by the lecturer that the pedagogic purposes could disappear and users lose all notion of interacting with the T&L system. On the other hand, AR offered a better and clear correspondence with the real world, allowing the user an active T&L experience perceived by the human senses, and still experience a rich and engaging virtual environment.

VR user interaction was more difficult than AR user interaction. VR interaction presented more problems for pursuing goals and executing actions than AR. VR users commented being frustrated when using the technology and had to resort to ask for help or guidance. Therefore, a careful consideration of end-user requirements and expectations is needed to engage students. Interactivity is essential when creating AR/VR content. While animations may not have any interactivity, they can provide a visually pleasing platform to communicate TD information. The large file sizes may limit their use as it would require high internet speeds to download animated content which could be hosted on a website. AR users showed more autonomy and dynamism of user interactions, fostering a co-operative learning through collective participation. We found that using AR tools to obtain information was easier than VR. The reason might be that AR technologies are easy to operate, whereas VR requires more technical knowledge from users.

Positive feedback was received from the initial pilot study where selected students used the developed AR/VR and animation content. Early results showed that although the users (students and lecturers) encountered technical difficulties in both AR and VR applications, they persisted with the task/objective and engaged positively in the learning process. Despite this demonstrating early results for AR/VR applications in the education of TD field the possibilities to improve the TD teaching methods and the overall T&L experience are promising. Moreover, further research should be conducted to investigate the latest and most efficient technology from T&L point of view. The limitations indicated in this study mostly highlight the issues related to the technical and pedagogic aspects of using this type of tools in the T&L process.

Applications for AR/VR can be integrated into the classroom environment for individual use, although it would require adding individual work inside a scenario that usually centres around group activities. The expected T&L scenarios need to be acknowledged prior to the development of AR/VR application. As pedagogical activities evolve beyond an individual, team, or classroom, so does technology to encompass the classroom periphery [7]. Good interaction and functionality for individual or team use are crucial to the assimilation of these technologies within classroom workflows.

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