Immersive Learning Project Final Report

IL–TS–18-01

March 2019 to January 2023

"Elevating tunnelling and underground construction skills training and virtual access into different tunnelling environments through immersive technologies"

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Project Partners
Neil Hancox – TunnelSkills - Project Lead
m: 07791 275988
e: n.hancox@alignjv.com and chair@tunneskills.org

Samantha French – TunnelSkills - Group Training Officer
m: 07786 330942
e: fto@tunnelskills.org

Ben Dykes – Make Real - Project Lead
m: 07970 686019
e: ben.dykes@makereal.co.uk

Sophie Costin – Make Real – Head of Learning Design
p: 0845 0178 777
e: sophie.costin@makereal.co.uk

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Project Summary

The project has delivered a range of immersive learning resources to address challenges of sufficiently simulating or recreating the tunnelling environment to develop the behaviours and competencies required to work in such environments. These resources were designed for use as training aids in existing accredited and employer specific short courses, apprenticeships, and as engaging tools to attract new entrants to the sector. They have been made freely available to download and install into headsets via the Oculus App Lab Store platform and, as a result of the pandemic, further work was undertaken to re-design the resources to be additionally available as web-based versions and via the FULmax VR cave platform.

The resources were conceptualised, designed, developed, tested and piloted with partners with expertise in the learning technologies sector, a significant number of project partners from within the tunnelling industry including specialist tunnelling-specific training providers, and education partners including schools, education charities, colleges and universities.

The results of the project have been a suite of immersive learning resources made freely available to all. These have been embedded within the resources provided by the awarding bodies for training providers of specific tunnelling qualifications, and also within the curricula of further education colleges providing civil engineering qualifications. Key industry employers have purchased their own hardware specifically to use these resources within their own internal training programmes and their outreach / careers activities. As a direct result of engaging with this project, a major joint venture employer delivering a section of the largest infrastructure project in Europe (High Speed 2) has ensured the legacy of this project by using it as a guide to develop their own tunnel-specific mixed reality learning resources.

Recommendations to share with industry:

- **Ensure a broad range of expertise** is engaged and committed in your immersive learning project

- **Secure advice from trusted partners** who have been through this process themselves

- **Technology moves fast**. Decisions about which hardware and equipment to use are key to the success of your project. Ensure you have the best available research and advice to guide these decisions.

- **Put your audience at the centre of your design** to inform the choice of what technology best suits your audience. By ensuring that the proposed technology makes the lowest demands of the end user, you can ensure that the tech you use doesn't overwhelm your learner.

- **Flexibility and adaptability** are required to manage unexpected events such as the loss of key project partners, pandemics, and changes of key project staff

- **Capture feedback from a wide range of people** having experienced the resources – to inform changes and enhancements

- **Keep an open mind** and think 'outside the box' – at the outset, the benefits of the learning resources may not be fully envisaged, and may become evident at later stages

- **Be prepared to spend a significant amount of time supporting and coaching** those who are unfamiliar and/or hesitant with the technology and equipment

- **VR should be treated as an additional tool** within an existing training toolbox, rather than a complete replacement of existing methods and materials, to instead enhance and complement.

Introduction

Context of the tunnelling sector and rationale for the project

In 2017 CITB commissioned the report – 'A new reality: immersive learning in construction'. This report defined immersive learning as "An approach to learning which uses digital technologies, such as virtual and augmented reality, to better engage learners through an interactive learning environment. This involves using game-based techniques (such as collaboration, communication, problem-solving and visual immediacy) to replicate environments and scenarios, and practice skills." The report was commissioned to explore how the sector can modernise and innovate its training methods. The report identified challenges with digital adoption along with a lack of appeal to young potential recruits. These challenges were adopted as an action plan for industry to devise digital projects that inspire innovation, appeal and improve learning.

The opportunity to develop immersive and innovative new resources for our sector came at a time when the tunnelling sector in the UK was experiencing a significant growth in demand which would increase over the next fifteen years to 2030 and beyond. Tunnels provide a valuable solution to many of the current issues in civil engineering and society - such as pollution control, conservation of environments, improved efficiency of power and utility systems etc. Projects 'in train' or planned include High Speed 2, Thames Tideway, Hinkley Point C, York Potash Mine, London Power Tunnels 2, Silvertown Tunnel, Lower Thames Crossing. The collective value of these tunnelling projects are estimated at £140 bn. Prior to 2018, the major tunnelling projects (Crossrail, Jubilee Line Extension, Channel Tunnel, London Water Ring Main) collectively totalled around £40bn. It was clear that the increase in future tunnelling projects would provide work for thousands of people, many of whom would be moving from different subsectors of the construction industry. The companies involved in the tunnelling sector are made up of clients, consultants, contractors and manufacturers; all have slightly different views on their training requirements but essentially all will want the same training outcomes. TunnelSkills, a training group bringing together all the different types of organisations involved in tunnelling, consulted with its members and the vision for this project was agreed.

So much of the tunnelling industry in the construction phase is 'hidden' from public view, and as a hazardous environment, existing workers undertaking tunnelling-specific training and new entrants / potential new entrants to the sector face challenges in developing their understanding, knowledge, skills and competencies essential for working in the below-ground environment. Modules and resources (including 360-degree film of significant current tunnelling projects, digital models, and game-like experiences) have been developed to give stakeholders a realistic, engaging, consistent and safe environment replicating tunnelling sites and machinery.

In tunnelling, we're dealing with environments which are hard to understand and visualise, especially when only using presentations, diagrams or photographs. Developing immersive learning technologies have provided a solution to address challenges of sufficiently simulating or recreating the tunnelling environment for workers to develop the behaviours and competencies required to work in such environments – in a safe and non-hazardous settings. This is especially appropriate for those who may have moved into tunnelling from other subsectors of the construction industry and may never have experienced the below-ground environment previously. It has also proved successful in creating appealing and engaging resources to attract new people into the sector.

Aims and objectives of the project

The original action plan described a number of project objectives:

- **Enhance the tunnelling industry's appeal**
- **Enhance the quality of learning** by providing experiences not possible via traditional methods and in a **safe environment**
- **Inspire adoption of new learning technologies** through showcasing examples of best use
- **Reduce cost of delivery** and optimise trainers' time

Summary of the budget and funding sources

The original budget was £360,503, composed of £249,903 grant funding from CITB and £110,600 match funding from partners (match funding included both 'in-kind' and cash match).

As discussed below, the pandemic highlighted additional activities that were required to make the resources more easily accessible in the circumstances, and this meant that the actual match funding increased to £201,237.50, while the grant funding remained at the original agreed level. Therefore, the final actual budget was £451,114.50.

Initial Approach

Tom Lane, the Chair of TunnelSkills when the project was conceived, played a major role in securing buy-in to the project vision and agreement to proceed with the funding application from all members of TunnelSkills, representing all the different sections of the sector. Tom consulted with innovation experts within his own organisation (Morgan Sindall) and also learning and development specialists across the infrastructure and tunnelling world - particularly those who had experience of using immersive learning technologies. In doing so, a number of potential developers were identified, and after discussions with these developers, Make Real Ltd. was identified as the most suitable technical partner for the project as a result of their extensive experience of working with infrastructure customers. TunnelSkills and Make Real, as projects leads, developed the funding application, match funding agreement and outline project plan based on feedback from TunnelSkills members along with the technical expertise from Make Real and their experience in developing learning solutions. Both VR and AR solutions formed part of the proposal. CITB approved funding support for the project in February 2019.


We shared our initial approach with members of the CITB Commissioning Team, who tried out the technologies proposed.

Project Plan – what we did

Phase 1 - Design and development of the resources (March 2018 to February 2020)

➢ In March 2018, a Working Group was formed, led by Tunnelskills and Make Real, including 20 tunnelling professionals from the TunnnelSkills membership (including Dragados, Morgan Sindall, Balfour Beatty, Barhale, Tunnelcraft, London Bridge Associates). In addition to this, J3M Construction as a highly experienced training provider of tunnelling-specific health & safety courses was included to ensure technical and training-based expertise.

➢ Behaviours that were required to work safely in a tunnelling environment were mapped

➢ The significance of these universal behaviours would be enhanced and highlighted by 'real life' stories from the industry professionals to share their experiences of working in tunnelling, why they enjoyed their roles, and also what impact accidents and 'near misses' had on people – due to incorrect behaviour.

➢ Different types of tunnelling require different behaviours, skills and knowledge – therefore a selection of the key tunnelling methods and environments were identified. This approach would also support the objective of attracting new entrants into tunnelling – through demonstrating the variety of activities and types of environments in the industry.

➢ There are two tunnelling-specific qualifications which are mandatory for working below ground – the City & Guilds 6151-02 Tunnel Entry & Associated Emergency Procedures, and the CITB / Site Safety Plus Tunnel Safety Training Scheme (TSTS). The rules set out for Approved Training Organisations for these courses stipulate that the trainer should use their own experiences in delivery, allowing for supporting resources to be changed. The learning outcomes set out in these qualifications were used as a basis to identify the key content in the design of the resources. The Make Real team attended these courses to familiarise themselves with the traditional training approach.
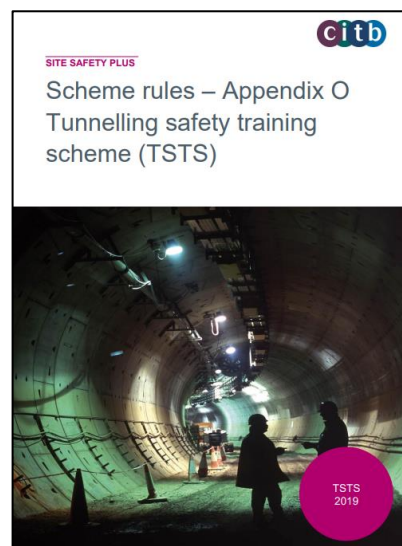
➢ A design was devised of three parts, based on the above findings from the Working Group:
  1. **'See it'** - a series of 360 degree films showing four specific types of tunnelling (Tunnel Boring Machine, Sprayed Concrete Lining (SCL), Hand Mining, and Pipe jacking) – the most effective way to give people a broad introduction into different types of tunnelling.
  2. **'Try it'** - two 3D simulations that allowed people to practice the most dangerous and important parts of working in a tunnel, e.g. identifying hazards, correctly checking and putting on their self-rescue kits, setting of the alarm, using the tally system correctly etc.
  3. **'Hear it'**, a 360 documentary with experienced tunnellers sharing their insights

➢ 'Storyboarding' was undertaken, and the structure of the resources finalised

➢ Augmented Reality (AR) developers PAULEY were engaged to create the AR resources (two interactive scenarios covering Safety in Tunnelling and Tunnel Emergencies)

➢ Investigation visits to current, iconic tunnelling projects (Thames Tideway 'Supersewer', Bank Station Upgrade, M6 SMART Motorways, Hinkley Point C) (May – August 2019)

➢ Filming of the 360 degree videos on the selected project sites arranged (Bank Station Upgrade, Thames Tideway, Institute for Civil Engineers) (September 2019 to February 2020)

➢ Development of the first app versions of the resources

Scenes from Tideway West project where the 360 videos for 'See it' TBM experience was filmed

Pushing the technology – an example of how we maximised the power of VR to create realistic, engaging and interactive scenarios

- In the second Try it simulation - 'Emergency Response' - the mission for the learner is to evacuate a tunnel in the event of a fire. This is critical because although fires in tunnels are rare, when they do happen, they can be deadly. The fire services aren't trained to enter the tunnel so the tunnellers need to get everyone out so that people can receive treatment and the fire can be extinguished.

- We needed this simulation to feel as real as possible, so that people really engaged with what that experience would be like, how it would feel, and we didn't produce 'trained bystander syndrome'.

- The smoke effect was critical to this because the loss of visibility is one of the key challenges in this emergency scenario. But a smoke effect like this would usually take an amount of processing power reserved for big budget games. Make Real's tech team came up with a creative solution where the smoke effect is only ever in front of your vision, wherever you turn your head in the scene.

- We also looked at the soundscape to help simulate the stress you would feel in that situation and another visual effect helped simulate how oppressive it feels wearing the MSA self-rescue kit

- The success of the 'Emergency Response' module can be measured by its popularity - the number of people who chose this module. When offered a choice, with an 'explanatory menu' about what the experience would be like, 54% of the 452 people completing feedback forms selected this experience. This is the one that often sticks with people and the one people talk about. Comments recorded on the feedback survey include:

  - "The VR Training was a good experience as it allowed me to be in an emergency situation and to learn the correct way to get out safely"

  - "I learnt about the correct procedures you need to follow in case of an emergency in a tunnel. It also gave me an insight into what issues can occur in a tunnel"

  - "I found the emergency response the most engaging as it was very interactive whereas the SCL {Sprayed Concrete Lining] was a lot more reading involved".

Innovative smoke and noise effects and highly interactive learner activity contributed to the high popularity and satisfaction ratings of the Try It 'Emergency Response App. Here you can see the learner opening the MSA self-rescue kit and learning how to put it on correctly.

Project Plan Phase 2 – Testing and piloting of the resources

- In February 2020, the first BETA app versions were all completed, and reviewed and approved by the Working Group
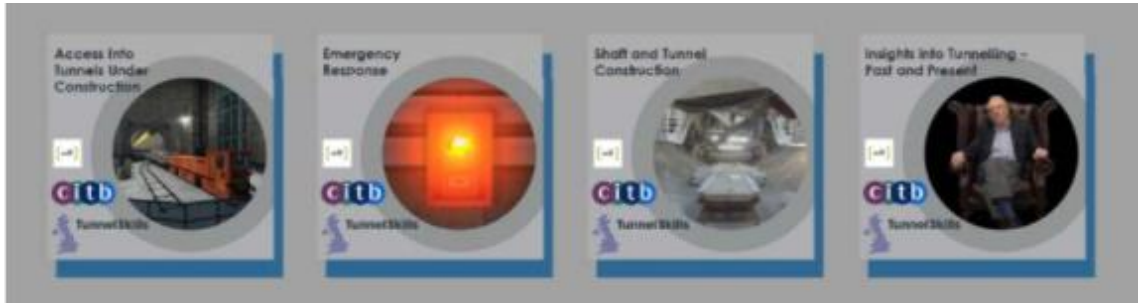
The four VR apps - loaded onto the headsets for distribution to project partners

- The first cohort of Level 2 Tunnelling Operative Apprentices based on the Tideway project receive a day of VR and AR learning sessions to complement their learning programme. Feedback from the apprentices is developed into amendments to the apps

Gareth McCracken, Tunnelling Operative Apprentice employed by Tunnelcraft on the west section of the Tideway Supersewer project, at Carnwarth Road – one of the first group of learners to experience the Immersive Learning resources

- Headsets and related hardware were purchased between November 2019 and February 2020. The apps developed were loaded onto these headsets and they were distributed to selected Working Group members who had agreed to pilot the materials within their organisations and across major tunnelling sites (through inductions and training sessions)

- All headsets distributed along with instructions and User Guides in February / March 2020

- March 2020 Covid pandemic – UK wide lockdown commenced, and severely impacts the rollout and deployment due to the 'in-person' nature of the resources (headsets)

- Activity and meetings between the project team continued via online platforms

- May 2020 - CITB advises of suspension of funding for the project until further notice

- October 2020 – The TunnelSkills Forum received an update on the project and funding situation and agreed that the project continues with proposed mitigation measures caused by the pandemic are taken forward. These included enhanced web-based versions of the resources and a re-designed plan to disseminate, pilot and test the resources

- Web XR versions are developed by the tech partners for launch online hosted by Make Real and PAULEY and available via links on the TunnelSkills website

- The Working Group developed scripts for new 'Guided Tour' versions, developed to enhance the experience of the web-based resources

- Project partners receive links to the new web-based versions and requested to support with completion of the Learner Feedback Surveys via MS Forms online

- As UK lockdowns started to ease, and 'in-person' events started to resume, the revised dissemination and deployment plan commenced, including:
  - Learner sessions with tunnelling workers on major tunnelling project sites (including Thames Tideway West BMB Carnwarth Road, HS2 Maple Cross Align JV, HS2 Euston Mace Dragados JV, London Power Tunnels 2 across multiple South London sites)
  - Official launch at the tunnelling industry's key UK event (British Tunnelling Society's Conference)
  - Development of relationships with key education-hub partners (including Construction Youth Trust, Morgan Sindall's Knowledge Quad project, Buckinghamshire Skills Hub) to promote the materials to potential new entrants through integration with their careers syllabus and at key careers events
  - Development of relationships with universities and Technical and Further Education Colleges (including Leeds College of Building, Riverside College, Black Country and Marches Institute of Technology Dudley College, Thomas Telford University Technical College, South Bank University Technical College, University of Wolverhampton, Chalfonts Community College)
  - Promotional and marketing plan (including an article to launch the resources in September 2021 issue of Tunnels and Tunnelling International magazine, a Linked in platform, a section on the TunnelSkills website,a partnership with The Brunel Museum, promotion through TUCA after March 2022, and other key tunnelling industry events)
  - Working in partnership with the awarding bodies of the two tunnelling-specific qualifications which are mandatory for working below ground – City & Guilds, and CITB Site Safety Plus to promote the resources and make them available to Approved Training Providers.

- 30th September 2021 – Official launch of the resources at The British Tunnelling Society Conference and Exhibition with support from the CITB Commissioning Team

Cheryl Morgan of CITB's Commissioning Team tried out the Immersive Learning resources - official launch at the British Tunnelling Society's Conference 30th September 2021

The results of the project - inputs

Gathering feedback

The project's original plan for the rollout, piloting and testing of the resources had been significantly impact by the pandemic. It had originally been planned that the headsets would be distributed amongst selected Working Group members and Project Partners who had agreed to pilot the materials within their organisations and across major tunnelling sites (through inductions and training sessions). The pandemic hit just as these headsets had been distributed – and as a result, those originally planning to use and demonstrate the resources among their tunnelling workforce and collect feedback and survey data were unable to do so.

A revised plan to deploy, test, pilot and secure feedback was put in place, which included several actions, including:

<u>**Online activities to secure feedback**</u>

- New web-based versions of the resources (Web-XR) were developed to overcome the issue of ongoing lockdowns and peoples' hesitancy to be in close contact and use headsets others had used (despite anti-bac procedures). Project partners receive links to the new web-based versions and requested to support with completion of the Learner Feedback Surveys via MS Forms online. Only 21 responses were received in total, which reflects the challenge in securing feedback when not face-to-face with those experiencing the resources. The full results from the online survey of web-based resources can be seen at **Appendix 1.**
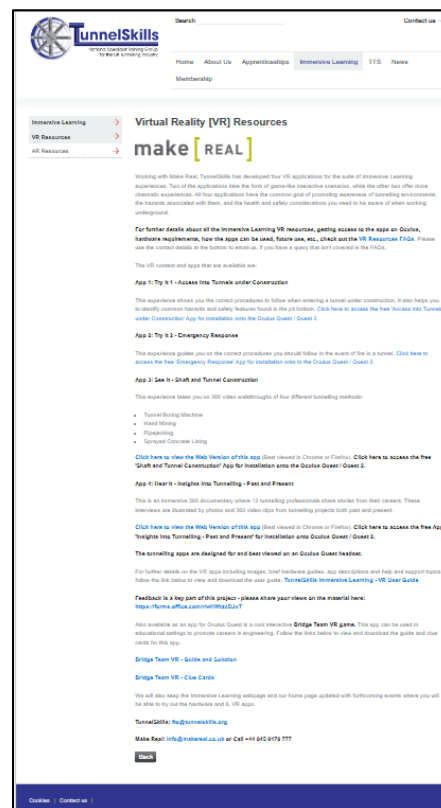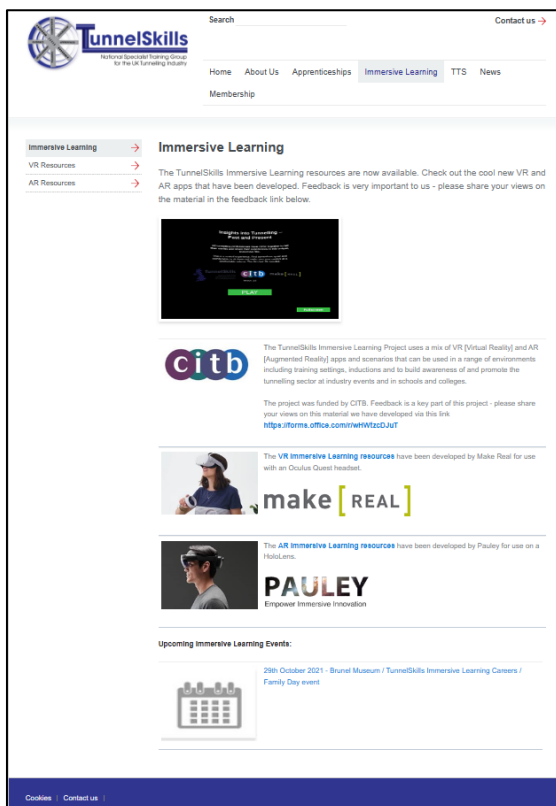
Screenshots of TunnelSkills webpages with access to the web-based versions of the resources
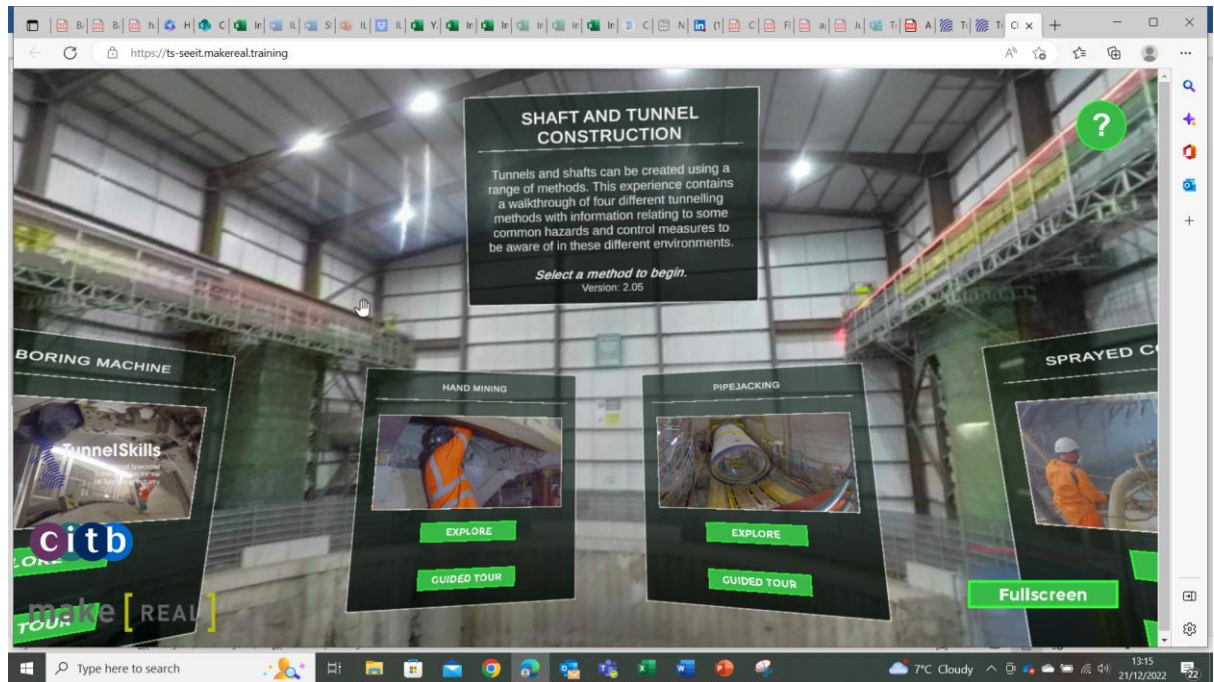
Screenshot of one of the resources available via web-based (Web XR) version

- Google Analytics reporting was set up to capture the unique users that visited the webpages on which the web-based materials are hosted. This reporting also identifies numbers of those engaged with the web-based versions. The full results from Google Analytics Reporting can be seen at **Appendices 2 and 3.**

- Oculus App Lab Store reporting. The VR resources were made available (free of charge) to download from the App Lab Store from December 2021. The full results from the App Lab Store, managed by Make Real can be seen at **Appendix 4.**
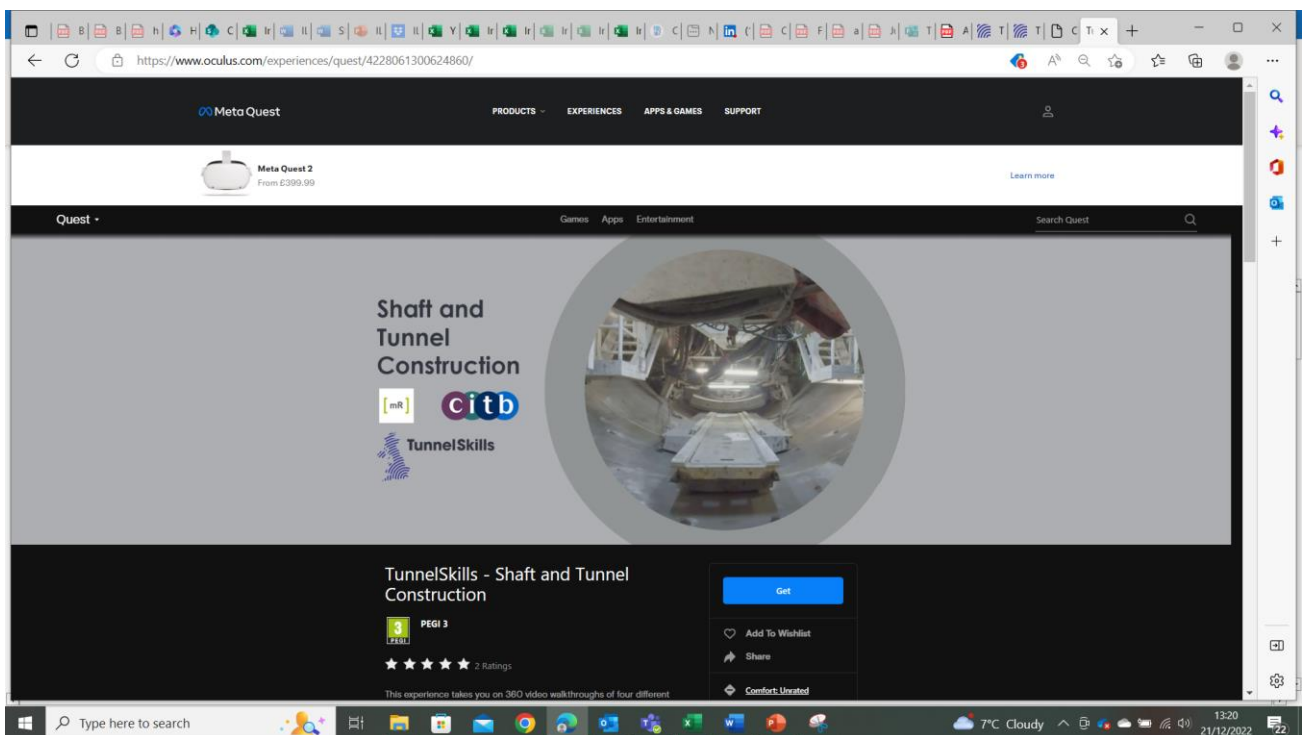
Screenshot of the Oculus App Lab Store, showing one of the resources available to download free of charge

In-person activities to secure feedback

Once lockdowns eased, training sessions were delivered to trainees / learners including:

➢ Existing employees working in the sector (both risk-facing and non-risk facing) on major tunnelling projects

Employees on major tunnelling projects undertaking VR training sessions

• Those in education – students, teachers and those in pre-employment training via education-hub partners and schools / Technical and Further education colleges and universities incorporating the resources (in-person) into their curricula and careers activities

Students experiencing the resources within their curricula and at careers events

- Working with project partners Fulcro, the resources were also amended to ensure their compatibility with the VR 'Cave' (FULmax). Multiple FULmax VR caves have been installed with the Immersive Learning resources, including those based on major tunnelling project sites (Tideway, BMB Carnwarth Road site, HS2 Align JV South Portal site) and also those located at education establishments (Dudley College Black Country and Marches Institute of Technology and Riverside College, Cronton). The full results from the online survey of FULmax VR cave resources can be seen at **Appendix 5,** however it must be noted that only 4 people completed this.

Learners at tunnelling projects and technical colleges experiencing the resources designed for the FULmax VR cave
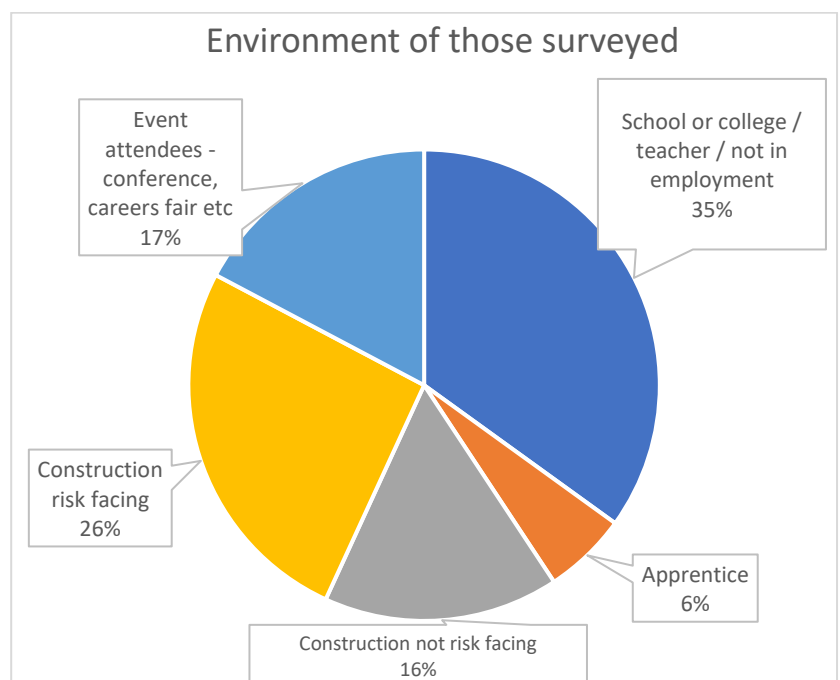
Analysis of feedback data

A total of 455 hard copy feedback survey forms were completed, composed of 372 trainees / learners, 78 event attendees, and 3 tunnelling specialist trainers. Hard copy feedback survey forms were completed by only a small proportion of those who experienced the Immersive Learning resources – this was due to the length of the forms, the volume of people experiencing the resources with limited headsets and time. For the full set of data from these completed feedback survey forms please see **Appendix 6.** For an example of a completed Trainee / Learner survey see **Appendix 7**. For an example of a completed Event Attendee survey see **Appendix 8.**

Who was surveyed

The largest proportion of trainee / learner respondents are existing employees in the tunnelling sector (42%). Those working in risk facing environments form 26% and those in non-risk facing environments 16%.

Then, trainees / learners in education or training environments (students, teachers, pre-employment) represent 35% of respondents.

Event attendees form 17% of respondents, and the smallest group of respondents are Level 2 Tunnelling Operative Apprentices (6%)
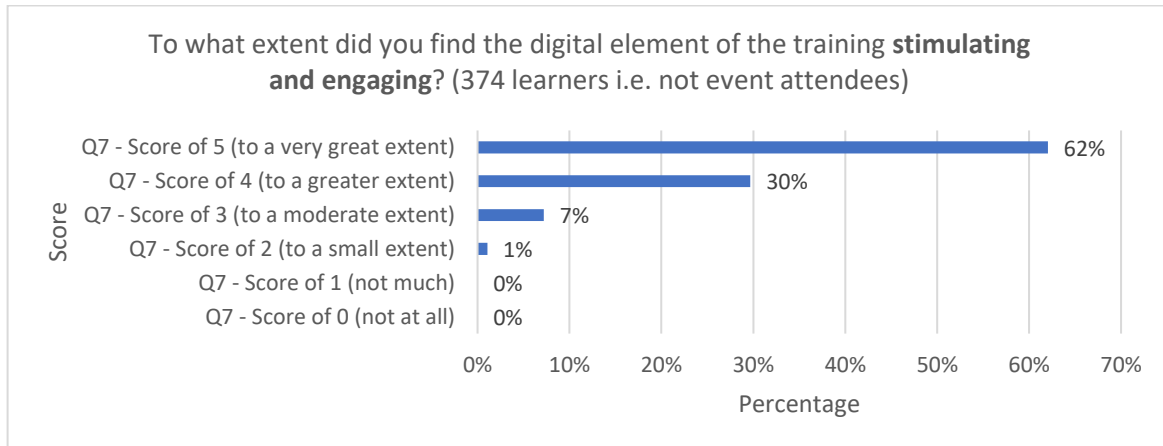

Environment of those surveyed

- Event attendees - conference, careers fair etc 17%
- School or college / teacher / not in employment 35%
- Construction risk facing 26%
- Apprentice 6%
- Construction not risk facing 16%

What learners said

1. The resources enhanced the learning experience – stimulating and engaging

When learners experiencing the resources 'in-person' and through the headsets were asked whether they found the digital element (i.e. the applications) of the training stimulating and engaging, 62% gave the highest score of 5.

92% of learners gave the top two scores (4 or 5). 0% of learners gave the bottom two scores of 0 or 1.

To what extent did you find the digital element of the training stimulating and engaging? (374 learners i.e. not event attendees)

Score	Percentage
Q7 - Score of 5 (to a very great extent)	62%
Q7 - Score of 4 (to a greater extent)	30%
Q7 - Score of 3 (to a moderate extent)	7%
Q7 - Score of 2 (to a small extent)	1%
Q7 - Score of 1 (not much)	0%
Q7 - Score of 0 (not at all)	0%

Is there a difference between those working in construction versus those in education?

When we interrogate the data to understand whether there is a difference in scoring by people in education versus those in construction on this question, we find that 86% of those in education scored the top two scores of 4 or 5, while 96% of those working in construction gave the top two scores.
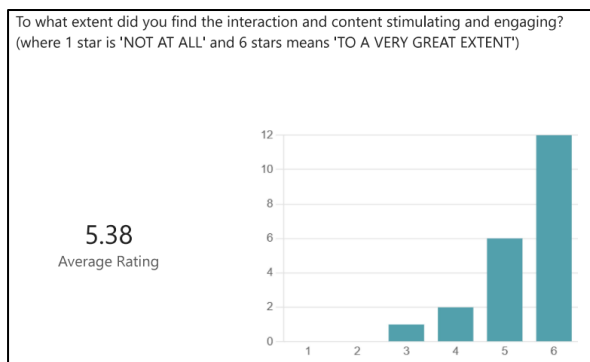
Is there a difference in scoring for people (from all environments) in different age groups?

When we interrogate the data to understand whether there is a difference in scoring by age, we find that when grouped into two distinct age categories, 88% of those aged up to 24 years old gave the top two scores of 4 or 5, while 95% of those aged 24 and above gave the top two scores.
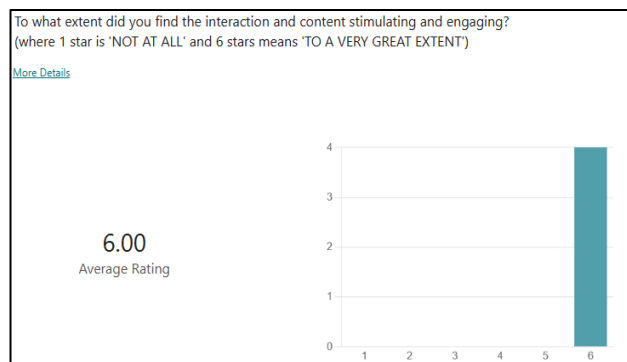
This analysis may surprise those who assume that younger people and / or those in education would find the VR resources more stimulating and engaging.

Is there a difference for those experiencing the resources through other platforms (NOT headsets)?

When we look at the results from the survey completed by those experiencing the resources through the web-based versions and through the FULmax VR Cave, we see that the scoring follows that of those who experienced via the headsets (86% give top two scores for web-based experience, and 100% for FULmax). However, it must be noted that the respondent numbers are significantly lower (21 for web-based, 4 for FULmax VR cave – see **Appendices 1 and 5** for details)

To what extent did you find the interaction and content stimulating and engaging? (where 1 star is 'NOT AT ALL' and 6 stars means 'TO A VERY GREAT EXTENT')

5.38
Average Rating

To what extent did you find the interaction and content stimulating and engaging? (where 1 star is 'NOT AT ALL' and 6 stars means 'TO A VERY GREAT EXTENT')

More Details

6.00
Average Rating

Web-based rating (86% top two scores)	**FULmax VR cave rating (100% top two scores)**

What learners said

Satisfaction rating of the training sessions

Overall satisfaction with the training (374 Trainees / Learners)
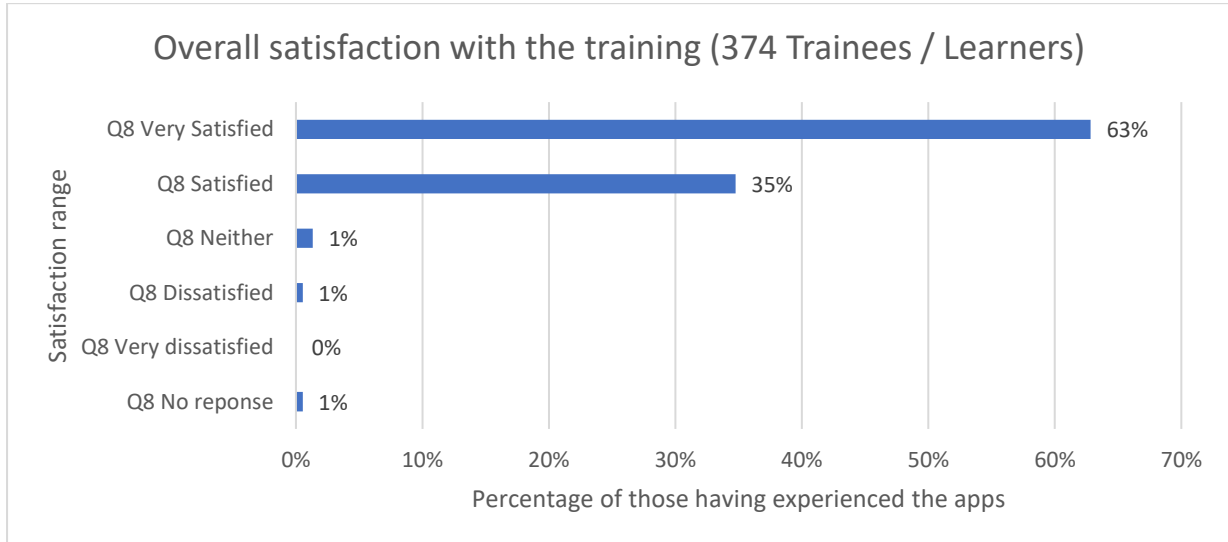
63% of the trainees / learners having experienced the training sessions using VR through the headsets are very satisfied, with 35% satisfied. 98% scored the top two ratings. Free text / qualitative responses giving reasons for their response to this question include:

- 'Far more memorable than a PowerPoint session'
- 'It was fun and easy to see and learn'
- 'I am able to retain more information by participation'

Learning & Skills Development - Achievement of Learning Objectives (planned training sessions)

There are a total of nine different Immersive Learning experiences – and a variety of ways of accessing them (via headsets, the Fulmax cube, and via web-based versions). There are a total of 19 Learning Objectives across the nine different experiences. One person could give multiple responses to this question. From the 374 learner / trainee respondents, there were a total of 1462 responses to the question "Has the training helped you to achieve the [following] Learning Objectives?". Examples of the Learning objectives include:

- Choosing the appropriate PPE
- Understanding the Tally Hut procedure
- Hazard and Observation spotting
- Emergency response in a tunnel

Were your learning objectives achieved?
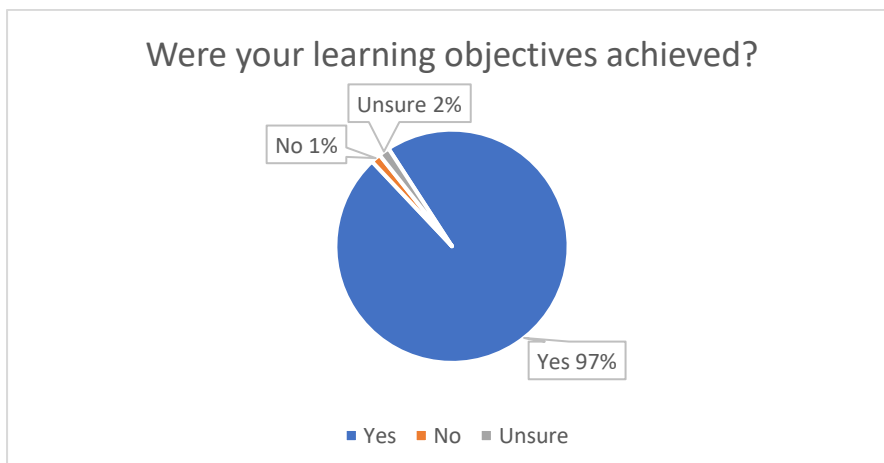
97% (1420 no.) responded that their learning objectives were achieved. 1% (20 no.) responded that their learning objectives were not achieved. 2% (22 no.) responded that they were unsure.

Development of additional skills of knowledge

74% (275 no.) of the trainees / learners confirmed that they had developed other skills or knowledge as a result of the immersive learning resources.

13% (50 no.) did not consider that they had developed other skills or knowledge, and 13% (49 no.) did not respond.
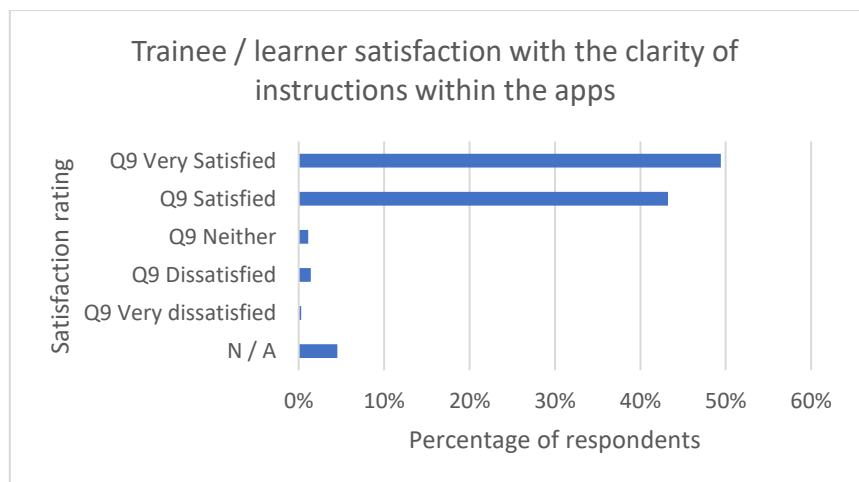
Free text / qualitative responses giving reasons for the response include:

Did you develop any other skills or knowledge during the AR / VR training experience?

Did not respond 13%

No 13%

Yes 74%

- Yes - No - Did not respond

- 'First time using a VR headset - learnt navigation also how a TBM works' (TBM = Tunnel Boring Machine)
- 'An understanding of the size and scale of different tunnelling environments'
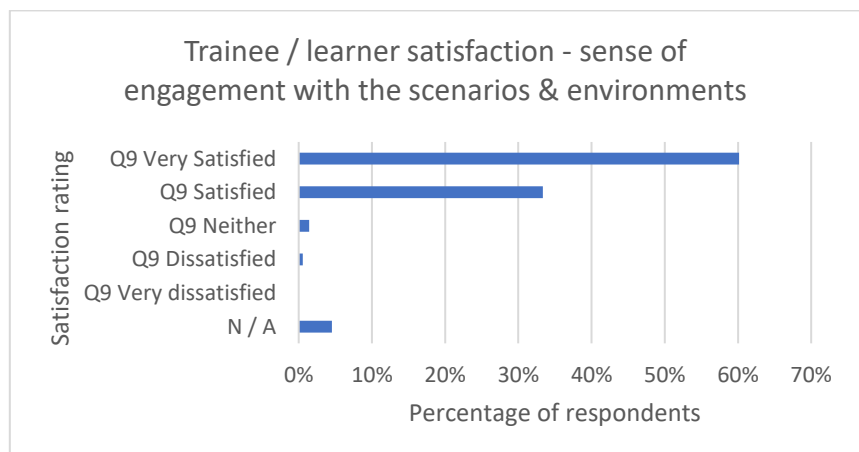- 'To observe things better, slow down and think before acting'
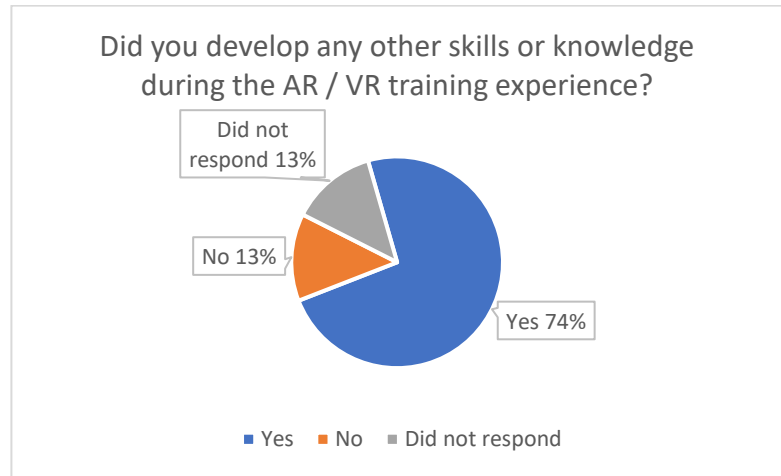
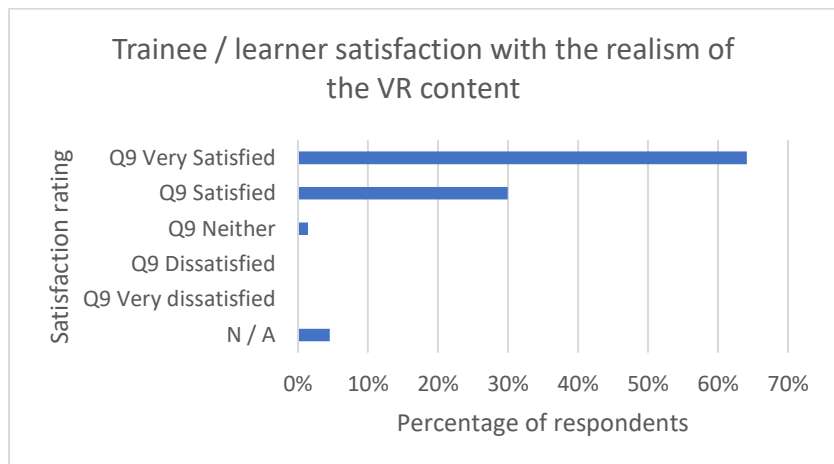**Satisfaction levels with different aspects of the immersive learning experience**

49% (175 no.) were very satisfied with the **clarity of instructions within the apps,** 43% (153 no.) were satisfied, 1% (4 no.) were neither satisfied nor dissatisfied, 1% (5 no.) were dissatisfied, and 0% (1 no.) were very dissatisfied. 5% (16 no.) answered 'Not Applicable' as they accessed the resources via web-based versions.

Trainee / learner satisfaction with the clarity of instructions within the apps

Satisfaction rating

Q9 Very Satisfied
Q9 Satisfied
Q9 Neither
Q9 Dissatisfied
Q9 Very dissatisfied
N / A

0% 10% 20% 30% 40% 50% 60%

Percentage of respondents

60% (213 no.) were very satisfied with the **sense of engagement with the scenarios & environments,** 33% (118 no.) were satisfied, 1% (5 no.) were neither satisfied nor dissatisfied, 1% (2 no.) were dissatisfied, and 0% (0 no.) were very dissatisfied. 5% (16 no.) answered 'Not Applicable' as they accessed the resources via web-based versions.

Trainee / learner satisfaction - sense of engagement with the scenarios & environments

Satisfaction rating

Q9 Very Satisfied
Q9 Satisfied
Q9 Neither
Q9 Dissatisfied
Q9 Very dissatisfied
N / A

0% 10% 20% 30% 40% 50% 60% 70%

Percentage of respondents

64% (227 no.) were very satisfied with the **realism of the VR content,** 30% (106 no.) were satisfied, 1% (5 no.) were neither satisfied nor dissatisfied, 0% (0 no.) were dissatisfied, and 0% (0 no.) were very dissatisfied. 5% (16 no.) answered 'Not Applicable' as they accessed the resources via web-based versions.
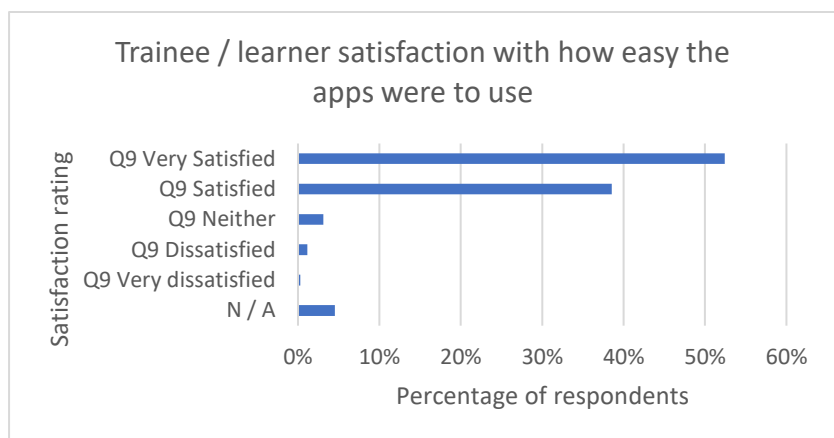
Trainee / learner satisfaction with the realism of the VR content

Satisfaction rating (vertical axis), Percentage of respondents (horizontal axis, 0% to 70%)

- Q9 Very Satisfied
- Q9 Satisfied
- Q9 Neither
- Q9 Dissatisfied
- Q9 Very dissatisfied
- N / A

52% (185 no.) were very satisfied with **how easy the apps were to use,** 39% (136 no.) were satisfied, 3% (11 no.) were neither satisfied nor dissatisfied, 1% (4 no.) were dissatisfied, and 0% (1 no.) were very dissatisfied. 5% (16 no.) answered 'Not Applicable' as they accessed the resources via web-based versions.

Trainee / learner satisfaction with how easy the apps were to use

Satisfaction rating (vertical axis), Percentage of respondents (horizontal axis, 0% to 60%)

- Q9 Very Satisfied
- Q9 Satisfied
- Q9 Neither
- Q9 Dissatisfied
- Q9 Very dissatisfied
- N / A

Each of the four different aspects of the apps were given the top two rating by an average of 92.5% of respondents.

Qualitative analysis and individual comments from the feedback survey

When asked to provide up to 3 elements that worked well in the apps, free text qualitative responses included:

- 'Very visually engaging - could see sizes and proportions'
- 'Clarity and realism of the tunnel environment excellent'
- 'Best for people who haven't been on a site before'
- 'Sensory stimulus e.g. smoke in emergency'

When asked to provide up to 3 elements that could be improved in the apps, free text qualitative responses included:

- 'Hard to focus and get used to the headset'
- 'Apps in one headset difficult to share in a training group'
- 'Hazard spotting took a very long time with the 'eye' mechanism'
- 'Tricky to action some actions in 'Try It' e.g. the waist strap in Emergency Response'

Listening to feedback and continuous improvement

All qualitative responses were reviewed and actioned where appropriate and possible. For example, there were several comments about the 'waist strap' activity in the 'Try It – Emergency Response' app. These comments were reinforced by facilitators noting that this area was causing a significant amount of frustration. TunnelSkills worked with Make Real to improve this aspect of the app, resolving the issue.

Trainer feedback

Three tunnelling specialist trainers were loaned headsets to test and pilot the AR and VR resources.

Feedback was mixed, with all three recognising that the technology provided a positive learning experience and opportunity in some ways (it allowed for content to be delivered that otherwise may have been inaccessible, and it allowed learners to interact with the various environments).However, in terms of reducing the time needed to deliver training, two of the trainers strongly disagreed and that in fact it had the opposite effect in that more time was needed to explain any queries raised by the technology.

Positive qualitative comments included elements that worked well:

- 'Recognising dangers and risks in a safe environment'
- 'VR Emergency Response (e.g. pneumatic tool and feedback from controller) worked well to create a realistic environment'

Positive impacts for the trainees listed by the trainers - that they felt were achieved by the use of the immersive learning that a traditional approach did not achieve - included;

- 'Better candidate engagement'
- 'Better situational awareness which cannot be achieved through traditional methods'
- 'Better awareness of specific hazards of tunnelling through 360 degree videos'

Negative impacts were largely focused on the practical aspects of using the headsets, including the time taken to demonstrate the equipment and navigate to the apps, how to manage trainees that are unfamiliar or uncomfortable with the technology – and this could result in potentially isolating candidates that struggle with technology, and these candidates may not pay attention if left on their own.

Other practical issues and barriers to using the resources and technology were highlighted by trainers.

- **Time**
  In delivering the two tunnelling-specific qualifications which are mandatory for working below ground – the City & Guilds 6151-02 Tunnel Entry & Associated Emergency Procedures, and the CITB / Site Safety Plus Tunnel Safety Training Scheme (TSTS), that the 7.5 hours required for delivery is already stretched to fit in all the content to deliver the information required to pass the assessment.
- **Cost of hardware**
  The cost of hardware (The Microsoft Hololens headset required for the AR apps costs £1,000) is currently an issue for training providers
- **Limited number of headsets**
  Limited numbers of headsets can practicably be used as a result of cost implications and transporting the multiple headsets to various sites to deliver training
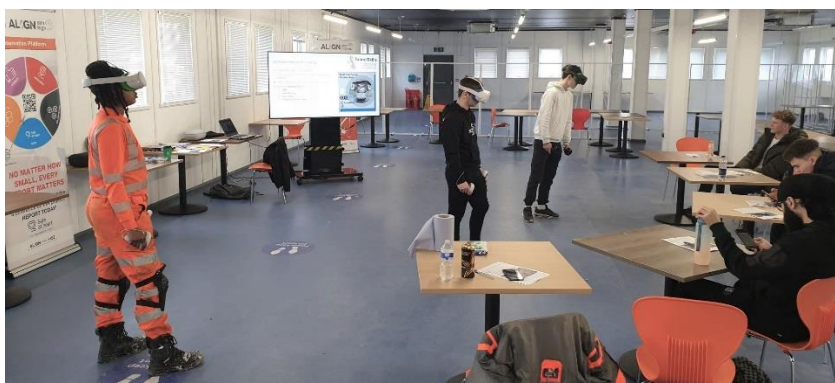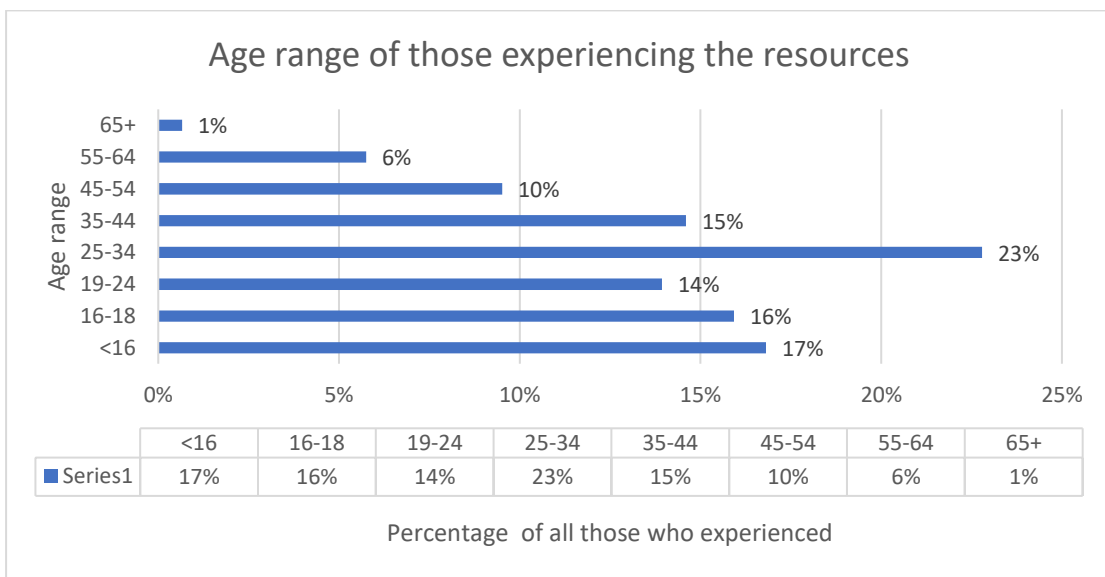

Immersive Learning training delivered to the apprentices, which worked well because this tunnelling specific apprenticeship programme is not subject to the time pressures that are inherent in the mandatory one-day courses

Reaching a diverse audience

Age

Of the 452 Trainees / Learners and Event Attendees who experienced the resources, 17% (76 no.) are below 16 years old. 16% (72 no.) are 16-18 years old, and 14% (63 no.) are 19-24 years old. When compared with industry statistics, we can see that the proportion of young people reached through the this project is significantly higher when compared with the existing construction sector workforce - the Chartered Institute of Building (CIOB Diversity Report) states that 1-2% in the industry are between 16-18, and only 10% are 19-24 years old. The hope is that this will support in addressing the low representation of these age groups in the tunnelling by inspiring younger age groups (Years 9 to 11) to think about careers in tunnelling and civil engineering. This was achieved by working in partnership with education hub organisations such as Construction Youth Trust, The British Tunnelling Society Young Members Schools and Education Committee, and Morgan Sindall's Knowledge Quad based in Aylesbury. In addition, we worked with schools, technical and further education colleges, and universities directly.

Age range of those experiencing the resources

	<16	16-18	19-24	25-34	35-44	45-54	55-64	65+
■ Series1	17%	16%	14%	23%	15%	10%	6%	1%

Percentage of all those who experienced
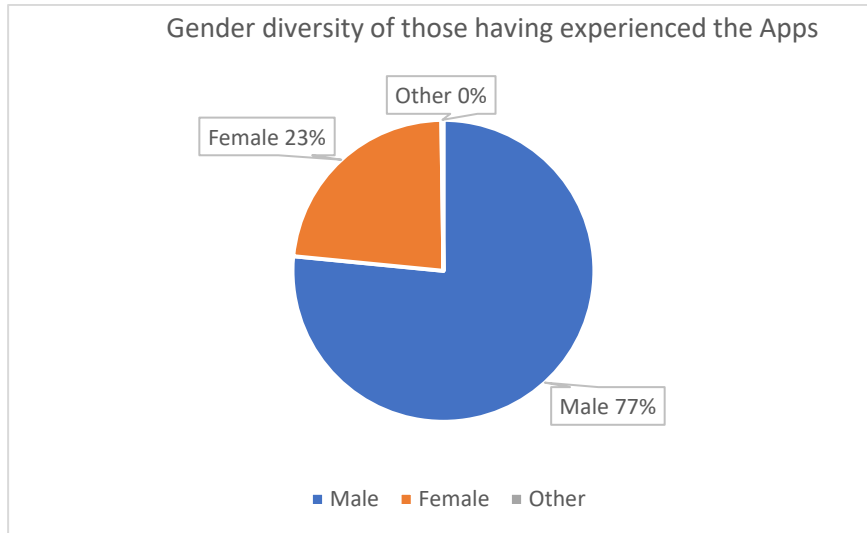
Careers Events

Another strategy to reach a diverse audience was to target specific Careers Fairs – typically for young people look for inspiration in their choice of future careers, but also for those looking to change careers. Many of the Event Attendees who experienced the resources did so at careers fairs. These events were targeted because of their geographical location, near to major infrastructure project sites which would be looking to recruit into the tunnelling sector specifically over the next few years – therefore providing an achievable and local pathway into a career in tunnelling. These events included: Generation Dacorum Careers Fair, Bucks Skills Show, Brent Council Careers Insight Event, Oak Wood School Careers Fair in Uxbridge, Chalfonts Community College Employability Event, West Midlands Combined Authority Construction Jobs Fair.

Some of the careers events where the immersive learning resources were in demand!

Gender

The immersive learning project demonstrates reach to a high proportion of females. 23% of those completing feedback survey forms are female, which is significantly higher than the 13% female population currently within the construction sector as a whole (stated as 12.3% by the Chartered Institute of Building CIOB Diversity Report).

Gender diversity of those having experienced the Apps

Other 0%

Female 23%

Male 77%

■ Male ■ Female ■ Other

The deployment strategy included targeted activity to support reach to females, particularly those making decisions about their future careers. Girls' schools including Swakeleys School for Girls (Hillingdon) and St Martin-in-the-Field School for Girls. We are continuing to work with our partner, The Brunel Museum (site of Marc Brunel's original Thames Tunnel shaft), to target their STEM activity to young female students aged 11-14, with early career female tunnelling engineers delivering sessions using the immersive learning resources to bring the underground working environment to life.

The Brunel Museum casting the immersive learning from the headset onto the historical Brunel Thames Tunnel shaft wall – and girls' schools experiencing the resources during their STEM and careers sessions.

Ethnicity

37% of those having given feedback are from BAME backgrounds. Again, this is a proportion which is significantly higher than the percentage of those from BAME backgrounds currently within the construction sector as a whole (stated as 5-7% by the Chartered Institute of Building CIOB Diversity Report).
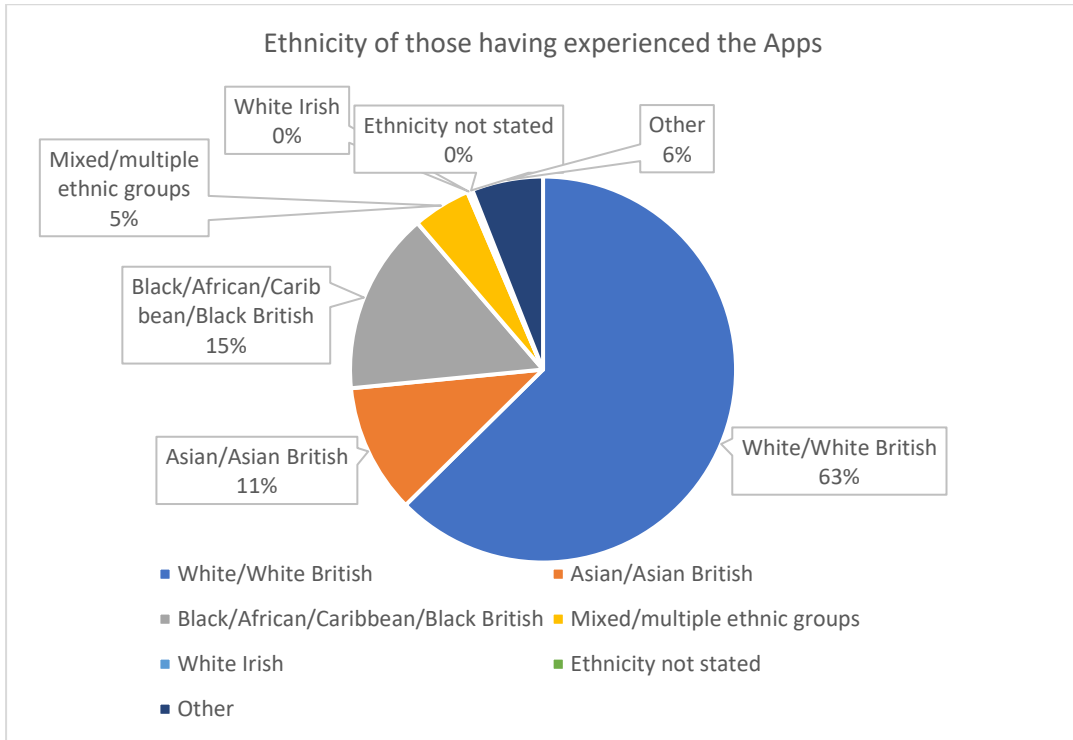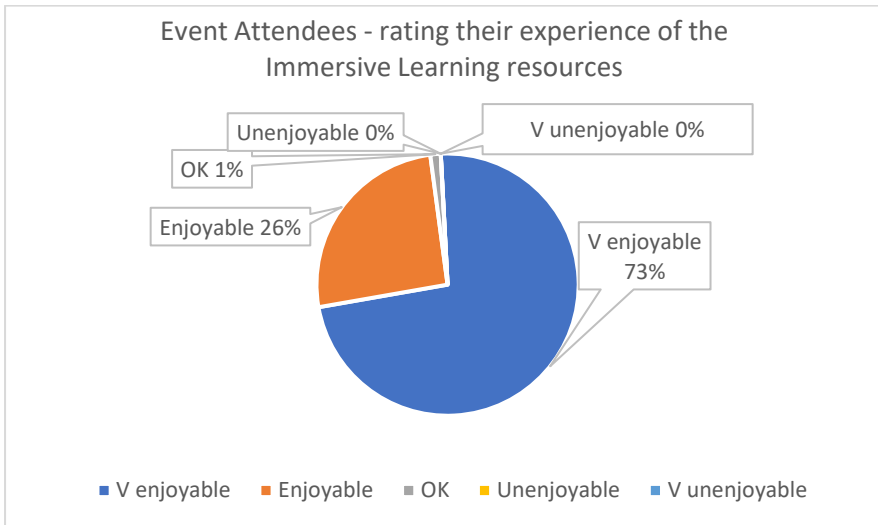

Reaching a wider potential talent pool to enhance the image of the tunnelling industry

Tunnelling is a very difficult industry to break into. Historically, people come into the sector through existing connections and certainly in times where tunnelling work is abundant, they tend to stay in the sector until they leave the workforce. Working in tunnelling requires a lot of skill and only recently has it developed entry level opportunities – coming to the fore in the long pipeline of work available in the UK over the next 15-20 years. Driving and sparking interest in this career path is essential for our industry so that we attract a wider pool of interest from which to identify the best talent. Immersive learning provides an engaging 'hook' as an integral part of sustained and coordinated careers-based activity by our industry.
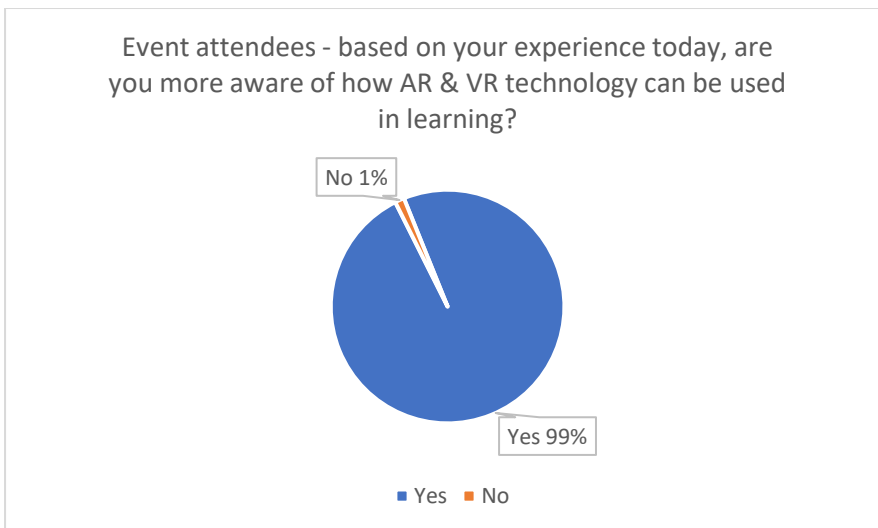
"It gave me a good idea on how it is to be in a tunnel"

"I loved the ability to be in a tunnel - never seen one before!"

Event Attendees

Event Attendees - rating their experience of the Immersive Learning resources

- Unenjoyable 0%
- V unenjoyable 0%
- OK 1%
- Enjoyable 26%
- V enjoyable 73%

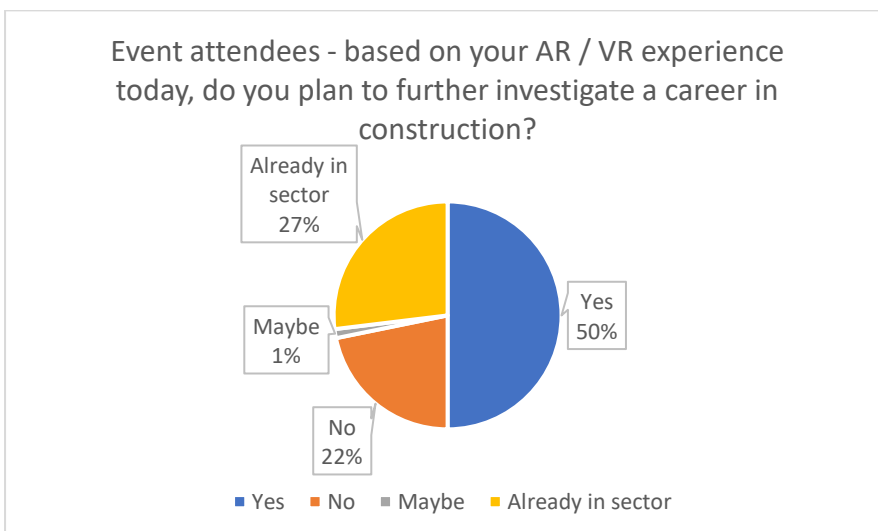Legend: ■ V enjoyable ■ Enjoyable ■ OK ■ Unenjoyable ■ V unenjoyable

An enjoyable experience

Event attendees rated their experience of the immersive learning resources as overwhelmingly positive with 99% rating in the top two categories (Very Enjoyable and Enjoyable).

Event attendees - based on your experience today, are you more aware of how AR & VR technology can be used in learning?

- No 1%
- Yes 99%

Legend: ■ Yes ■ No

Increased awareness of how AR and VR technology can be used in learning

99% (77 no.) agreed that as a result of their immersive learning experience, that they were more aware of how AR and VR technology can be used in learning.

Event attendees - based on your AR / VR experience today, do you plan to further investigate a career in construction?

- Already in sector 27%
- Maybe 1%
- Yes 50%
- No 22%

Legend: ■ Yes ■ No ■ Maybe ■ Already in sector

Immersive learning – Inspiring people to further investigate a career in the sector

Due to its 'hidden' nature underground, it may not be surprising that people looking to start their careers have never considered tunnelling or even civil engineering! However, improving access to the often awe-inspiring working environment of tunnelling through VR and AR appears to have inspired event attendees – with 50% (39 no.) planning to further investigate a career in the sector.

Open access to the resources and numbers who have accessed

TunnelSkills and Make Real made the decision to make the VR resources available via the Oculus App Lab Store from December 2021 (see below in the 'Products' section for links to these). Make Real as the developer has access to the data published regarding downloads and installs.
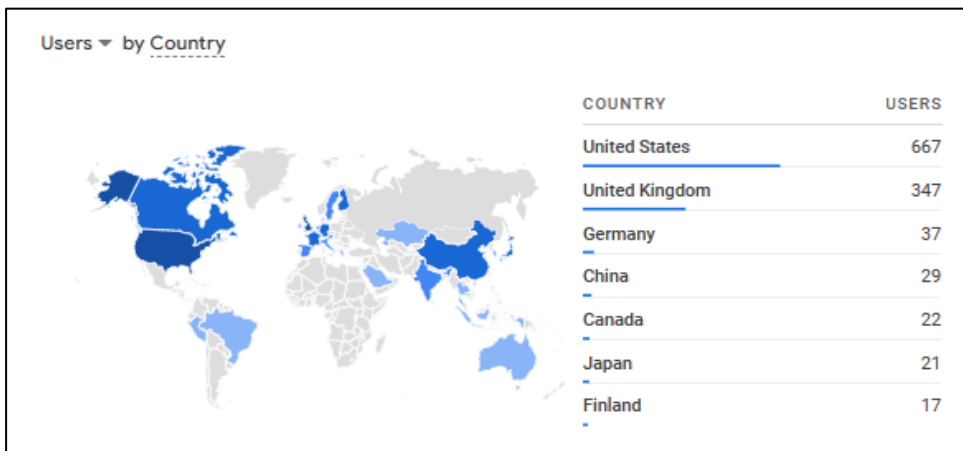
To date, there have been **1,110 App Lab downloads**, and an average rating of 4 (out of 5) Stars on App Lab.

App	Total lifetime downloads / installs	App Lab reviews (max 5 Stars)
Try it – Access into Tunnels under Construction	**449**	**3.7**
Try it – Emergency Response	**275**	**4**
See it – Shaft and Tunnel Construction	**276**	**5**
Hear it – Insights into tunnelling	**110**	**3**

Google Analytics report data on the web-based resources

Since Google Analytics reporting was set up on 1st September 2021, there have been **1.2k users worldwide** who have accessed the web pages where the web-based versions of the resources are hosted.

347 of these unique users are based in the UK. The most popular page viewed is '**See it – Shaft and Tunnel Construction' with 992 views**, followed by 'Hear it – Insights into tunnelling' with 435 views.

Users ▾ by Country

COUNTRY	USERS
United States	667
United Kingdom	347
Germany	37
China	29
Canada	22
Japan	21
Finland	17

WHICH PAGES AND SCREENS GET THE MOST VIEWS?

Views by Page title and screen class

PAGE TITLE AND SCREEN CLASS	VIEWS
CITB: Shaft & Tunnel Construction	992
CITB: Insights into Tunnelling	435
citb - Tunnel Skills - PAULEY	193

WHAT ARE YOUR TOP EVENTS?

Event count by Event name

EVENT NAME	EVENT COUNT
page_view	1.6K
session_start	1.6K
scroll	1.3K
first_visit	1.3K
user_engagement	668

Reach and influence

Recognition and Awards

In July 2022 the project won the 'Education' category of the CLC / CECA Inspiring Change Awards.

The Inspiring Change Awards, supported by Civil Engineering Contractors Association (National) and Construction Leadership Council recognise companies working in the construction and built environment sectors that demonstrate they value and promote inclusion and diversity in the workplace and wider community.

The judges highlighted how the project seeks to attract a diverse range of new entrants by bringing tunnelling to life in a fun, inclusive and accessible way, and also aims to enhance the learning experience of those already working in tunnelling.

It is an honour for TunnelSkills and Make Real to receive this prestigious recognition, especially in view of the strength and quality of the shortlisted finalists, which included Jackson Civil Engineering Ltd, Morgan Sindall Infrastructure and VGC Group.

In August – September 2022, the project was also shortlisted as a finalist in two learning technology sector awards - the AIXR - The Academy of International Extended Reality VR Awards 2022, and also the Learning Technologies Awards 2022.

Finalists 2022 - VR Awards 2022 (aixr.org)

These awards recognise and celebrate outstanding achievement in VR.

Our project was a finalist in the 'VR Enterprise Solution of the Year' category that specifically rewards projects that satisfy the needs of an organisation or group rather than individual users - a fitting validation of our key objective to deliver and demonstrate the value of innovative learning solutions for the benefit of the UK tunnelling industry as a whole.

Learning Technologies Awards 2022 Shortlist - Learning Technologies 2022

These awards recognise and celebrate the commitment, enthusiasm and passion for learning technologies across the world. Our project was a finalist in the 'Virtual Environments & Simulation' category.

Products

The gateway to all of the TunnelSkills / Make Real Immersive Learning resources is through the TunnelSkills website here: TunnelSkills. There is also a gateway to the Oculus App Lab downloads here: CITB / TunnelSkills - Induction Suite - Make Real (see links on the right hand side of the page).

1. **VR app - Try It 1 – Access into Tunnels under Construction**
   Description - Game-like and highly interactive. This experience shows you the correct procedures to follow when entering a tunnel under construction. It also helps you to identify common hazards and safety features found in the pit bottom.
   Oculus App Lab download here: TunnelSkills - Access into Tunnels Under Construction on Oculus Quest 2 | Oculus
   Web-based version YouTube end-to-end video only: TunnelSkills VR App - Try It - Access into Tunnels Under Construction - end to end video - YouTube

2. **VR app - Try It 2 – Emergency Response**
   Description - Game-like and highly interactive. There is a fire in the tunnel – can you raise the alarm, put on your self-rescue kit correctly, set off the water curtain and tally out correctly? This experience guides you on the correct procedures to follow in the event of fire in a tunnel.
   Oculus App Lab download here: TunnelSkills - Emergency Response on Oculus Quest 2 | Oculus
   Web-based version YouTube end-to-end video only: TunnelSkills' 'Try It' VR App - Emergency Response - end to end video for a web-based VR experience - YouTube

3. **VR app - See It – Shaft and Tunnel Construction**
   Description - Real-life tunnelling jobs in 360 degrees – grab and drag your mouse to learn about 4 different methods of tunnelling – travel through the scenes and learn about the process / equipment and the associated health and safety issues.
       i.   Tunnel Boring Machine
       ii. Hand Mining
       iii. Pipejacking
       iv. Sprayed Concrete Lining
   Oculus App Lab download here: TunnelSkills - Shaft and Tunnel Construction on Oculus Quest 2 | Oculus
   Web-based version – can move and select objects on the screen: CITB: Shaft & Tunnel Construction (makereal.training)

4. **VR app - Hear It – Insights into Tunnelling Past and Present**
   Description - This is an immersive 360 documentary where 12 tunnelling professionals share stories from their careers. These interviews are illustrated by photos and 360 video clips from tunnelling projects both past and present. Learn about how health and safety practice in tunnelling has evolved over the years
   Oculus App Lab download here: Insights into Tunnelling Past and Present - TunnelSkills - Insights into Tunnelling – Past and Present on Oculus Quest 2 | Oculus
   Web-based version – can move the screen around with mouse: CITB: Insights into Tunnelling (makereal.training)

5. **VR User Guide here**: TunnelSkillsVRUserGuide.pdf

6. **AR User Guide here**: TunnelSkillsARUserGuideV012.pdf

7. **Web-based AR scenarios here:** citb - Tunnel Skills - PAULEY

Making the difference

"**National Grid** took the decision to **invest in the hardware specifically to use the TunnelSkills / Make Real Apps** in our school and college engagement programme. For National Grid, this not only demonstrates that we are a **forward-thinking organisation** offering technology-based careers appealing to the next generation of talent, but it also **minimises the safety risk, cost and disruption** of bringing young people down into our project sites and tunnels. **It's a win-win for us.**"
  - Sarah Wooham-Jaffier, EPC Project Manager - London Power Tunnels

See the full case study at **Appendix 9.**

Skanksa Costain STRABAG JV - inspired by TunnelSkills Immersive Learning project to develop their own Mixed Reality Tunnel Induction and specialist Tunnelling Training

The SCS team has taken the TunnelSkills resources as a basis and are using these as inspiration to create their own their own bespoke and targeted immersive mixed reality (XR) training packages so that they can virtually put people to work in these environments, assess their skills and provide ongoing support and coaching to work in the SCS tunnels.

They are developing multiple training courses including Tunnel Induction, Entry and Emergency Arrangements, Tunnel Slinger / Signaller, Tunnel Gantry Crane Operator, Tunnel Traffic Marshall, and Tunnel Driver.

Andy Levett, Head of Tunnel Safety at SCS says,

"Tunnelling competence and safety are key to the success of the SCS project, and we wanted to develop our own unique tools to drive forward continuous improvement."

"The TunnelSkills Immersive learning project has trailblazed the way for us, giving us the confidence to build our own innovative solutions and delivering a fantastic step forward for the industry."

See the full case study at **Appendix 10**

Review and discussion

What worked well

Feedback from trainees / learners and event attendees has been extremely positive and the interest and engagement from the education and pre-employment & careers sector continue to be high. Major employers in the sector have engaged, adopted the resources produced, and have even been inspired to create their own. This can be demonstrated in the following successes.

- **Embedding of the resources into the education curricula**, particularly where the institutions have access to - and ringfenced funding for - new learning technologies, such as Leeds College of Building, Riverside College, Thomas Telford University Technical College.

- **Embedding of the resources and purchase of the hardware by major employers in the infrastructure and tunnelling sector** to support their careers outreach and STEM education programmes (National Grid, Joseph Gallagher Ltd)

- **Sustained integration of the resources into High Speed 2's 'Pathways into Tunnelling' programme.** This has now formalised into a Tunnelling-focused Sector-Based Work Academy Programme (SWAP) (a sector focused pre-employment programme) to be delivered between November 2022 and February 2023 in the London area, focused on areas where the HS2 sites are situated. This programme of pre-employment training and work experience will lead to a number of Level 2 Tunnelling Operative Apprenticeship roles. The Immersive Learning resources play a key role in the Information and Engagement sessions and the training elements of this programme. From February 2023, this programme will be replicated along the route of HS2, with the next programme based in the West Midlands and launched in National Apprenticeship Week.

- **Embedding of the resources into work-based learning materials via the two awarding bodies'** online, secure ('walled garden') area to provide suggested training support materials and documents for their Approved Training Providers. City & Guilds and CITB SSP. Also promoted in Site Safety Plus eNEWS – a newsletter for Approved Training Providers.

CITB Site Safety Plus eNEWS newsletter promotion of the resources

City & Guilds promotion of the resources to their Approved Training Organisations

- **Embedding of the resources into the Level 2 Tunnelling Operative Apprenticeship programme**
  The resources have been successfully embedded in work-based learning in the Level 2 Tunnelling Operative Apprenticeship programme – with a cohort of 14 apprentices on the Tideway project, and 12 on the HS2 / Align JV project to date. Access to the hardware, the support / facilitation from TunnelSkills, and the longer timescale of the learning programme will ensure that this is sustained into the next 2 cohorts of this apprenticeship programme on HS2 sites (commencing February 2023 and May 2023).

- **Inspiring the adoption of new learning technologies** through showcasing examples of best use
  A clear demonstration of this success is the Skanska Costain STRABAG JV. Through early engagement in the TunnelSkills immersive learning project, this major delivery partner on the HS2 project has been inspired and supported in developing their own XR mixed reality resources specific to their own project sites, using new learning technology. This is an enduring legacy and validation of the immersive learning project, demonstrating that it has contributed to industry's greater capacity and capability to deliver immersive learning.

What has not worked so well

- **Resources not having been embedded into the short, mandatory tunnelling specific courses**
  There is mixed feedback from specialist trainers who deliver short tunnelling-specific courses – most notably from those that deliver the mandatory one-day tunnelling courses. Although they welcome the resources as a potential aid to training and are positive about the concept and positive impact of immersion in environments otherwise unachievable using traditional methods in a classroom, they cite numerous practical barriers to embedding the resources within their deliver (time pressures, cost, practicality of transport etc.). As a result, the tunnelling-specific trainers have not continued to use the resources via VR nor AR (although some do use the web-based versions).

- **Gathering metrics and evaluation of knowledge acquisition and retention**
  The proposed activity to gather metrics on knowledge acquisition and retention has provided the project with an ongoing and unresolved challenge. The issue lies in following up with trainees who received the immersive learning training, particularly on the busy major infrastructure sites where tunnelling is predominantly found – people may move sites several times in a month. Many operatives may not be contactable via email, and therefore are unlikely to respond to email communication, as evidenced by disseminating the web-based versions during the pandemic and requesting that people completed the online feedback survey form. People working on site have limited time, so gathering feedback and data from trainees / learners is most successful when you are with them and request that the forms be completed there and then. Visiting site in-person again to follow up with the original learners after a period of time has passed (e.g. 3 months) it is unlikely that the same people (even if still on the same site) would be willing to undertake the same activity with no additional benefit. Operational workers are by nature busy and always on the move!
  Although there are not consistent metrics to measure knowledge acquisition and retention, there are, however, numerous qualitative comments captured by the trainee/ learner feedback forms which suggest that the project has succeeded in enhancing. One of the most frequent words used in the feedback was 'engaging'. Comments relating to knowledge acquisition and retention include:
    - 'I am able to retain more information by participation'

- o 'It's a super fun and informative way to learn and develop skills, also a great insite [sic] into future technology'
- o 'Brilliant really liked it the VR kept me engaged'
- o 'Very engaging and taught me a lot of information in a highly memorable way'
- o 'The VR segment was able to provide a sense of scale and immersion that is hard to get when just looking at a picture of something.'

Although there are areas that have not been so successful, when the original objectives of the project are reviewed, only one of these appears not have been achieved.

- **Enhance the tunnelling industry's appeal**
- **Enhance the quality of learning** by providing experiences not possible via traditional methods and in a **safe environment**
- **Inspire adoption of new learning technologies** through showcasing examples of best use
- **Reduce cost of delivery** and optimise trainers' time

Legacy and next steps

While TunnelSkills may not be seeking additional support to extend or take the immersive learning project to the next stage, we will continue to support partners who may wish to take immersive learning in new directions. Industry demand for the resources continues with events using the resources planned into the future:

- 25th January 2023 – VR training session for the National Highways Engineering team at Maidstone Head Office
- National Apprenticeship Week 6th – 12th February 2023
  - o 6th February 2023 BBV Principal Contractors on HS2 project launch of their 'Pathways into Tunnelling' pre-employment programme, leading to Tunnelling Operative Apprenticeship opportunities
  - o 8th February 2023 Align JV Principal Contractors on HS2 project – Apprentice event
  - o 9th February National Grid Work Experience Week using the resources to show students the tunnelling environment
  - o 9Th February 2023 London Bridge Associates demonstrating careers in tunnelling using the VR resources at The Cottesloe School in Aylesbury area

It is clear that a lasting legacy has been created by this project. Project partners and members of TunnelSkills have bought into the concept and continue to use the resources in their own operations and have even developed their own immersive learning resources, inspired by this project. As a National Specialist Training Group, addressing issues and challenges that our sector faces, TunnelSkills will continue to support and encourage members and partners using the resources where they are valued and bring benefit e.g. in attraction and recruitment activities, and advise where others look to adopt new learning technologies.

As CITB and the other Immersive Learning projects develop their own legacy strategies, TunnelSkills are keen to contribute to this emerging knowledge partnership and will continue to support the use of the resources and celebrate the successes achieved.

List of Appendices

Appendix 1   Online Learner Feedback Survey all - web-based material

Appendix 2   Google Analytics Report Overview 1 Sept 2022 - 20 Dec 2023

Appendix 3   Google Analytics Report Engagement Overview 1 Sept 2021 - 20 Dec 2023

Appendix 4   Oculus App Lab Store report of downloads and installs

Appendix 5   Online Learner Feedback Survey all (FULmax)

Appendix 6   MASTER Immersive Learning Project ALL FEEDBACK spreadsheet

Appendix 7   Example of a Trainee / Learner Feedback VR Form participant 414

Appendix 8   Example of an Event Feedback Form participant 75

Appendix 9   Case Study National Grid – London Power Tunnels 2 project

Appendix 10   Case Study SCS inspired to create their own Immersive Learning resources

End