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# Assessment Of Different Platforms For Online Virtual Lab Demonstrations

Owen M CLARKIN
*Dublin City University, Ireland*, owen.clarkin@dcu.ie

Anne MORRISSEY
*Dublin City University, Ireland*, anne.Morrissey@dcu.ie

Muhannad Ahmed OBEIDI
*Dublin City University, Ireland*, muhannad.ahmedobeidi@dcu.ie

*See next page for additional authors*

## Authors

Owen M CLARKIN, Anne MORRISSEY, Muhannad Ahmed OBEIDI, and Alma RYAN

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**O.M. Clarkin** [1]
School of Mechanical & Manufacturing Engineering, Dublin City University,
Dublin, Ireland
0000-0001-6007-806X

**M. A. Obeidi**
School of Mechanical & Manufacturing Engineering, Dublin City University,
Dublin, Ireland
0000-0003-2733-3828

**A. Ryan**
Gaelscoil Chill Mhantáin
Wicklow, Ireland
0009-0002-0822-7819

**A. J. Morrissey**
School of Mechanical & Manufacturing Engineering, Dublin City University,
Dublin, Ireland
0000-0002-3112-7739

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[1] O.M. Clarkin, owen.clarkin@dcu.ie

## ABSTRACT

As we move to a more sustainable world, expansion of education is key to the eradication of poverty (SDG1) and societal inequalities (SDG10). Global expansion of tertiary education offers opportunities to deliver Sustainable Development Goals by providing wide access to education in flexible learning environments. However, the quality of education (SDG4) must be maintained and enhanced as it is key to a partnership for the goals (SDG17). While increased learning online can facilitate achievement of these SDGs, there is also a move, within the education sector, to a constructivist approach and a more active learning environment. Interactive virtual learning environments (*e.g.* Virtual Reality) can offer considerable potential in the integration of active learning in an online environment

With this background in mind, the objective of this study was to evaluate the hardware and software resources currently available for effective delivery of remote virtual laboratory learning against nine technical, social and design criteria. At the same time, it is also important to consider sustainability in this evaluation including carbon (SDG13) and ecological footprints (SDG14/15). Hardware options examined were the Computer, Google Cardboard, Meta Quest 2 and Microsoft HoloLens 2, while the software platforms examined were H5P Virtual Tours, 3D Vista Pro, Dynamics 365 Guides and a professionally created VR platform. The main findings were that there is no 'one-size-fits-all' system and each system has its own advantages and disadvantages depending on the resources available at the institution and the type and level of knowledge and/or skill being delivered.

## 1 INTRODUCTION

### 1.1 Section 1

Virtual Reality (VR) technology has gained considerable traction in recent years, with applications spanning several industries, including engineering education. One of the most significant advantages of VR-based simulations is that engineering students can learn, practice, experiment, and make mistakes in a virtual environment, without the fear of causing real or physical damage. For example, in engineering, VR-based simulations can be used to train students on how to construct structures and how to test their designs in a formative way with minimal risk to the students. Furthermore, VR simulations can provide a realistic 3D environment, enabling engineering students to explore complex three-dimensional models from different angles and viewpoints, giving them a better understanding of the model's structure, function, and behaviour.

Another advantage of VR is that it can facilitate collaborative learning. This can be particularly beneficial in situations where students are located in different parts of the world from the teacher and where face-to-face interaction is difficult or not possible. This offers opportunities to deliver Sustainable Development Goals (SDGs) and the globalisation of teaching by providing wide access to education in flexible learning environments (SDG10). VR-based simulations can also be accessed remotely, making it easier for students to learn at their own pace, in their own time, and from any location. These simulations can increase student engagement and motivation (di

Lanzo et al. 2020) and can contribute to a higher quality education (SDG4). Additionally, students can learn at their own pace, with the ability to repeat simulations until they understand the concepts fully (di Lanzo et al. 2020; Al-Ansi et al. 2023; Soliman et al. 2021). More broadly, SDGs and sustainability concepts can be effectively incorporated into engineering education using virtual labs. For example, students can learn about renewable energy sources like solar, wind, hydro, and geothermal power in a virtual lab, which mimics real-world situations and difficulties pertaining to the creation, improvement, and management of sustainable energy systems. Finally, it should be noted that while VR does not replace the need for physically interactive labs, VR allows for increased student interaction, within the constraints of resources available (namely, lab time).

In summary, VR can be a significant tool for engineering education. VR-based simulations can provide students with hands-on training, enhance their visualization and spatial understanding skills, facilitate collaborative learning, and be cost-effective and flexible. VR can also increase student engagement and motivation, providing a more immersive and interactive learning experience. With the continued development of VR technology, its role in engineering education is likely to grow in the coming years.

## 2 METHODOLOGY

With this background in mind, the objective of this study was to evaluate the hardware and software resources currently available for effective delivery of remote virtual laboratory learning against nine assessment criteria, while also considering the impact of these technologies on sustainability. These criteria were identified based on the authors experience with the technology and are listed below:

1) Integration into Learning Management System (Moodle)
2) Integration of software and hardware tools (Cross-platform translation)
3) Immersive experience
4) Level of user interactivity
5) Ability of system to formatively assess and scaffold learning
6) Ease of use
7) Cost (user cost, institutional cost, maintenance cost)
8) Universal Design for Learning
9) Ethical issues (H&S, GDPR, etc).

Following the identification of the criteria, four different hardware platforms (Computer, Google Cardboard, Meta Quest 2 and Microsoft HoloLens 2), and four types of software (H5P Virtual Tours, 3D Vista Pro, MS Dynamics 365 Guides and a professionally created VR platform) were assessed for compatibility. Appropriate combinations (‘systems’) were then shortlisted for further assessment. It should be noted that the list of available VR/MR equipment and the software evaluated is not exhaustive, and this study represents a discrete examination of the potential options which were available to show the potential of VR as an engineering tool. A ‘least-required’ approach was also adopted, whereby if a software or hardware was considered useful on their own and worked across various platforms then they were included individually; on the other hand, if a hardware/software combination was required, then they were evaluated as such. The final systems that were identified for further evaluation were:

a) H5P Virtual Tours (H5P Group AS)
b) 3D Vista Pro (3DVista España S.L.)
c) Microsoft HoloLens with native apps
d) Microsoft HoloLens with Microsoft Dynamics 365 Guides
e) Custom-created VR platform (on Meta Quest 2)

Assessment factors such as ‘immersive experience’ depend on both the hardware and the software platforms and so they need to be assessed together. Therefore, 3D Vista Pro was assessed as a cross-platform system, as was H5P Virtual Tours, whereas, due to limited overlap, Microsoft HoloLens 2, was assessed separately with, and without, 365 Guides integration and the professionally produced platform will be assessed with Meta Quest 2 only, as it is the only hardware on which it runs.

Systems identified were evaluated in a semi-quantitative way by round table discussion of the authors. Dr Clarkin and Dr Obeidi used their first-hand experience of using these devices with student cohorts in conducting the assessment, while Dr Morrissey and Ms Ryan focused on the non-technical and social aspects of the evaluation. Each system (a-e) was assessed against each criterion (1-9) in a semi-quantitative scale from one to five, with one representing a low rating and five representing an excellent rating. A ‘heat map’ was subsequently produced and a percentage score calculated (Table 1).

No student assessment was carried out in this study as this represented a ‘first-step’ in the system evaluation. It is envisaged that a student-centred study will be carried out in the near future to further evaluate the systems.

## 3 RESULTS

The findings from the initial analysis of different hardware and software combinations are shown in Figure 1. Following a technical analysis based on the nine criteria, a summary table of the findings is shown in Table 1.


**Figure 1:** Venn Diagram outlining interaction between different hardware and software options, associated costs and traffic light overall ratings.

**Table 1**: Summary evaluation of the VR systems from 5 (excellent) to 1 (poor)

| **Assessment Criteria:** | **H5P Virtual Tours** | **3D Vista Pro** | **HoloLens with native apps** | **HoloLens with MS Dynamics** | **Custom-created VR platform** |
|---|---|---|---|---|---|
| Integration into Learning Management System[a] | 5 | 4 | 1 | 1 | 1 |
| Integration of software and hardware tools[b] | 3 | 5 | 2 | 2 | 2 |
| Immersive experience[c] | 1 | 2 | 3 | 5 | 4 |
| Level of user interactivity[d] | 1 | 2 | 3 | 5 | 4 |
| Ability to scaffold learning[e] | 3 | 4 | 2 | 4 | 3 |
| Ease of use[f] | 5 | 4 | 2 | 1 | 1 |
| System Cost[g] | 5 | 4 | 2 | 1 | 1 |
| Universal Design for Learning[h] | 3 | 4 | 2 | 3 | 3 |
| Ethical issues (H&S, GDPR, etc)[i] | 5 | 4 | 3 | 3 | 2 |
| **Total Points (out of 45):** | **31** | **33** | **20** | **25** | **21** |
| **Percentage (%):** | **69%** | **73%** | **44%** | **56%** | **47%** |

***Integration into our Learning Management System (LMS) (a).*** HP5 Virtual Tour is already integrated into DCU's learning platform 'Loop', a Moodle platform, and data from quizzing can automatically move into the Moodle gradebook. 3D Vista Pro can be exported as a SCORM package, which can then be uploaded to Moodle. This is useful when quizzing elements are incorporated into the 3D Vista Pro experience. However, many LMS systems have upload limits set by the administrator and where data intensive elements such as 360 videos are incorporated into the 3D Vista Pro experience this may cause issues. Additionally, grading elements do not transfer across systems, so if using the 3D Vista Pro experience on the Meta Quest 2 this will be independent of the LMS and quizzing elements will not automatically transfer. None of the other systems allow for integration in the LMS.

***Cross Platform translation (b)***. As indicated in Figure 1, 3D Vista Pro integrates across several different platforms while H5P Virtual Tours had some, but minimal, cross-platform integration. The other systems were linked to their individual devices but integrated well overall with those device/software combinations.

***Immersive experience (c) and Level of User interactivity (d)***. Both the custom created VR platform and the HoloLens with Microsoft Dynamics 365 Guides performed well under this criterion. Though it is difficult to compare MR with VR, while both are truly immersive, the HoloLens with Microsoft Dynamics 365 Guides, because of the integration with the real environment and movement, is rated slightly higher.

***Ability of system to formatively assess and scaffold learning (e)***. For hands on learning HoloLens with Microsoft Dynamics 365 Guides far outpaces any alternatives but for information-based learning 3D Vista Pro is very useful for more traditional quizzing options. H5P Virtual Tours does provide quizzing options but those options are very limited. Surprisingly, though one can embed 2D video content (e.g. from YouTube) into H5P Virtual Tours, it does not at present allow for integration of 'H5P interactive video' content with embedded quizzing, which would be a considerable advantage to the system.

***Ease of use (f)*** was evaluated predominantly from the instructor's perspective, but where systems are intuitive for the students they will also ease the burden on the instructors and the resources required to run VR/MR sessions. The H5P Virtual Tours are very intuitive for learners and will require next to no instructor intervention. 3D Vista Pro is similar in this regard, with very minimal instructor input requirement, even when students are first time VR/MR users, which is generally assumed. The other modalities will require some time for users new to VR/MR to become familiar, though it is expected that this will reduce with societal adaption of VR/MR technologies in general. As a result, the amount of instructor resources required for these sessions can be considerable and the time required for allocation of these sessions will be longer.

***System cost*s (g)** were evaluated with regard to user (student) costs, institutional costs and maintenance costs. H5P Virtual Tours is free on Moodle and so it was rated highly. 3D Vista Pro has a nominal cost for content developer (€499+vat) and no costs for users. However, this assumes that the system is to run on a PC, for which the cost is not included. However, in the future, and in certain developing economies where PCs are less commonplace this may be worth considering in more detail. It should also be noted that '3D Vista Pro hosting' adds considerable ease of use for the instructor, avoiding multiple uploads to multiple devices and making integration with Google Cardboard much easier, but at a cost depending on the amount of data space required.

Both Microsoft HoloLens and associated 365 Guides represent a considerable cost to facilities, costing ~€4,000 per unit of hardware and anywhere between €708-€1,956 per year (Microsoft 2023). Custom developed VR content can be very expensive when outsourced to professional companies (~€15,000-€30,000). However, the reuse of such systems over the years for many students can reduce the cost to a per student basis but headsets (in this case Meta Quest 2) are still required to be purchased on top of this cost, adding ~€499 per headset.

***Universal Design for Learning (UDL) (h)***. All platforms score low in terms of '*choice of assessment instruments'* but 3D Vista Pro, H5P Virtual Tours and HoloLens with Dynamics 365 Guides do provide for assessment instruments, which can be seen as an alternative assessment means. All platforms score low in terms of providing '*different types of media*' but 3D Vista Pro slightly higher due to its ability to be used on multiple devices. HoloLens with 365 Guides is the only platform that can provide a limited opportunity for collaboration. As the platforms and systems develop, the authors are of the opinion that multi-user experiences will become more commonplace, which would be advantageous in terms of adopting UDL principles.

***Ethical issues (i)*** were evaluated with regard to health and safety concerns and GDPR/user data issues. Neither H5P Virtual Tours nor 3D Vista Pro gather personal data or require login in and of themselves. However, Meta Quest 2 used with 3D Vista Pro or the custom VR Platform does require Facebook sign in. HoloLens with Dynamics 365 Guides is designed around data and gathering of employee data for company analysis (*e.g.* optimisation of production lines). For HoloLens and associated software, Microsoft does gather some data and your organisation will also potentially gather data. It is difficult to fully ascertain the level of data risk with Meta Quest 2 but certainly there is lots of concern. The scope of this project did not allow for a full analysis of the management of data across the different systems and associated use or risk of data leaks but this is certainly something that should be considered in by individual institutions in adopting these technologies.

Though this analysis compared and evaluated different VR/MR systems against one another, there is no 'one size fits all' system and each system has its own advantages and disadvantages depending on the resources available at the institution and the type and level of knowledge and/or skill being delivered. To further assist with this evaluation, the VR/MR systems were also evaluated in terms of Bloom's taxonomy (Figure 2). The 3D Vista Pro and H5P Virtual Tours systems were found to be very flexible and adaptive, easy to use systems but they have limited interactivity and so are best suited to delivering knowledge (Blooms Level 1). The custom developed VR platform in combination with the Meta Quest 2 provides considerably more comprehension capabilities (Blooms Level 2), delivering a more interactive experience but with limited formative assessment capabilities. The HoloLens with Dynamics 365 Guides offers a truly immersive experience that scaffolds user learning in an experiential way and allows them to apply their knowledge (Blooms Level 3) and analyse options (Blooms Level 4); however, the costs can be prohibitive, and use is restricted to a single platform. An ideal scenario would be to provide a multiple systems approach to student training, whereby a simplified introduction to the 360-degree space, with embedded knowledge acquisition is provided by a platform such as 3D Vista Pro. Once complete, students could learn the more interactive requirements of the system using a custom developed VR platform on the Meta Quest 2. Once students are familiar with the requirements to operate the system they can move on to a guided operation with the machine (or machine analogue) using the HoloLens with Dynamics 365 Guides. This will provide a fully automated training system through use of VR/MR platforms. This will provide students with more access to the higher levels of Bloom's Taxonomy (evaluation and synthesis) and future iterations of the systems may allow students to design and test hypotheses and experiments in the virtual world by providing limited branching scenario within the VR/MR platforms, allowing them to better apply and analyse both real world (thorough MR) and virtual (through VR) data.

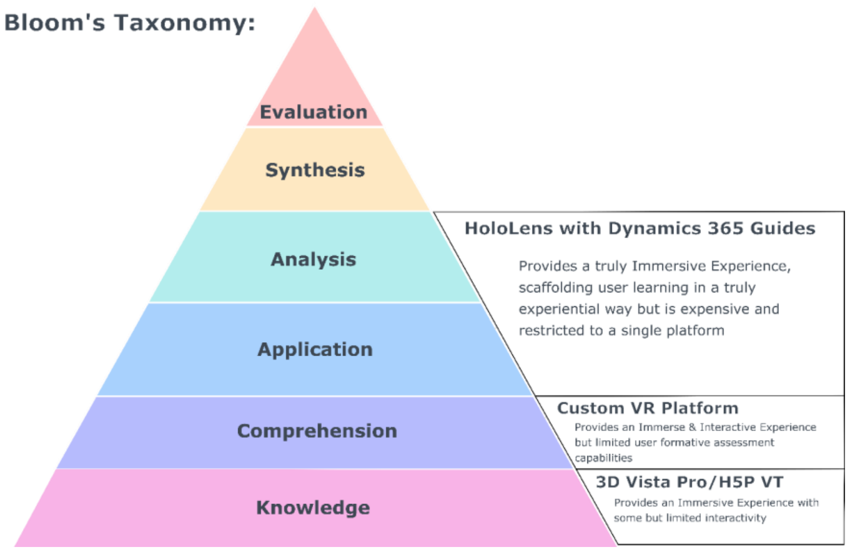


**Figure 2:** Bloom's Taxonomy Analysis of Three VR/MR Systems

## 4 SUSTAINABILITY CONSIDERATIONS

Sustainability is a key factor in all industries including engineering virtual reality labs and additive manufacturing as a good example. Below, a summary of some strategies for incorporating sustainability into these fields (Peng et al. 2018; Sandhu et al. 2022, 4-9; Ball et al. 2019, 3-25).

i. **Energy efficiency**: Making sure the used equipment is energy-efficient is a significant approach to encourage sustainability in VR labs. This can be done by adopting energy-saving features like automated shut-off or power-saving modes or by selecting equipment with high energy efficiency ratings (Vo and Huesmann-Odom 2023, 4-9).

ii. **Use of renewable energy sources**: Using renewable energy sources to run the VR lab is another approach to enhance sustainability. In order to lower carbon emissions and energy costs, one option is to produce power using solar or wind energy.

iii. **Recycling and waste reduction**: Unused materials and unsuccessful prints frequently result in a large quantity of waste in additive manufacturing. Utilising recycled materials, improving designs to use less material, and implementing a recycling program for unused materials and unsuccessful prints are all ways to reduce waste and promote sustainability.

iv. **Sustainable material selection**: By choosing sustainable and ecologically friendly materials, additive manufacturing may also be made more sustainable. For instance, using biodegradable materials, it is possible to make items that are both easily biodegradable and environmentally friendly (Reen et al. 2021).

## 5 CONCLUSION

In conclusion, the integration of virtual reality in engineering education holds immense potential for revolutionising the learning experience. By providing immersive and interactive simulations, fostering spatial understanding, and promoting active learning, VR can enhance students' engagement, comprehension, and practical skills. Addressing the challenges of affordability, technical expertise, and accessibility in line with the SDGs, will be vital in realizing the full benefits of VR technology. With continued research, development, and collaborative efforts between educators, engineers, and VR experts, the future of engineering education stands to benefit greatly from the integration of virtual reality. Each VR/MR System has its own advantages and disadvantages, and educators should choose the combination of hardware and software that best meets the learner needs and learning outcomes required. Providing cross-platform options is also highly recommended where possible, to provide the learner diversity of interactions and cater for diversity of learners.

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