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Redefining Seafaring Pedagogy
– Impacts of Virtual Reality on
Maritime Education and Training

By
Solent University (SU)

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Theme: The changing reality of MET
***(Research title: Redefining Seafaring Pedagogy – Impacts of Virtual Reality
on Maritime Education and Training)***

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Abstract This report presents the outcome of a study investigating the transformative potential of blending virtual reality into theoretical curriculum, the setting is in commercial maritime education and training. Its potential to support meaningful learning is discussed. From here, a shift to the need to rethink and restructure the learning experience occurs and its transformative potential is analyzed. Finally, the impact on student learning and assessment is highlighted. The conclusion finds that memory retention can be significantly increased through the blending of VR lessons and experiences. VR makes it easy to reconstruct past incidents to create learning experiences for the future. It also enables creation of realistic scenarios to address safety issues. Virtual reality enables the laying of solid foundations for safety and situational awareness on vessels. Quantitative and qualitative analysis confirmed that memorisation of process and theory could be enhanced and also revealed a number of pedagogical, technological and logistical factors that supported learning. The project developed a prototype smartphone downloadable application used with low cost smartphone based VR to carry out the field testing. The report concludes with discussion of present and future implications of blending reality for learning and teaching and that a significant impact might be realised not just locally, but researchers believe that it could have a significant effect internationally if the adoption of blended VR was more widely adopted in theoretically based maritime education and training. The traditional teacher centric approach was witnessed to change when using virtual learning environments for education, from that which tended to exist in the traditional commercial maritime classroom environment. During field testing the change in student requirements saw the expert and perhaps the sole or major information source, move to facilitator, coach, or mentor – in other words, to one who, first and foremost, provides leadership and wisdom in guiding student learning.

Keyword: *virtual reality; maritime education and training; higher education; blended learning; pedagogy; learner engagement; higher-order learning; self-regulated learning*

1. Introduction

The maritime education and training framework in which commercial maritime training institutions operate, is based on the use of generic competencies stipulated through regulation. There are however downsides to creating standards on this basis, not least of which is the potential to place requirements with in the workforce in a constant position behind the curve. Therefore to circumvent negative effects in such a system, both the regulator and the subsequent training provider must attempt to act with agility in identifying and adapting to changing needs. The focus of this study is on the agility requirements of the training provider.

In completion of a period of study designed to obtain a commercial maritime certification of competency, maritime training providers across the globe differ in the order in which curriculum is delivered. However, despite these differences two main requirements will remain consistent. Firstly, the seafaring trainee will always experience a period of shore based theoretical learning; secondly, this will be combined with sea based experiential learning. The latter means of learning has always been fundamental to seafarer education and will remain so. However as time and technology have moved on, shore based institutions have embraced the use of simulation, providing the opportunity for some of the experiential elements of training to be carried out remotely on shore instead of aboard ship. This move is evidenced by the wide scale adoption of ship simulation, however, the downside is that bridge and engine room simulation is costly and suitable only for certain types of knowledge acquisition. The benefit however is that experiential learning can take place in a safe, secure and risk free environment, and this can be combined with a more learner centric approach. It is well understood that the traditional method of teacher centric lecturing delivery to large groups of students on mass, whilst cost effective for in situ education can produce low student engagement. Furthermore, on mass delivery can produce low knowledge uptake, poor knowledge retention, and can facilitate negative learning experiences.

In contrast, the more theoretical areas of the curriculum not seen as suitable or too costly to apply simulation to, by and large have remained with the dictatic or teacher centric model of teaching, over the more student centric nature of learning adopted in the use of simulation. As a result, anecdotal evidence suggests that there is growing disconnection between the skills required at sea, and the more theoretical knowledge being taught onshore by shore based training institutions. This investigation therefore sought to determine a means by which more experiential approaches could be blended to the existing curriculum, and done in a cost effective way so as to blend the experiences onboard, to the classroom theory.

This report outlines the steps taken in this project and is referred to as Project WAVE (Working in Augmented and Virtual Environments). The investigation adopts a critical realist approach and sought to address a number of gaps in the knowledge identified during the literature review. These include how the maritime education and training provider might provide for greater opportunity for students to construct their own learning in a more learner centric environment, so as to maximize whole class engagement as well as encourage collaborative learning opportunities. This was achieved through the introduction of blended teaching and learning activities (TLA's) based in synthetic virtual learning spaces with existing curriculum.

In addition to the development of maritime education and training, this project was also guided by number of principles namely, cost effectiveness and access for all. This was achieved by creating a downloadable prototype smartphone application (App) for use with low cost virtual reality (VR) headsets. The application consists of a number of maritime related blended VR learning experiences, developed to feel realistic, and provide high fidelity learning scenarios.

Virtual worlds are suitable for knowledge based, abilities based and skill-based learning outcomes. Merchant et al, [1] found that virtual learning environments facilitated learning to the same extent across all three learning outcomes. This study however, concentrated on the acquisition of declarative knowledge, as skill based knowledge requires lengthier time spent inside the virtual environment because of the practice required. Also, the need to use low cost VR devices provides for a problem in itself in terms of the negative physical effects which come as a result of the use of low cost VR devices. Therefore participation was restricted in these synthetic scenarios to short sessions. This is evidenced

in the literature, when instructional design is considered, “...time as an essential feature of the learning environment when designing instruction that requires skill acquisition [2]. The literature also establishes that:

“Studies differed on the learning outcomes measures for (VR) simulation, where studies assessing students' knowledge level were found to be more effective than the studies assessing skill level. This is likely because it may be easier for students to recall factual information than to develop the skills that they were expected to acquire from simulation because skill acquisition is a gradual process and may require repeated practice.”[3]

The research sample consisted of students in training for commercial seafaring qualifications who spend time both at sea and ashore during their training. As outlined previously, the experiential element of learning at sea is easily facilitated when at sea, however shore based training can be seen as disconnected. Therefore to reconnect the ship and the shore the relationship between the learners interacting with virtual reality and Kolb's concept of the experiential learning cycle [4], was used to help to create this link. Experiential learning is defined, “...whereby learning is initiated in the works of an interaction between the learner and his or her environment [5]. A gap in the knowledge exists in the instructional effectiveness of virtual reality-based instruction in the context of retention and transfer of learning from virtual to the real environment [6]. This research adds to the body of knowledge in addressing this gap.

A further gap in the knowledge resides in the effectiveness of collaborative learning environments and their effectiveness in this setting.

“We found that students performed better when they worked individually rather than collaboratively when learning through games. This is contrary to the results found by Vogel et al., who found that there was statistically non-significant difference between the studies that used collaborative versus non-collaborative design for the learning environment.” [7]

WAVE's primary output determined the optimal conditions for enhancing student engagement through the use of synthetic teaching and learning activities and informs future pedagogy, determining the impact, ways and extent to which shipping's global pool of seafarers training needs might be influenced.

2. Background and Structure

2.1 Background

Virtual reality surges towards mainstream in everything from theme parks to car show rooms. Adopters are diverse, embracing the technology for multiple utilities from engineering to pornography. No longer is it just for those so-called gaming ‘techies’ with the resources and impetus to dig deep in to their pockets to purchase the latest high end product offering such as the HTC VIVE or Sony HoloLens, from which to enhance the gaming experience. China is leading the charge as the largest adopter of this technology to date, plans are afoot for over 10,000 “experience centres” for VR. Deals are being made with Karaoke bars. E-Commerce companies are even planning to sell physical goods using VR Tech.

Therefore, for those working in maritime education, it is time to get ahead of the curve in getting students inside synthetic environments and to take advantage of promises like active over passive experiences. Through this medium we can create immersive experiences that remove distractions, suitable for all for all learning styles. Captivating, dynamic, memorable and motivating. However, learning inside synthetic environments must first prove its worth and be fully understood by maritime educators before it can offer the great advantages hoped for. We also need to be trained in its use, and not because it’s all about the teacher, but because we need to understand how to get the most from it, and how it relates to the delivery of subject matter and learning.

The likely way in which the adoption of virtual reality into maritime education will happen is through the use of blending learning, i.e. using several approaches combined together in a single lesson. We know that all students learn in different ways and that a hybrid approach helps to meet the needs of different learners, irrespective of learning style. The easy option however, will simply be to rely on engaging students through the novelty or wow factor, and we know too well that the ‘wow’ soon turns into ‘oh’, or even ‘no’ (thanks). The danger is that the adoption of VR into our maritime classrooms if implemented incorrectly will become another so-called death by PowerPoint experience longer term. Therefore, its adoption must be carefully considered.

As the face of maritime education changes and the needs of the learners change, institutions also need to become more agile in seeking ways to educate their students. The adoption of mediums such as VR into our teaching is also a way of flipping the classroom in the direction of the learner. There are other advantages that might facilitate the growth of distance learning and shore to ship learning, which is so desperately needed in maritime education.

Therefore to facilitate this, the Warsash School of Maritime Science and Engineering at Solent University, conducted this research named WAVE - Working in Augmented and Virtual Environments.

2.2 Objectives

Throughout its duration, the project delivered on four objectives, each hosting several tasks. They are as follows:

1. To produce a thematic report/literature survey in connection with the current knowledge in the use of virtual reality and multi-modal sensory feedback systems for education and training.
2. Adopt a qualitative learner journey analysis methodology, to produce a validation to understand the learner experience.
3. Develop existing cost effective technology to create a VR based training scenario/s for use by a trainer to assess a trainee’s task performance against a set of objectives with combinations of both visual and cognitive tasks; this will include validation by quantitative measures and the running of experimental trials; including development of a mechanism to record and monitor student achievements against training objectives during training events; and also including development of a mechanism to record/deliver learner feedback.
4. To contribute findings from the analysis to derive a set of recommendations / toolkit of good practice for the use of synthetic teaching and learning activities through the use of empirical

data that industry, maritime regulators, training providers and other stakeholders can use to inform seafarer pedagogical practice.

2.3 Structure of the report

This reported is divided in ten sections. Each section gives information about a specific topic.

- **Sections one and two** introduce the subject of educational maritime training and, the challenges of maintaining validity within the curriculum and, concludes with the project's pedagogical underpinning.
- **Section three** provides the results of a literature review into the world of virtual reality technology in the form of a thematic report in connection with the current knowledge relating to the use of virtual reality and multi-modal sensory feedback systems for education and training in comparable industries. Beginning with the general landscape in the use of synthetic spaces, then focusing on the use of Virtual Reality (VR) pertinent to education. Results include a review carried out on commercially available VR technology, both for use in desktop and mobile applications
- **Section four** provides an overview of the structure and essential components contained within the smartphone application
- **Sections five** presents the results lesson design and virtual experiences examining cross disciplinary engagement in the use of synthetic spaces including best practice criteria.
- **Section six** – approach and methods
- **Section seven** - results, analysis and discussion of results
- **Section eight** – conclusions and recommendations
- **Section nine** - acknowledgements
- **Section ten** - attachments

3. Literature Review

3.1 Virtual Reality

The term ‘Virtual Reality’ has a rather broad definition, and has evolved significantly in recent years. Virtual Reality (VR) essentially it means ‘near reality,’ and is based on technologies which allow the user to have a version of reality which is not actually real but can be perceived as so. This primarily relies on the use of computer-generated graphics, presented to the viewer in such a way as to immerse them in the virtual environment.

By making use of visual stimuli, audio and kinaesthetic/haptic feedback, the virtual environment can be elevated to different levels of VR, improving immersion and allowing interaction with elements of the simulated reality. ‘The more the system captivates the senses and blocks out stimuli from the physical world, the more the system is considered immersive’ [7].

While other research may refer to different levels of VR, considering any 3D environment to be a form of virtual environment, this project specifically considered smartphone based VR, but it will explore some use of modern Head Mounter Display (HMD) technology. It should be noted that modern VR is a rapidly changing market. As such, all figures and hardware discussions are the current standards as of the time of this report.

3.2 Head Mounted Display Technologies

The Head Mounted Display (HMD) or VR headset, provides a stereoscopic presentation of images to the viewer. This is done using a head worn device, in which independent images are presented to each eye on a screen.

‘The goal of the hardware is to create what appears to be a life-size, 3D virtual environment without the boundaries we usually associate with TV or computer screens’[8]. Special hardware is required to generate the virtual environment for the headset [9]. This additional hardware can be in the form of either a computer, games console or even a mobile smart phone.

Virtual reality headsets incorporate head tracking technology to allow for the virtual environment to move and subsequently adapt relative to a user’s head movement when wearing the device [11]. Motion tracking has also started to be incorporated by virtual reality headsets, allowing accurate movement of physical movement of the user.

Several virtual reality headsets are currently available, with the two best-regarded being the HTC Vive and the Oculus Rift [12]. Both headsets require either a computer or a games console to drive the graphics and audio [13]. They can be roughly grouped into two categories:

- 1- PC based systems; containing a good quality HMD, higher PC processing power and allowing for complex interaction using motion controllers.
- 2- Mobile smart phone based systems; with a lower quality display and less processing power, but are portable, widely accessible, cheap and easy to use. This includes both low-end and high-end mobile VR.

3.3 Educational Benefits of VR

Virtual Reality has a wide range of applications in education; content ranging from the training of highly specific interactions in higher education and industry, to the lower-level teaching of groups using more visual experiences. Because of the potential benefits incorporating the use of virtual reality could have within an educational setting, the development of educational frameworks is necessary [14]

One framework that has been created is in regards to examining the ‘relationship between Virtual Reality Environments (VLE) and conceptual learning’ [15]. The framework can be observed to consist of three elements; ‘representational fidelity, immediacy of control and presence’ [16]. However at the time the

model was developed, the authors suggest that there was a shortage of published information concerning certain aspects related to virtual environments and their use as a learning tool [17].

A further model that has been suggested for learning in three-dimensional environments has been proposed by Barney Dalgarno and Mark J.W. Lee in 2009. Their published model highlights an overall ‘model of learning in 3-D VLEs’ [18]. Dalgarno and Lee state that ‘This model presents an overall or big picture snapshot of what authors are claiming/ asserting and implying about 3-D VLEs, their characteristics and potential learning benefits, much of which calls for further investigation’ [19].

Previous work, such as the framework developed by Whitelock *et al* have been recognised and incorporated into the model [20]. However, Dalgarno and Lee’s [21] model further examines previously suggested concepts such as representational fidelity. As such, several factors have been determined to exist under the term representational fidelity. For example, these have included the consideration of factors such as force feedback and audio [22].

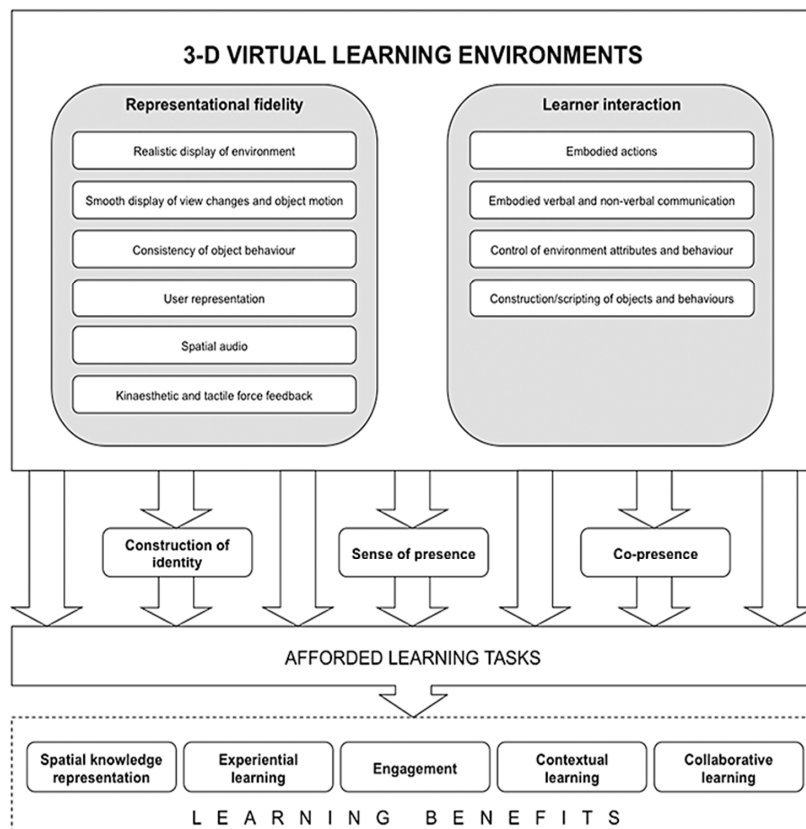


Figure 1: Dalgarno and Lee’s proposed model of learning within three-dimensional learning environments (Source: Dalgarno and Lee).

As recommended by Dalgarno *et al*, there are five areas in which VR excels as a learning medium. These areas can be translated to their educational benefits, and potential applications in the classroom discussed.

- **Spatial knowledge representation.** Learning the physical dimension, size and layout of an environment or scene.

- **Experiential learning.** Content that requires a physical presence and active involvement to gain the required knowledge.
- **Engagement.** Improving the involvement of students in a lesson and their attention.
- **Contextual Learning.** Learning about a task or system in with appropriate context, such as the environmental conditions it is performed in.
- **Collaborative Learning.** Working together as a group to learn and engage in a lesson.

3.4 Current Training Applications

The processing power of a good PC combined with the external devices allows for utilising the performance of a computer to render detailed environments. Lessons delivered using this technology can be highly immersive, interactive and specialised. These systems excel at the training of specific tasks and interactions. The virtual environment can allow students to repeat a task until they accomplish a comfortable level of proficiency, with low cost and without the risk of injury. Because of this, they are ideal for use in the maritime industry where mistakes have the potential to cause severe repercussions.

For similar reasons, it has become a very attractive option as a learning tool for the medical industry. Virtual reality based training can be carried out within a safe virtual environment and as such no real-life patients are potentially endangered. Furthermore, it has been added that the use of this virtual technology allows surgeons to repeatedly carry out virtual procedures whilst constantly improving their skills before subsequently advancing to operating on real life patients [23]. Additionally, it has been regarded that virtual simulators allow for a wide range of procedures to be carried out, some of which may not be possible in the real world due to not having the access to patients suffering with that condition [24]. The overall experience that virtual reality is acknowledged to generate is implied to surpass other non-technical alternatives. An example of this is real life cadavers which have been traditionally used as a teaching tool have been noted to not release blood upon incision. Economic advantages to using virtual reality based simulation technology have been recognised. This includes the fact that through the use of this virtual reality technology, it eliminates the reoccurring need for access to physical equipment such as cadavers [25]. This is due to the circumstance that unlike virtual reality simulators that can be reused multiple times, cadavers have a limited use before they need to be replaced.

The rail industry can be observed to be a further industry that have incorporated the use of virtual reality as a training aid. Arriva Trains Wales for example have launched a virtual cave environment replicating a station platform in order to train their station staff with the ultimate aim of improving passenger safety on a station platform [26]. The virtual cave environment exhibits several scenarios allowing for station staff responses to these scenarios to be practiced [27].

3.5 The use of VR in maritime training

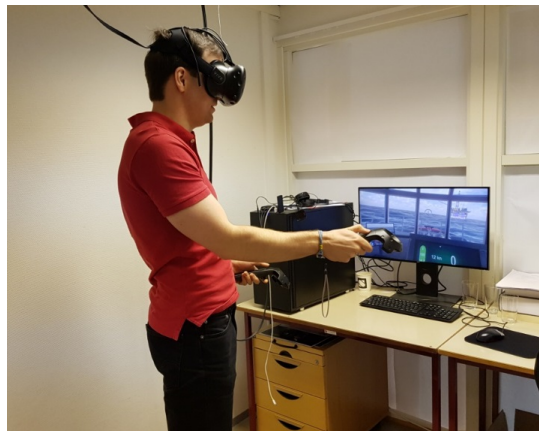
At the time of writing (2018), virtual reality is still scarcely used in any maritime education and training, despite large potential. However, several studies are being carried out in addition to this project from which to introduce virtual reality in training of seafarers, ideas are being realized and activities being started.

The “Innovating maritime training simulators using Virtual and Augmented Reality (InnoTraining)” project is a research project with following partners:

- Kongsberg Digital.
- HSN University College of Southeast Norway.
- Institute for Energy Technology, Norway.
- Politecnico di Milano.

InnoTraining is an on-going research project and the outcome of the project will shed more light on the feasibility and applications of VR and AR technology in maritime training and operations. When it was

conceptualised it mainly focused on different aspects of training for the seafarer like the bridge crew and engine room operators. The main idea was to create relatively inexpensive, portable, train anywhere anytime solutions for the maritime industry using latest VR technology. Since pilotage is also a critical phase of navigation, it can make use of the VR technology in pilotage training. The portability of the VR technology enables training simulators to be packaged in a suitcase and at the same time could provide fidelity close to a full scope simulator. This means each ship/tug boat can have its own simulator and the crew can train (refresher/special scenarios) at their convenience which could result in better training that ultimately leads to safer and efficient operation. A conceptual VR based tug simulator would look like as shown in figure 2, rather than a traditional simulator as shown in figure 3.



Source: TARG

Fig 2: InnoTraining - University College of Southeast Norway". Person with the VR headset and controllers in his hands. Controllers are used for interacting with the VR environment, for example, instruments in the VR ship simulator will be manipulated using these controllers. The person also sees more than what is on the computer screen, which is the novelty of VR. The VR goggle has 110 degree field of view. So the user actually is immersed in the virtual environment (in this case ship bridge)

Fig 3: A conventional Tug simulator



Source: Damen

Despite these advances, VR cannot yet replicate the fidelity, touch and feel of the bridge simulator, even if a Cave Automatic Virtual Environment (CAVE) is used. However, VR still does enlarge the possibilities of maritime training greatly. Further study is needed in how to implement VR training in the various training courses of pilots and tug masters, whether for classical training, on the job, or in

combination with a ships bridge simulator. For the training of pilots and tug masters, the possibility of interaction with real bridge equipment is an important and essential aspect. Using real equipment, in particular the manoeuvring controls for example, increases fidelity exponentially. It is likely that a combined vision of the real bridge equipment with a synthetic 3D representation of the outside environment will achieve this using see-through HMDs (Mixed Reality HMDs). Figure 4 shows an example of Mixed Reality in for nautical training.



Figure 4: Mixed reality. View through a VR headset. The real consoles with hands are combined with a virtual ship bridge with ECDIS, radar, windows and outside view.

VR and MR are techniques that can well be used in maritime training. The systems using these techniques are flexible, transportable, cheaper than present ship bridge simulators and have the potential to bring training at a higher level and so potentially increase safety in ship handling.

As can be seen, there are already several promising activities to introduce VR and MR into maritime training of pilots and tug masters. It can therefore be expected that in the coming years maritime training may well undergo a large change due to these new developments.

3.6 Access to Educational Content

With the wide-spread public adoption of VR - particularly for smartphone devices – there has developed a large store of public content. This is easily accessible educational VR content usually ranges from free to £40, available on; the Apple ‘App Store’; ‘Google Play Store’ for Androids; and Valves ‘Steam’. containing thousands of custom apps. In 2016 there were approximately 226 million downloads of VR content for mobile devices alone. [28].

One of the caveats of this widely accessible content is the lack of quality assurance. This brings up a few concerns to be tested when selecting new content for an educational purpose:

- Is the content valid and correct?
- Is the content a good enough of quality VR experience?
- For what level of system has the application been optimised for?

3.7 Teacher's role within a virtual environment

Literature published examining the role of the teacher teaching within a general virtual environment has emphasised that the role of a teacher will change in a virtual learning environment, from that in a traditional classroom environment [29]. This has been recognised to be the case within a multi-user virtual environment [30]. This change has been suggested to be 'From expert and perhaps the sole or major information source, to facilitator, coach, or mentor – in other words, to one who, first and foremost, provides leadership and wisdom in guiding student learning' [30]. This research was guided by this evidence and informed the approach that was taken in the development of the student lesson blended virtual learning experiences. Therefore on this basis the following research question was composed in order to further estimate and validate this evidence and the potential change to the educators role in the learning.

Research question one:

What do learners prefer when engaged in VR learning experiences. Do they prefer:

1. Self-guided Exploratory Experience

The students are given guidance on their objectives, and left to explore and seek the required information themselves. The students have complete control over their location on the bridge, the information they see and the order in which they consume the information.

2. Teacher Guided Experience

The students have a degree of freedom in their interaction within the scenes, however the teacher channels their focus through the use of guided visual indicators.

3. Teacher Controlled Experience

The teacher has absolute control over the experience, changing the location of the users and highlighting and displaying text and images as they see fit.

3.8 Options of VR Systems and application design - Hardware - PC Based

There are two main headsets available for PC in the VR market; the Oculus Rift, and the HTC Vive [31]. Both these devices have accompanying motion controllers, head tracking (allowing the user to move their head through 3D space), and the option of both standing and seated movement. The two devices differ in their tracking method. HTC Vive is designed for 'room-scale VR', using a laser technology to track the wearer around a large space. The Oculus was primary designed for a more seated experience, using IR cameras to track the headset, however it can also fully support room-scale VR using multiple tracking sensors.

Aside from this regard, they can be considered to function essentially the same, both providing high quality visuals, motion controller tracking, allowing the interfacing of other PC technologies and run very similar software (with the exception of 'exclusive' gaming content). Recommended pre-built PC's running from between £800 for basic VR up to £2500 for the most demanding applications [32] (Oculus 2017), a benchmark setup costing roughly £1200.

Whilst the Vive and the Rift can be seen to undoubtedly offer a superior virtual reality experience, both headsets do not offer true mobility as they both must be located within close range for connection to a

computer [33]. In an educational context, this means specialist PC VR facilities are required to run a VR class. This takes up a large amount of space, particularly for room-scale VR, limiting the number of simultaneous users and takes considerably more time to set-up and maintain.

An alternative option is Console VR. The only currently available system was developed by Sony, the PlayStation VR for the PS4 Pro games console. This has potential to be a promising market due to the lower cost of the setup, £350 for a console and £400 for a headset and motion controllers. This could be ideal for educational institutions which would like specialist facilities with numerous systems, but at a lower price point. Currently however, console VR makes up the smallest portion of the VR market [34], and is considered more arduous to develop content for than PC and smartphone

VR device	HTC Vive	Oculus Rift	PlayStation VR
Cost	£500	£400	£300
Hardware	High-end PC £1200	High-end PC £1000	PS4 Pro + PS Move £400
Sum	£1700	£1600	£700
Pros	+Good at room scale VR +Highly immersive +Good for extended use +Interactive motion controls +A lot of software, easy to make	+Good at room scale VR +Highly immersive +Good for extended use +Interactive motion controls +A lot of software, easy to make	+Medium cost +Highly immersive +Good for extended use +Interactive motion controls
Cons	-Expensive -Not-portable -Takes up a lot of space -Timely to setup	-Expensive -Not-portable -Takes up a lot of space -Timely to setup	-Less software -Harder to develop -Small audience -Not-portable

Table 1: Summary of PC / Console based VR headsets

3.9 Hardware – *smartphone based*

There are several virtual reality headsets which are based on smartphones and personal media devices. These include but are not limited to the Samsung Gear VR, the Google Daydream View and the Google Cardboard [35]. Instead of being connected to a computer, video is streamed through a smartphone, giving independent images for each eye. This is then inserted into the headset, which uses independent lenses to produce the stereoscopic image [36].

These smartphone headsets have a significantly lower retail price than other virtual headsets, ranging from between £15 and £100 in 2018, in comparison to £400-£600 for a PC HMD system. However, in comparison to their computer-generated competitors, smartphone based virtual reality headsets are acknowledged to not be as powerful [37], leading to more ‘lag’ in presentation of images, and often lack a controller device for interaction [38]. They also lack the sophisticated head and motion tracking of the full HMD solutions such as Vive and Oculus Rift.

However, the portability and low cost makes mobile VR very quick to implement into a teaching environment. With a lesson plan in mind, multiple VR devices can be set up and running content within minutes, all in the same classroom whilst requiring no specialist facilities. Smartphones are a very widely accessible device, with it being extremely common for people (particularly students) to own a modern smart phone, with a growing trend of ‘Bring-Your-Own-Device’ (BYOD) policies in organisations. Another crucial factor in the ever contracting financial bottom line, is that students purchase devices themselves.

The potential for at-home learning is also very promising; It is predicted that by 2022 there will be over 36 million consumers owning smartphone VR devices [39], while educational institutions may easily be able to provide low-end mobile VR headsets to pupils to support this. When compared to the growth of PC and Console VR in the same time period (Figure 5), it can be seen that the use of educational VR in a home setting for those devices is significantly less plausible due to accessibility issues.

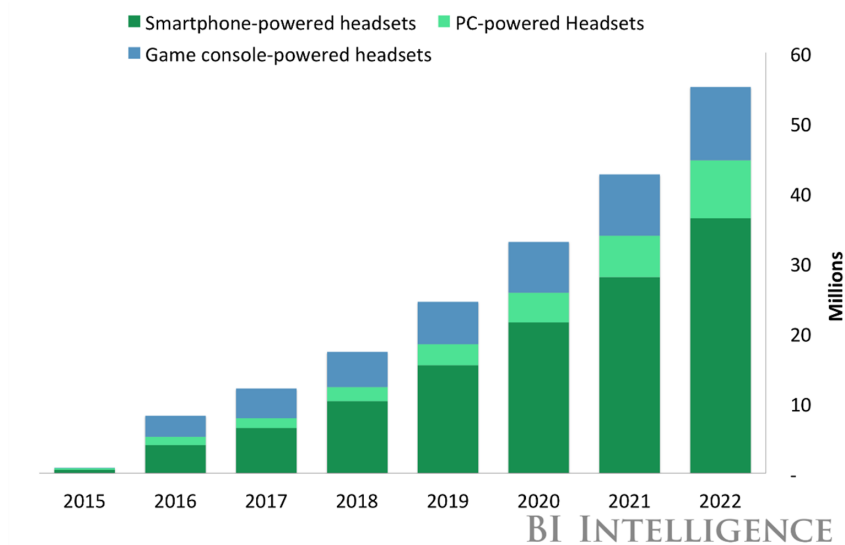


Figure 5: Forecast of Global VR Headset Shipments [40]

Headset	Google Cardboard	Plastic Headsets	Google Daydream	Gear VR	Standalone Headset
Price	£5 – £15	£5 - £70	£69	£79.99	£500 +
Hardware	Any phone	Any phone	High-end Android	New Samsung phones	<i>Built in hardware</i>
Pros	+universal access +portable +cheap	+universal access +durable +range of types	+comfortable +better tracking +more control	+comfortable +better tracking +more control	+high quality +quick to use +portable
Cons	-inconsistent -less comfortable	-inconsistent -less portable	-limited devices	-limited devices	-no mobile interface -more expensive -less compatibility

Table 2: Summary of mobile based VR headsets

3.10 Low-end smartphone

The most basic form of VR comes in the form of Google Cardboard, a headset literally made from cardboard and plastic lenses. Google Cardboard contains a button on the top or side, allowing the wearer basic interaction using their gaze and click interactions, though there are many different viewer types for Google Cardboard, at varying degrees of quality [41]. Some cheaper versions contain lower quality lenses with a lower field of view, and potentially containing no button to interact with the screen. If purchasing one of these headsets, at least a Cardboard V2 can be recommended, or to test the desired headset to determine its quality.

Plastic mobile headsets also exist, offering a sturdier option to Google Cardboard that may be more suitable for repeated usage. However, it is worthy of note that during this study we found that the quality of the viewing lens provided was more important in adding to the overall experience. There are many different manufacturers for these, ranging from cheap off-brand headsets, to high quality devices such as MergeVR's Goggles, anything from around £5 to £100. Plastic headsets are also more hygienic, as some come with detachable washable liners. As skin on the face produces sweat and oils, repeated or extended use of a headset can pick these up, creating an unpleasant experience and potentially a health hazard [42].

Low-end mobile VR is the most accessible form of VR available, running on most modern phones across both Android Devices and Apple iPhone's. This is also currently the only mobile option available for iPhone users, which make up a sizeable chunk of the smartphone market. This does however come at cost, as each model of phone will run a VR application at different quality levels, display sizes and resolutions. This makes the experiences less consistent, harder to optimise and prone to issues.

3.11 High-End Smartphone

For high-end mobile VR, there are currently two main options; the Gear VR and Google Daydream. These devices are higher quality than counterparts, and come with additional benefits to improve the experience. Both headsets come with a basic wireless controller containing multiple buttons and a small track pad. They also contain additional tracking sensors inside the headset, allowing for accurate movement resulting in a more comfortable experience.

Several companies are developing also producing 'standalone' VR headsets, with an integrated display and processing built into the device. Google, HTC and Lenovo are working together on two standalone VR headsets, complete with built in motion tracking [43]. Devices are also available from ClassVR. This option allows for high quality VR without cables or phones, and is a very quick and easy option for a portable simple VR solution. This means that VR apps run directly from the headset, requiring no assembly and no involvement with student's personal devices.

A limitation of high-end mobile VR is that they have specific compatibility requirements [44]. The Gear VR will only accept Samsung Galaxy S6 phones or newer Samsung models, making up a small section of the mobile market. Google Daydream is also restricted, working with only a handful of high-end android devices. This restriction allows applications to be optimised to the specific phones, ensuring they have the processing power and display quality required for a smooth experience. There are currently no high-end HMD's available for iPhone devices (2018).

For longer viewing sessions on mobile, these types of devices are recommended due to their quality experience and improved comfort. While they are not as accessible on as wide a level as with the Google Cardboard, these restricted phones (and integrated solutions) are still relatively cheap in comparison to PC based VR. This makes purchasing dedicated mobile VR devices and headsets a valid option, rather than requiring bring-your-own-device policy for lessons. Alternatively, it is possible to hire devices from an external company as needed.

3.12 External Services

There are several organisations which can support the integration of VR into an educational environment. Google have developed an educational environment titled Google Expeditions [45]. The purpose of the application is to allow schools the opportunity to take virtual school trips in order to explore new environments [46]. It does this using mobile VR headsets, exploring high resolution 360 images with text overlaid in the environment

Rather than purchasing permanent in-house devices, VR devices can be purchased directly from companies such as Aquila, providing all the necessary hardware to run a session [47]. These also allow for the licensing of content through Google Expedition, acquiring a license to use their VR content and lesson plans on a yearly basis.

Alternatively, equipment can be hired on an as-need basis. Services such as Prime VR allow the hiring of full VR kits for periods of time [48], providing the hardware, lesson plans and even teachers to deliver the sessions if desired. These services also offer to train teachers on teaching their specific lesson plans in virtual environments [49]. There are numerous companies that offer these services, however the trend of their educational purpose is for teaching primary school students, using VR primarily as a tool to improve engagement [50].

3.13 Smart Phone Virtual Reality - Barriers to VR in the Classroom

This review of the literature had highlighted that there has been very little published as to how teaching should be carried out within a virtual learning environment, particularly one that is formed around virtual reality technology. Therefore in our approach we sought to consider what the needs of teachers would be to practically implement VR into the classroom, using VR as an additional learning tool through lesson blending.

Being efficient in the classroom setting was considered of high importance also. Without the VR content being quick and easy to access, the technology has a lower likelihood of being adopted by current maritime educators. Mobile VR fits this area well, as it can be used in the same classroom without relocating to specialist VR facilities, and can also be set up very quickly. Specialist VR facilities suffered in this regard, as while they can produce fantastic learning results for specialised training, the process of booking facilities and moving students is a large inconvenient for more general use.

Another key consideration was student access to the technology. Whilst the educational benefits of VR are apparent, if only limited numbers of students can experience it during a lesson it becomes ineffective. Again, mobile VR stood out as an ideal solution, as many students can use the technology at the same time. This is due to both the minimal physical space the technology requires, the low cost and abundance of smart phone technology, meaning that an entire class could view the VR environment at the same time. To demonstrate PC VR to an entire class simultaneously requires a very large amount of space, and an extremely costly amount of equipment. Alternatively, lower numbers of students could use the technology and take turns, though this makes lessons much less efficient. This is impractical for a normal learning environment, and does not fit well into a standard lesson plan.

3.14 Selection of a Mobile Solution

After considering the potential applications and requirements for effective implementation, it was decided to proceed with a smartphone solution. Mobile VR was apparent as a cost effective and accessible technology that filled a gap in the needs of maritime teachers, as well as the gap in research of VR pedagogy.

The target hardware was selected was Google Cardboard, the baseline entry VR device. Developing the application for this platform made it accessible to the highest number of test subjects possible, whilst providing flexibility to adapting for different platforms if desired. Other core benefits of smartphone VR being;

1. It's efficient to set-up in a classroom for multiple students, with minimum disruption to learning. The alternative of moving to a separate VR suite would be very disruptive.
2. It's cheap and accessible. The benefits of VR content can be implemented across many different lessons, and the low entry cost of mobile VR makes it realistically accessible with minimal investment.
3. Two large benefits of VR in Maritime which were apparent included spatial knowledge representation and engagement, which can be provided sufficiently through smartphone based VR.
4. The quick opening and operation of smartphone VR could be well implemented into a lesson plan, utilising it intermittently amongst other teaching methods. Whilst low-level smartphone VR should not be used for extended periods of time, this intended usage would not require extended use.

Pursuing this route of development would also enable users to be able to revisit the environments in their own time. Given that acclimatisation to spaces and spatial recognition were identified as key benefits of VR training, providing students with the ability to revisit sessions at home.

4 Application Design

4.1 Application Goals

With the selection of Google Cardboard as the target device, and the direction of the lesson goals established, principles of the application's design were established;

- Create a mobile application structure that allows VR to be quickly implemented into a lesson.
- Create a VR environment that allows the guiding and delivery of information about different physical spaces of a ship.
- To have a level of interaction that allows users to explore and consume specific information.
- To create a VR based training scenario/s for use by a trainer to assess a trainee's task performance against a set of objectives with combinations of both visual and cognitive tasks;
- To development of a mechanism to record and monitor student achievements against training objectives during training events; and also including development of a mechanism to record/deliver learner feedback.
- To create the app in a modular way, so that content type, project scope and lesson plans can be easily adjusted as the research develops.
- To work on as many devices as possible

4.2 Application Structure

To enable the app to be quickly implemented into the lesson, a standard mobile app was designed as the initial point of entry. This allowed for simple selection of a specific lessons, the distribution of information about the app, as well as the potential for connection to different services (Figure 6). This modular design allows for additional lessons to be added and accessed from a single place, creating a more realistic learning scenario for future testing.

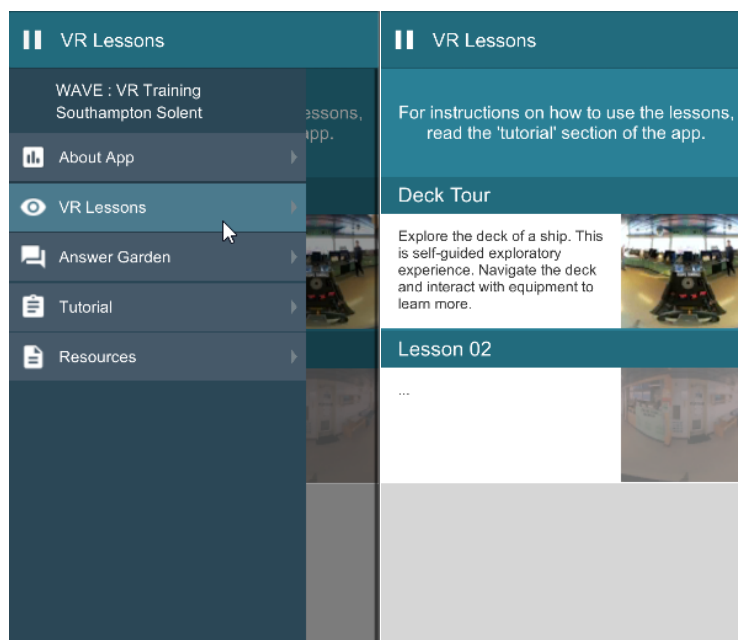


Figure 6: Prototype layout of the main application lesson selection structure

For the virtual reality environment, different options of interaction were considered. Two main options were considered; a student lead experience, or a teacher lead experience. A student lead experience leaves the student to view the content and navigate the virtual environment of their own free will. A teacher lead experience uses multiplayer technology to connect themselves to the student's devices, providing basic control over what their location and the information in the virtual environment. Both options have different benefits, and require a different approach of teaching for the delivery of the content. This formed another one of the research questions.

4.3 VR Content

When developing virtual environments, there are different mediums of the content to be observed. Fully rendered 3D environments allow for interaction with every part of the scene, with vast potential for movement. The caveat of this is that it takes a great deal of resources to develop content for, requiring 3D modelers, texture artists and software engineers to create a scene.

360 images and 360 video are another very popular choice for displaying VR content. This uses a special type of camera which can capture a photo or video with a full '360' view, allowing the viewing of a scene in VR. With the right equipment, this content is very quick to create, and creates an accurate unaltered view of a location.

For the initial medium of development, 360 video was selected. This allowed for accurate and realistic display of a ship, whilst being much quicker to implement than 3D models of the same environment. This allowed more focus to be placed on developing core app functionality, including the user interaction and interface with the scene.

4.4 Cardboard Design Principles

In creating the app, good design principles had to be followed in order to create a quality experience. Poor design principles would make the VR environment difficult to use, or cause nausea and discomfort, creating barriers to effective learning. Following good design principles enables the content being delivered to be as effective as possible, resulting in a good user experience and ensuring that future testing focused on VR pedagogy is judged solely on the content and teaching methods.

Designing content for a VR environment is considerably different than working with traditional 2D material. Google Design Lab is an application which demonstrates these principles, covering how 'Virtual Reality introduces a new set of physiological and ergonomic considerations to inform our design work', then recommending 10 core design principles for creating a quality experience [51].

Whilst quality VR can be achieved outside of these design recommendations, established design practices are generally recommended as a baseline. As more VR applications develop, this also enables users to quickly adjust to new apps, given that interaction will be similar to their previous VR experiences. More detailed guides on these principles can be seen on Google's online 'Cardboard Design Guidelines', placing high importance on avoiding simulator sickness and establishing familiarity. The ten design principles are discussed below (Table 3), as well as how they were planned for implementation into the app.

Design Principle	Description	Current implementation
1. Using a Reticle	A reticle is a visual indicator which shows where the user is currently looking. This is necessary to show the user where they are looking, to aid with depth perception, and importantly as a visual indicator for interaction.	A circular white reticle is used in the WAVE app. This reticle is rendered in 3D space, moving its position to the surface of objects in the scene. When over an interactable object, such as a button or movement tile, the circle expands to indicate it can be clicked.
2. UI Depth and Eye Strain	When positioning 3D elements in a VR environment, they must be placed at appropriate distances from the user. If too close to the virtual camera (within 0.5m), refocusing their gaze to such close objects can cause eye strain and discomfort. The UI must be rendered in the 3D environment onto an object, and cannot be simply overlaid on the screen as in traditional 2D applications. Objects should not be grouped close together, as this can confuse interaction.	All UI elements in the app are placed in 3D space relative to the rough dimensions of the ship. As such, all elements in the app are placed at least 1m from the user, being careful not to be grouped too close together so as to ensure the user interacts with the correct objects.
3. Using Constant Velocity	VR sickness is caused when the visual representation and movement of the scene does not match the physical sensations and intentions of the user. For example if a camera is moving without the user choosing to do so, this will begin to induce simulation sickness. As such, maintaining smooth and clear movement is essential to preventing nausea.	The WAVE application uses fixed locations in the scene, moving between locations by fading in and out the users view. Rotating the camera is performed by a smooth rotation controlled by the user. This restricted movement method creates a smooth experience for minimal VR sickness.
4. Keeping the User Grounded	Immersion is a core component of VR. Keeping consistency in the environment and minimising distractions helps to maintain immersion in the scene. This is done through consistent visuals, smooth transitions and interactions and minimising external distractions (such as frame rate drops or app errors) as much as possible.	As the application moves between static scenes, and uses fading transitions between the scenes, a constant experience is maintained. Interface interactions are also smooth and clear, making sure to avoid fast popups and distracting elements.
5. Maintaining Head Tracking	Mismatching app visuals with the user's physical sensations can cause nausea. If constant head tracking is not maintained, mismatching begins to occur. e.g. A user may have rotated their head, but if head tracking is not maintained the environment will remain static.	Head tracking is handled by the game engine. Frame rate drops which affect tracking are dependent on device specific performance. To minimise lag, the app is developed efficiently so as to run smoothly on the majority of devices.
6. Guiding with Light	When working in a fully 3D environment, highlighting areas of interest through the use of light is an effective and subtle way to direct attention. If clear, users will naturally guide their attention towards bright areas and away from dark areas, creating an affective model of direction.	As the project is utilising 360 videos, the potential to use light to guide the user's attention is limited. This could be explored during any future stages of development when working in a 3D environment.

7. Leveraging Scale	One of the core benefits of VR is the ability to display scale using stereoscopic 3D. Rather than seeing a flat image, it gives the users an accurate view of how large an object is, the dimensions of a room, and places context on everything within the physical space. It is recommended to utilise scale to improve engagement and immersion. Care should be used to ensure a realistic scale, placing models and UI elements at appropriate distances and sizes in the environment.	High-end 360 video systems can capture fully 3D footage of an environment. Most footage however does not utilise this, and as such do not provide stereoscopic scale cues. WAVE has attempted to implement a sense of scale by positioning UI elements at a realistic distance from the camera relative to the objects position, providing stereoscopic distance cues to help better gage scale.
8. Spatial Audio	Spatial audio uses a type of audio processing called 'binaural audio', which simulates the way the human ear perceives sound. This allows users to accurately locate a sound within a virtual environment. This is important for two reasons. Firstly, it allows for a more realistic soundscape to be developed for objects within a virtual environment, improving immersion. Secondly, it can be used as an indicator of direction to support guiding interaction.	Spatial audio will be revisited at future stages of testing. The implementation of this may affect the lesson structure, as the constraints and benefits of wearing headphones while working in a group or with a teacher must be reviewed.
9. Gaze Cues	Gaze cues are visual indications of interaction. Without these, the user will not know what content they can interact with, or receive confirmation that they have selected an object. This can be in the form of visual timers for gaze based selection, changing the colour or highlighting objects that are being viewed, or a variety of other methods to confirm selection. It is important to place UI controls directly infront initially to guide the experience, otherwise users will often wait, feel confused, and have to look around for the controls. Click interaction should also be provided in addition to gaze based interaction, as restricting to only gaze based interaction can feel sluggish and awkward.	The WAVE app uses a progress bar method to indicate interactivity and the selection of objects. When gazing at an interactable object, the reticle will expand, the object will change colour, and slowly fill up with a progress bar. Once the progress bar fills the object, the UI element will be clicked. The user can also click any interactable object to immediately select it.
10. Make it Beautiful	Good visual design, while subjective, helps improve the overall experience of the experience. Poor design can distract users from the content and make them confused, particularly if an application is visually cluttered.	The visuals of WAVE have been kept simple to minimise visual clutter. Using both colour and shape to clearly indicate different types of interaction. The visual design of UI elements in the app are developed on an iterative basis, and will be improved based on feedback and user testing.

Table 3: Cardboard Design Principles and their Current Implementation [52]

4.5 Guiding Elements

To allow the display of information and a number of guiding elements were developed. These were designed in a modular way, allowing for the adding of additional and different content types for experimentation later in the project, such as 3D models and multiplayer connected sessions.

Being able to display text was the first type of display developed. This included both simple titles, as well as longer sections of text. By interacting with highlightable text boxes, this expanded information could be displayed. Annotations were also supported, done in the form of lines which can move through 3D space. This allowed specific parts of an image to be highlighted (Figure 7)

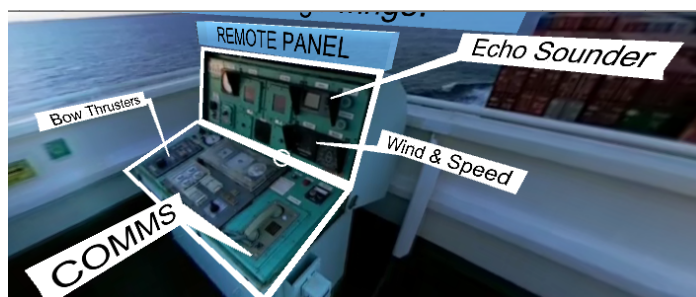


Figure 7: Virtual text boxes and annotations

Movement through the virtual environment was performed by utilising markers placed on the floor of the virtual scene. By either gazing at or clicking the marker, the users view fades out and moves to the selected location.

Additional elements were also developed to aid as guiding points in a lesson plan. This included a number of indicators, allowing a teacher or quiz to refer to locations or objects in a scene indirectly. Further the use of storytelling and mind mapping was adopted. The video was also implemented into the scene as an additional potential tool, allowing the display of more interactions which could not be displayed sufficiently using 360 video.

4.6 App Development Plan

The following diagram shows a rough outline of the current achieved and desired project goals in terms of application development.

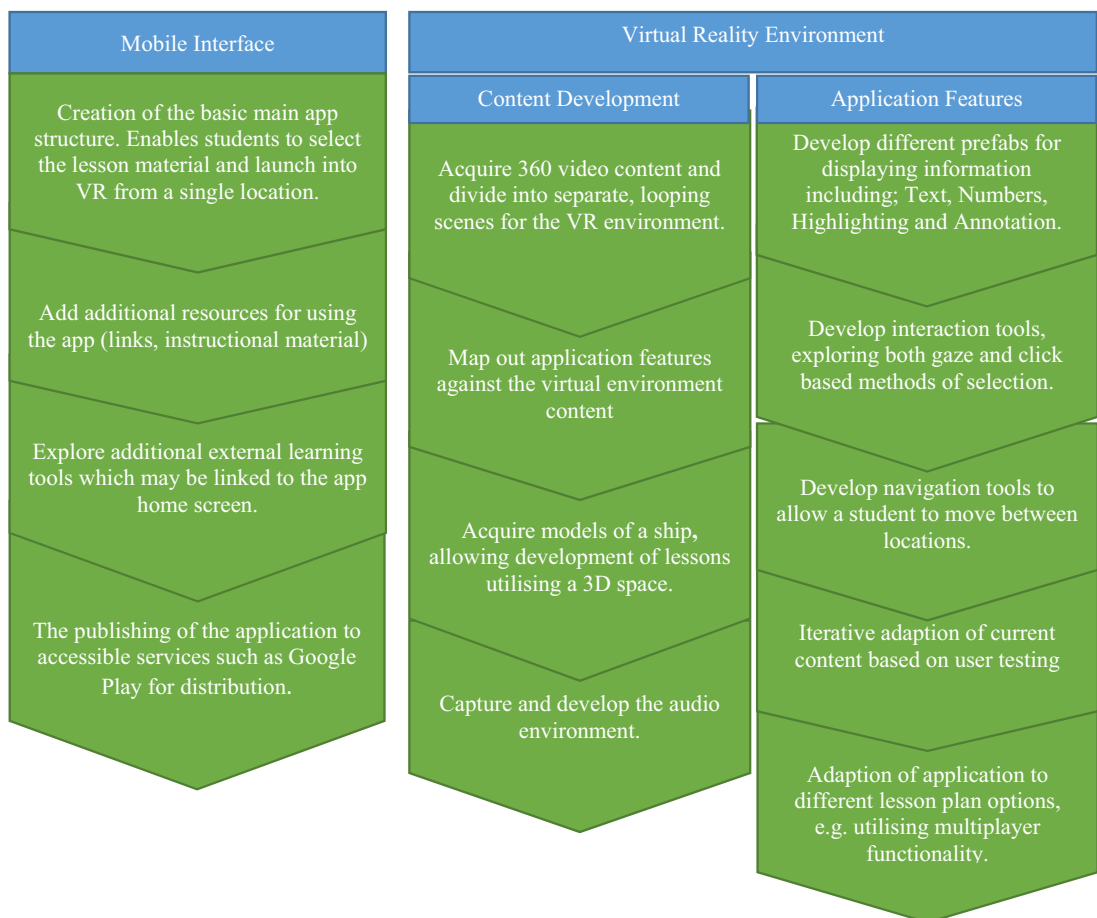


Figure 8: Current stages of achieved and desired application goal

5. Lesson design – virtual experiences

Students can be assessed largely under three broad categories, 1) Memorization, 2) application, and 3) synthesis [52]. Lesson design was therefore developed to encompass these three broad categories and is outlined below.

5.1 Lesson development: entry into an enclosed space - memorization

The guiding principles underpinning this lesson were as follows:

- To create a VR based training scenario/s for use by a trainer to assess a trainee's task performance against a set of objectives with combinations of both visual and cognitive tasks;
- Create a mobile application structure that allows VR to be quickly implemented into a lesson.
- To development of a mechanism to record and monitor student achievements against training objectives during training events; and also including development of a mechanism to record/deliver learner feedback.

Casualty estimates are in the dozens each year where both inexperienced and experienced seafarers are dying in enclosed spaces. Therefore it is imperative that those on ships and offshore units learn at an early stage of the dangers of entering into enclosed spaces. Students must understand how unsafe it can be to go ill-prepared into an enclosed space to assist a colleague as well as what to do when things go wrong. No enclosed space should be entered without proper precautions and training. Therefore, the emphasize of the blended VR lesson was to highlight the dangers, and to reinforce correct process as well as instill the culture of safety first, which subsequently generated our second research question.

- Can memorization of process theory in maritime education be improved through the use of blended virtual educational experiences?

Formative VR Test Number 1 – The kit (Equipment required prior to entry)

Educator: Takes the students through the equipment shown in the virtual room. This is done using numbers to highlight which piece of equipment is being referred to.

Students: In groups of two, they review the equipment laid out in the virtual room. They are asked to identify the missing equipment from the list shown in the previous theory session. One student's device is used to take turns in reviewing what's missing from the virtual room. The second student device is used to answer the mentimeter question posed on the projector screen. (Mentimeter is a cloud-based solution that allows teacher engagement and interaction with the target audience in real-time via a smartphone).

Formative VR Test Number 2 – First person entry and what to do in an emergency?

Educator: Students taught the six basic steps which must be carried out before entry into an enclosed space can take place. They are also taught what to do in an emergency. The students visit the virtual space and select the six options in the correct order to both reinforce as well as test their understanding. If an incorrect option is chosen, the options are reordered so that the learner must try again until the order is confirmed as correct. Once this task is complete, the student is prompted to enter an enclosed space to observe the action of an avatar. The student watches the avatar until an alarm sounds. The student is asked to make a decision as to whether they should leave the space immediately or choose to self-recover. As the student makes their choice, if they select to leave immediately they will witness the avatar being overcome due to oxygen deprivation. At this point, the safe oxygen content level of the space is reinforced inside the virtual environment

The lesson plan can be seen in figure 9 on the next few pages.

Nautical Science



ENTRY INTO ENCLOSED SPACES T: 50mins

LEARNING LEVEL /PRIOR LEARNING

- Suitable for cadet level
- No sea experience required

LESSON OVERVIEW

Casualty estimates are in the dozens each year, therefore it is imperative that those on ships and offshore units learn at an early stage of the dangers of entering into enclosed spaces. The emphasize of the lesson is to highlight the dangers, reinforce correct process and instill the culture of safety first.

Students must understand how unsafe it can be to go ill-prepared into an enclosed space to assist a colleague as well as what to do when things go wrote. No enclosed space should be entered without proper precautions and training.

This lesson is suitable for introductory training at cadet level. Deck, Electrotechnical and Engineer.

LEARNING OBJECTIVES

- Understand the dangers and risks
- Understand personal responsibilities
- Understand the role of the responsible person
- Understand action to be taken in the event to emergency

ASSESSMENT STRATEGY

This lesson consists of two VR experiences.
Students

VR SESSIONS

This lesson consists of two VR experiences.
Students

DANGER
CONTINUED SPACE
PERMIT REQUIRED

RESOURCES AND PREPARATION

- VR Headsets
- Personal device with downloaded app
- Student devices - Download should preferably take place before the lesson begins. If not, Broadband will be required (Check the speed).
- PowerPoint slides
- YouTube Video – Enclosed space entry
- Google Docs assessment link
- Mentimetre questions and student links
- Computer
- Projector

LITERATURE / PREVIOUS READING

The Standard Club - A Master's Guide to
Enclosed Space Entry

ENTRY INTO ENCLOSED SPACES

Scope and Sequence

1. Ensure students have downloaded both the VR app and Mentimeter app – Use the instructions given in the PP Slides.
2. Search youtube channel for Entry into Enclosed Spaces. An appropriate video introduction should last around 10 minutes.

Q1. Mentimeter – What is an enclosed space in a ship?

Q2. What is meant by an enclosed space?

3. Introduce the subject using the PowerPoint slides provided:



Formative VR Test Number 1 – The kit – (5 minutes)

Educator: Take the students through the equipment shown in the virtual room. You can use the numbers to highlight which piece of equipment you are referring to.

Students: In groups of two, review the equipment laid out in the virtual room. Ask them to identify the missing equipment from the list shown in the previous slides. One student's device is used to take turns in reviewing what's missing from the virtual room. The second student device is used to answer the mentimeter questions.

4. Continue with the lesson using the PowerPoint slides provided.



Formative VR Test Number 2 – First person entry and what to do in an emergency?

Educator: Explain the following to the students. We have just discussed the six basic steps which must be carried out before entry into an enclosed space can take place. Visit the virtual space and select the six options in the correct order. Once you have completed this task. Enter the space, and watch the person working in

the enclosed space. Remember, you are looking after their safety, so make the right choice when asked.

5. Continue with the lesson using the PowerPoint slides provided:



Formative VR Test Number 3 – Attendant responsibility - what to do in an emergency?

Final reflection

Reinforce the dangers of enclosed space entry. Reinforce the process required prior to entry into an enclosed space, the actions to be taken when something goes wrong.

Summative assessment

The assessment is prepared using Google docs. If time permits, wait until the next lesson to carry out a final test.

Assessment link:

<https://goo.gl/forms/6vpZ2eCZQ2Swi58B2>

Deeper Learning

Refer students to any of the P and I Club Publications. We used:

- The Standard Club - A Master's Guide to Enclosed Space Entry

Fig 9 – Entry into enclosed space lesson plan

Formative VR Test Number 3 – Attendant responsibility - what to do in an emergency?

The student is prompted to return to the outside of the space and is given a series of choices which they must choose one of which immediately. If the student chooses an option to perform a self-rescue, the danger is highlighted immediately.

5.2 Lesson development: ship familiarisation – synthesis

The guiding principles underpinning this lesson were as follows:

- Adopt a qualitative learner journey analysis methodology, to produce a validation to understand the learner experience.

With the kind permission of the United Kingdom's National Oceanographic Centre's research vessel the RRS James Cook, the research team created a 360 video footprint of the vessel, some examples of which may be seen below.

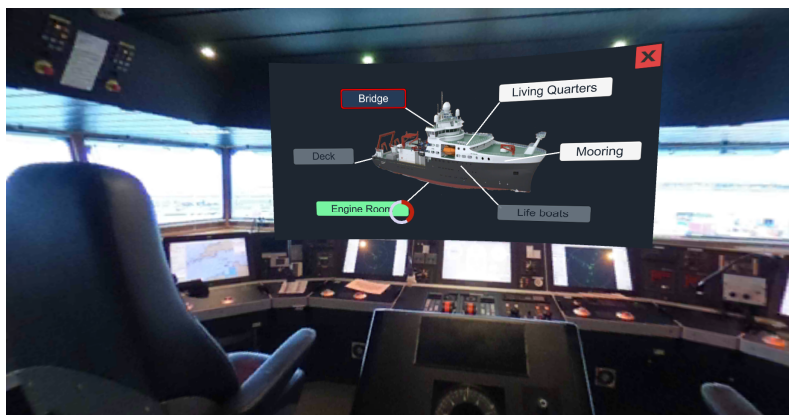


Fig 10 - Bridge Tour

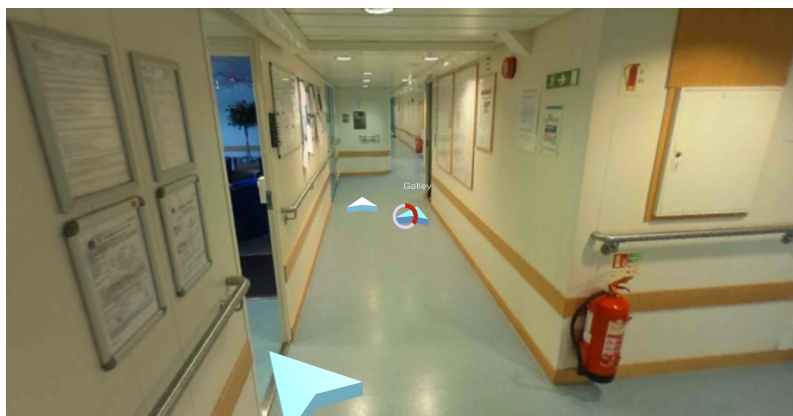


Fig 11 Bridge Tour – Self guided tour of the vessel's accommodation

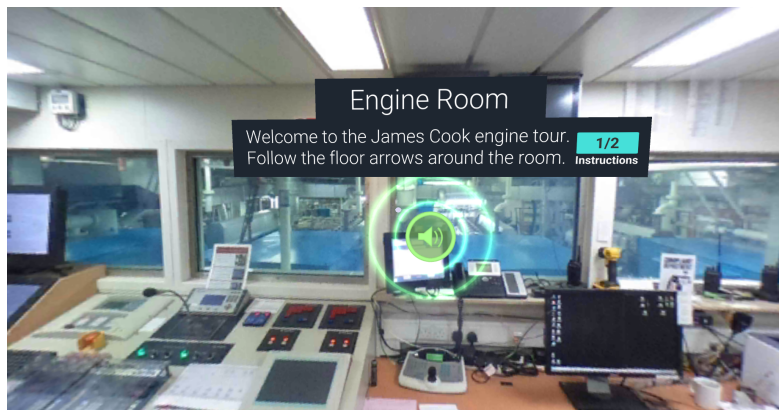


Fig 12 - The engine control room

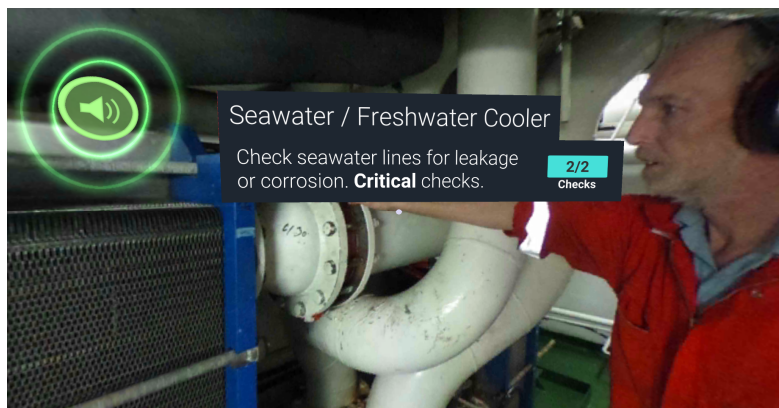


Fig 13 - The engine room – Seawater and freshwater cooler



Fig 14 - The engine room – Main air compressor

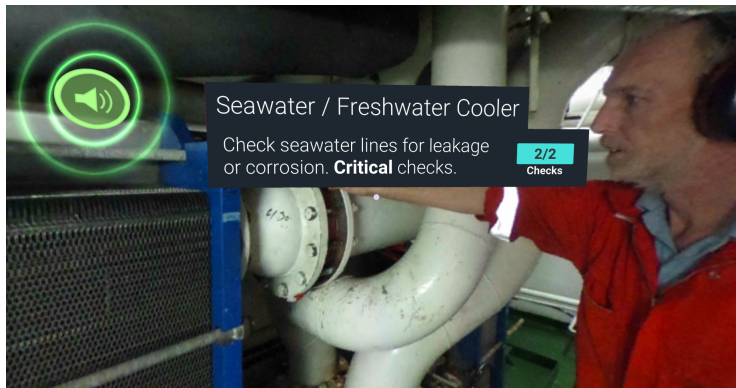


Fig 15 - The engine room – Main air compressor



Fig 16 Forward mooring stations

Each learner is able to select one of four locations around the vessel to navigate the space. Upon entering each new location the learner is greeted and introduced to that location by a member of the ship's crew. This was done by recording and embedding 2D video recordings.

Two options were tested in terms of user navigation.

1. On the bridge - the user learner was able to navigate independently in any chosen direction chosen.
2. In the engine room the learner could follow a linear path chosen by the developer

The learner was then asked to complete a VR Challenge.

‘When you enter the VR space we would like you to explore and tell us what you may like and what you may not like by carrying out a number of tasks. This is not graded and there is no wrong answer. Simply look around and explore to see what you can find out about your surroundings. You can interact with the labels placed on devices, read information about individual pieces of equipment as well as watch videos and listen to voice narration which will tell you about the equipment and how it is used in real life.’

During the field tests, participants were then given the option to choose one of the following:

1. Self-guided Exploratory Experience

The students are given guidance on their objectives, and left to explore and seek the required information themselves. The students have complete control over their location on the bridge, the information they see and the order in which they consume the information.

2. Teacher Guided Experience

The students have a degree of freedom in their interaction within the scenes, however the teacher channels their focus through the use of guided visual indicators.

3. Teacher Controlled Experience

The teacher has absolute control over the experience, changing the location of the users and highlighting and displaying text and images as they see fit.

5.3 Responding to the abnormal – application

Seafarers face an imbalance in their ability to cope with the unexpected event. To maximise onboard capability the seafarer needs to be provided with opportunities and time to practice the unexpected, so that individual competence is maintained above the requirements of everyday operations. Facilitation of this requirement is implemented through the use of mandatory drills, as prescribed by the use of the International Ship Management Code (ISM), in addition to the requirements as laid out in the Ship's Safety Management System.

Accidents however still occur, this is despite the mandatory implementation of a range of codes, regulation, onboard procedures and numerous safety campaigns. Therefore the final lesson attempted to provide a means by which to practice emergency procedures. Using mind mapping techniques, the team sought to create onboard 'ship specific' memories of stressful emergency relates experiences. The International Chamber of Shipping's bridge procedures guide was used to identify such an occurrences.

Unfortunately the limitations due to project funding and time made it impossible to fully develop and field test a third lesson. The team were however able to develop a VR based scenario where the officer on watch on the ships bridge found themselves standing at the chart table. The vessel was suddenly seen to run aground and the officer on watch, in this case the participant, would be required to respond to the emergency in the correct way, with a time period.

6. Methodology

6.1 Approach and methods

A mixed methods approach was adopted in completion of this research. The methods are categorized in four sections:

1. **Documentary research:** a literature review was performed to identify the knowledge in connection with the use of virtual reality and multi-modal sensory feedback systems for education and training;
2. **Survey methodology:** A questionnaire was conducted to commercial deck and marine engineering officer trainees.
3. **Survey methodology:** Interviews with qualified commercial deck officers
4. **Survey methodology:** Focus group sessions using commercial deck and marine engineering officer trainees.

6.2 Context, participants and overview of study

Field testing took place at three locations. Warsash Maritime Academy, part of Solent University in the United Kingdom. Marine Institute, part of Memorial University in Newfoundland, Canada and finally at Durban University of Technology, South Africa. Participants consisted of students undertaking training to become officers in the merchant navy. The participants included new entry merchant navy officer cadets as well as final year officer cadets in both deck and marine engineering disciplines. The number of students participating across the three institutions totaled 201. The mix of 1st year to final year officer cadets was maintained at a ratio of approximately 50%.

6.3 Objective 2

'Adopt a qualitative learner journey analysis methodology, to produce a validation to understand the learner experience.'

The goal of the usability test in objective 2 was to establish the experience of users when consuming educational material using Virtual Reality (VR) environments. Through our literature survey and testing, we were able to establish as well as validate the input device (mobile VR via Cardboard VR) and identify potential design concerns. These were addressed in order to improve the efficiency, controllability, and user understanding for future iterations of the system.

The aim of the user experience testing was to gather feedback on the core usability and framework of the application. That is, the effectiveness of presenting material to students using virtual reality concerning ease of use, immersion, and reception to the technology. The tests also examined the suitability of tools/controllers for undertaking teaching tasks, and how they should be adjusted for future iterations of testing.

The usability test objectives focused on the following:

- To determine the quality of the system¹. This first stage of testing highlighted areas of improvement for the application, particularly in regards to usability and the user experience. This enabled future testing to focus primarily on pedagogy.

¹ System here refers to the development of the Synthetic Learning Environment.

- To exercise the system under controlled test conditions with representative users. Data was used to identify whether usability goals were met regarding efficiency, controllability, and user understanding of the system.
- To establish baseline user performance and user-satisfaction levels for the system.
- Establish the practicality of setting up and implementing VR headsets into a lesson plan, and how efficiency in this area can be improved in future iterations.

6.4 Procedure

A number of participants between 15-20 at a time tested the application. This number allowed us to argue for both qualitative and quantitative findings, as well as provide a manageable sample size in the classroom environment. Each candidate was given a set of performing tasks/activities designed to interact with the virtual environment. Subjects were asked to complete a short pre-test questionnaire (including information about their background and their experience) and post-test (referred in literature below as post-hoc) questionnaires. An open discussion lead by the facilitator in the form of a focus group also took place at the end of the test.

Points considered:

- Since VR is such a relatively new technology, very few people can be considered experts in using Virtual Environments (VEs). For this reason, obtaining a representative sample of both novice and expert users was impossible, since often the only people who could be considered experts with the technology are the development team themselves.
- Given that most VR users will inherently be novices, evaluators can make no assumptions about their ability to use or understand their interface given real world and cultural experience. This can limit the types of evaluation techniques that may be employed, or require them to be reframed at a lower cognitive and physical level.
- The results of evaluations may be highly variable among individuals for this reason, requiring larger samples of users to obtain a clear picture of the performance, especially if statistically significant results are required.² We achieve this through a number of rounds of testing.

The four key elements for experiencing virtual reality include: a virtual world, immersion, sensory feedback (responding to user input), and interactivity [55]. For the purpose of WAVE, we also incorporated cost and accessibility of technology.

² <https://danamartensmfadt.files.wordpress.com/2016/08/virtuallyusable.pdf>

Evaluation type	Require User?	Generic/App Specific	Type of Result
Informal Summative	Yes	Generic	Qualitative
Formal summative	Yes	Generic	Quantitative
Formative (informal or Formal)	Yes	Specific	Both <i>Depends on Formality</i>
Post-Hoc Questionnaire	Yes	Either	Both
Interview/Demo	Yes	Specific	Qualitative
<i>Performance Model</i>	<i>No</i>	<i>Either</i>	<i>Quantitative</i>
Heuristic Evaluation	No	Either	Qualitative
Cognitive Walkthrough	No	Specific	Qualitative

Table 4: Table of usability test methodologies.

From the table provided the methodologies below are the most relevant to WAVE.

Formative (informal or formal) [56]

Requires Representative Users, Application Specific, Quantitative or Qualitative.

Formative evaluations are observational in nature and seek to empirically assess interaction techniques by iteratively placing users in task based scenarios. This evaluation method both seeks to identify specific usability problems and the design's overall ability to support user exploration, task learning, and task performance. More informal formative evaluations often yield only qualitative results (critical incidents, user comments, general reactions) while more formal versions can additionally generate quantitative results (task timing, error count etc.).

Formative evaluations are used to assess and improve the usability of an evolving design so they are best employed throughout the prototyping stages, informing each iteration of the prototypes overall design and usability. Traditional formative evaluations like cognitive walkthroughs require task/goal frameworks that help to collect quantitative (time on task, error rate) and qualitative (observation of confusion, struggling to follow the set directions) information. However the nature of VEs means that there are usually more stages of exploration that are required than just completing a task.

This was solved by extend cognitive walkthroughs into a VR specific model that explores more broad interactions than just task completion. One piece of research suggests creating three stages of interaction:

- task based activity,
- navigation/exploration (whether for completion of a task or serendipitous),
- system initiative (the user's role is to interpret actions taken by the VE and respond to them when initiative is returned, or interrupt/seize the initiative back if necessary) (Sutcliffe, Kaur 2000).

PostHoc Questionnaire [57] [58]

Requires representative users, generic or application specific, quantitative or qualitative results.

PostHoc (after the fact) questionnaires are written questions that collect demographic information as well as the opinions, views, and preferences of users after they have already participated in a usability evaluation session. They are good for collecting qualitative and subjective data and are often easier to implement and more consistent than interviews.

Given their nature, posthoc questionnaires are typically used throughout the prototyping process but in conjunction with another evaluation method. Since VR is such a new technology, responses could be extremely varied as to comfort levels, preferences for I/O configurations etc. In addition, specific feedback that can lead to design interventions may be hard to obtain if users are very inexperienced with the technology and care must be taken to frame questions very specifically to gather the best information possible.

Interview/Demo [59]

Requires users, Application specific, Qualitative Results.

During an interview, evaluators can collect similar subjective information as in a questionnaire, however they can often go more into detail. “Structured interviews” have a preset list of questions and responses they are seeking to gather while “Open ended interviews” allow the evaluator to ask broad questions without a fixed set of answers. These are more exploratory in nature and can allow the interviewer to ask more spontaneous and specific questions that they think of as the evaluation progresses. Often demonstrations of a prototype are used as an aid to guide the conversation.

Like posthoc questionnaires, interviews and demos can be used throughout the prototyping process, however they may be stronger than questionnaires for earlier prototypes if used in an exploratory manner, since VR is still relatively varied and user preference may also vary widely.

6.5 Procedure - Usability test - ship familiarisation – synthesis

Participants took part in the same usability test at Solent University, Marine Institute and Durban University of Technology. Students downloaded the WAVE application onto their own smart phones, following guidance. The participant’s interaction with the systems was monitored by the facilitators seated in the same room. The sessions followed a linear lesson plan corresponding to and engaging with the virtual environment. The sessions lasted for 50 minutes.

The facilitator briefed the participants on the system and instructed the participant that they were evaluating the system and not the participant.

Participants completed a pre-test demographic and background information questionnaire. The facilitator explained the tasks required to be completed. 15 minutes was given to the participants to set up the application and familiarize with the system. During this time the facilitator instructed the participants to ‘think aloud’ so that a verbal record exists of their initial interaction with the system. The facilitator will observe and enter notes of the user behavior, comments, and actions in a data logging application.

After the completion of the session, the participant completed a likert scale post-task questionnaire about the efficiency, controllability, and user understanding of the tasks. The post-test questioner provided data regarding Attractiveness, Perspicuity, Efficiency, Dependability, Stimulation and Novelty of the

system.³ In addition, there were open-ended questions aiming to get further information and comments about the users experience.

NOTES to consider

- These tests included the use of audio.
- The limitations of smart phone VR and the constraints of working inside a classroom can reduce the potential for high level immersion. The test however helped to deduce both how immersive classroom VR can be given the constraints, as well as the necessary level of immersion for effective and impactful learning.

A call out was sent to relevant personnel at each institution. The participants must have owned an android smart-phone to run the application, a link to which was provided before the lesson. The participants' responsibilities were to load the application on their devices as instructed, to follow and engage in the lesson conducted by the facilitator, and to provide feedback regarding the usability and acceptability of the user interface. The participants were directed to provide honest opinions regarding the usability of the application, and to participate in post-session subjective questionnaires and debriefing. No prior training or experience with the system was required.

³ More info see <http://www.ueq-online.org>

7. Analysis and discussion of results

The user experience data was gathered to gauge how acceptable the virtual reality lesson was on a non-pedagogical basis. The feedback from the user experience knowledge elicitation had a direct influence on the user experience design of the application in regards to; the experience of loading, viewing, following and interacting with the application, as well as the work flow of setting up the lessons and guiding the students through the lesson material. During the first field test carried out at Warsash Maritime Academy, we found that adopting a participatory methodology in the application development informed future iterations. On this basis the results appear to suggest that this worked.



Fig 17 User experience data, Marine institute, Canada

The analysis above in this case gathered at Marine Institute consisted of 82 participants and in general, the method was acceptable to all participants. The most common comfort problem experienced was eye strain (2.27 on a scale of 1 to 5). The eye strain is something that is common with a cardboard headset. It is important to note that the user must carefully align their device with the lens so that the view is perfectly in focus. This was included in briefing material for the final round of testing and appeared to remove this as a significant barrier to enjoyment.

The data was then analyzed based on a number of different subject characteristics. The first was prior user experience (question "Have you used VR before today?"). The participants responded either yes or no. It was feared that prior experience would have a significant effect on the acceptance or experience, but there was no effect observed in the data.

The next important concern was the effect age might have on the data. The subjects were divided into two groups, those 23 and younger and those 24 and older. There was some difference observed between the groups. The older group reported more eye strain (2.65 for the older group compared to 2.12 for the younger group) and more general discomfort (2.00 vs 1.60). This is perhaps to be expected but the difference was not statistically significant at the 95% level.

There was one unusual result. While not a statistically significant result, the older group tended to rate the virtual reality application as slightly more “dull” while the younger group rated it as more creative. Whilst it is important to draw out these conclusions from the data, there is little to suggest that this will be a significant barrier to the adoption of this technology to older learners.

Finally the user experience was examined based on male / female. Again, there was no statistically significant difference in the data, although it should be noted that the female group was relatively small compared to the male group (12 female compared to 70 males). The most interesting result was that the females reported less eyestrain.

From the participant responses to our inquiry in understanding the learner journey, there is clearer still work to be done. However, for an early stage test prototype application, what is perhaps the most compelling is that all responses saw the learning as an enjoyable and positive experience. This assumption was confirmed during subsequent focus groups. Although the data presented to the reader is based on data captured during the field test which took place at Marine Institute, when comparing the data analysis of all three field tests, there was little variability in results. It is important however to highlight whilst there was little variability, the results did not see any decree in user satisfaction and enjoyment, only moderate increase. We would argue therefore that this a result of the depth of work that went into the application design combined with the nature of our participatory approach in informing each interaction of the application development was beneficial.

7.1 Teacher led or student led?

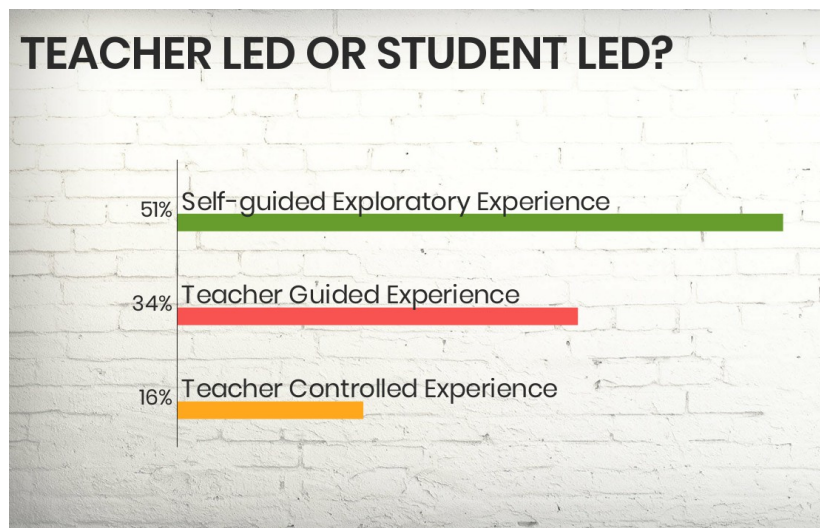


Fig 18 Teacher Led or Student Led, Durban University of Technology, South Africa

The analysis above in this case gathered from Durban University of Technology, South Africa asked the following question. What do you prefer when engaged in VR learning experiences? Do you prefer:

1. Self-guided Exploratory Experience

The students are given guidance on their objectives, and left to explore and seek the required information themselves. The students have complete control over their location on the bridge, the information they see and the order in which they consume the information.

2. Teacher Guided Experience

The students have a degree of freedom in their interaction within the scenes, however the teacher channels their focus through the use of guided visual indicators.

3. Teacher Controlled Experience

The teacher has absolute control over the experience, changing the location of the users and highlighting and displaying text and images as they see fit.

The participants were given guidance on their objectives for the session, and left to explore and seek the required information themselves. In addition to a choice of exploratory guidance, a further blind test was carried out to determine how participants might like to be guided during their ship explorations. Therefore, the participants had complete control over their location on the bridge, the information they see and the order in which they consumed that information. However during the tour of the engine room participants were only given one linear option that took them on a journey decided by the developer.

In response to the first questions, the majority of participants at 51% enjoyed the self-guided experience. 34% felt that they would like to be coached or guided, but that it was situation dependent. Only 16% of students prefer the fully teacher centric approach. Although the results presented above are restricted to the field test carried out in South Africa, however again, there was very little variation in results. Interesting to note was that the tests carried out in the United Kingdom and Canada showed slightly less in support of the teacher centric approach.

As highlighted during the literature review this would appear to conform that the view that the role of the teacher teaching within a general virtual environment will change in a virtual learning environment, from that in a traditional classroom environment [29]. Based on the analysis carried out across 201 participants, our test confirmed that in the virtual world the role of the educator is to be the facilitator, coach, or mentor – or in other words, the one who, first and foremost, provides leadership and wisdom in guiding student learning’ [30].

In response to the later question, free to roam or developer lead? Participant responses captured during the focus group sessions suggested that it was dependent on the complexity of the task. However as discussion progressed during the focus groups, participants concluded they enjoyed having the guidance over free to roam. They concluded that having a ‘museum style’ experience helped to do and interact with everything that was expected of them.

7.2 Objective 3

‘Develop existing cost effective technology to create a VR based training scenario/s for use by a trainer to assess a trainee’s task performance against a set of objectives with combinations of both visual and cognitive tasks; this will include validation by quantitative measures and the running of experimental trials; including development of a mechanism to record and monitor student achievements against training objectives during training events; and also including development of a mechanism to record/deliver learner feedback.’

The tests at the Marine Institute of Memorial University of Newfoundland and Labrador were carried out during the week of January 8th to 12th. The test subjects were again drawn from both Marine Engineers and Nautical Science students from both first and second years. The students were split into two groups with 37 students receiving a conventional lesson (CL) and 49 receiving the blended virtual reality (VR) lesson. On the 9th and 10th of January 49 students in 3 cohorts were given a blended VR

lesson on enclosed space entry. On the 11th of January a conventional lesson on enclosed space entry was delivered to 2 cohorts totally 37 students. All lessons were prepared and delivered by the same instructor, who also worked as the project principal investigator.

On the 12th of January a quiz was given to all 86 participants over 3 separate sessions. Whilst the same assessment was used in each session, participants did not interact. The quiz was based on a recall of important information in regards to enclosed space entry. The maximum possible score in the quiz was 21. The average score for the students taking the CL was 5.73 and the average score for the students taking the VR lesson was 9.16. It should be noted that the test was a challenging one and to score perfectly the student would need to be able to order 6 steps prior to entry and then recall 13 emergency/safety items available for an enclosed space entry. The maximum score was 17. The results are shown in the graph below along with the 95% confidence interval for the CL results and the VR results.

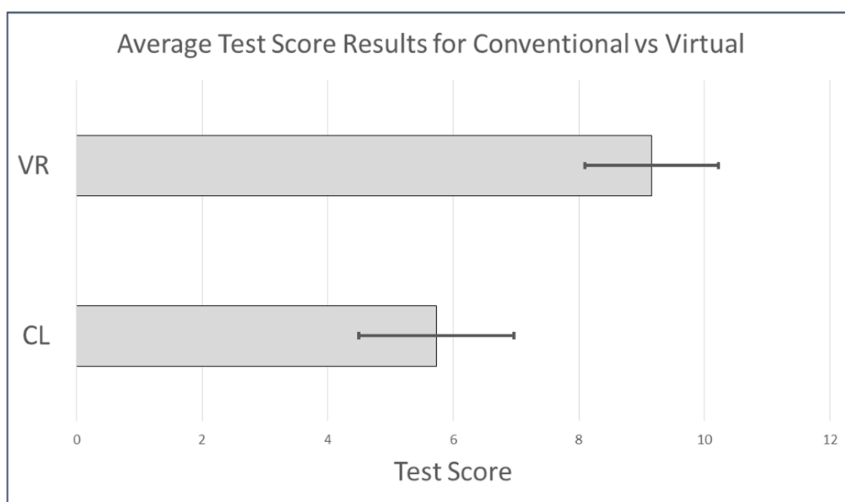


Fig 19 Quiz results – VR blended learning v non VR blended learning

As can be seen, the VR group did significantly better than the CL group at the 95% confidence level. The general breakdown of the results from the individual questions is similar to the overall results except for the question dealing with oxygen levels. In this case the CL group did better than the VR group. This was explained because during the lesson planning the instructor omitted to include the value of oxygen content to the blended VR group.

7.3 Objective 4

‘To contribute findings from the analysis to derive a set of recommendations / toolkit of good practice for the use of synthetic teaching and learning activities through the use of empirical data that industry, maritime regulators, training providers and other stakeholders can use to inform seafarer pedagogical practice.’

The results from the literature review combined with the research conclusions were used to construct a toolkit for best practice, contained in appendix D. This toolkit will be distributed widely throughout the industry by labour organisations, seafarer unions, the International Transport Workers Federation (ITF), maritime regulators and other stakeholders, all of which will widen routes to dissemination and exploitation of the results.

The commercial sector, and maritime training institutions will benefit from industry wide recommendations to understand legal responsibilities and to produce fair treatment policies as well as

8. Conclusions and recommendation

This report presents the outcome of a study investigating the transformative potential of blending virtual reality into theoretical curriculum, the setting is in commercial maritime education and training. It's potential to support meaningful learning is discussed. From here, a shift to the need to rethink and restructure the learning experience occurs and its transformative potential is analyzed. Finally, the impact of on student learning and assessment is highlighted. The conclusion finds that memory retention can be significantly increased through the blending of VR lessons and experiences. VR makes it easy to reconstruct past incidents to create learning experiences for the future. It also enables creation of realistic scenarios to address safety issues. Virtual reality enables the laying of a solid foundations for safety and situational awareness on vessels. Quantitative and qualitative analysis confirmed that memorisation of process and theory could be enhanced and also revealed a number of pedagogical, technological and logistical factors that supported learning. The project developed a prototype smartphone downloadable application used with low cost smartphone based VR to carry out the field testing. The report concluded with discussion of present and future implications of blending reality for learning and teaching and that a significant impact might be realised not just locally, but researchers believe that it could have a significant effect internationally if the adoption of blended VR was more widely adopted in theoretically based maritime education and training. The traditional teacher centric approach was witnessed to change when using virtual learning environments for education, from that which tended to exist in the traditional commercial maritime classroom environment. During field testing the change in student requirements say the expert and perhaps the sole or major information source, move to facilitator, coach, or mentor – in other words, to one who, first and foremost, provides leadership and wisdom in guiding student learning.

The review of the literature highlighted that there has been very little published as to how teaching should be carried out within a virtual learning environment, particularly one that is formed around virtual reality technology. Therefore in our approach we sought to consider what the needs of teachers would be to practically implement VR into the classroom, using VR as an additional learning tool through lesson blending.

Being efficient in the classroom setting was considered of high importance also. Without the VR content being quick and easy to access, the technology has a lower likelihood of being adopted by current maritime educators. Mobile VR fits this area well, as it can be used in the same classroom without relocating to specialist VR facilities, and can also be set up very quickly. Specialist VR facilities suffered in this regard, as while they can produce fantastic learning results for specialised training, the process of booking facilities and moving students is a large inconvenient for more general use

Another key consideration was student access to the technology. Whilst the educational benefits of VR are apparent, if only limited numbers of students can experience it during a lesson it becomes ineffective. Again, mobile VR stood out as an ideal solution, as many students can use the technology at the same time. This is due to both the minimal physical space the technology requires, the low cost and abundance of smart phone technology, meaning that an entire class could view the VR environment at the same time. To demonstrate PC VR to an entire class simultaneously requires a very large amount of space, and an extremely costly amount of equipment. Alternatively, lower numbers of students could use the technology and take turns, though this makes lessons much less efficient. This is impractical for a normal learning environment, and does not fit well into a standard lesson plan.

After considering the potential applications and requirements for effective implementation, it was decided to proceed with a smartphone solution. Mobile VR was apparent as a cost effective and accessible technology that filled a gap in the needs of maritime teachers, as well as the gap in research of VR pedagogy.

The target hardware was selected was Google Cardboard, the baseline entry VR device. Developing the application for this platform made it accessible to the highest number of test subjects possible, whilst providing flexibility to adapting for different platforms if desired. Other core benefits of smartphone VR being;

1. It's efficient to set-up in a classroom for multiple students, with minimum disruption to learning. The alternative of moving to a separate VR suite would be very disruptive.
2. It's cheap and accessible. The benefits of VR content can be implemented across many different lessons, and the low entry cost of mobile VR makes it realistically accessible with minimal investment.
3. Two large benefits of VR in Maritime which were apparent included spatial knowledge representation and engagement, which can be provided sufficiently through smartphone based VR.
4. The quick opening and operation of smartphone VR could be well implemented into a lesson plan, utilising it intermittently amongst other teaching methods. Whilst low-level smartphone VR should not be used for extended periods of time, this intended usage would not require extended use.

From the participant responses to our inquiry in understanding the learner journey, there is clearer still work to be done. However, for an early stage test prototype application, what is perhaps the most compelling is that all responses saw the learning as an enjoyable and positive experience. This assumption was confirmed during subsequent focus groups. Although the data presented to the reader is based on data captured during the field test which took place at Marine Institute, when comparing the data analysis of all three field tests, there was little variability in results. It is important however to highlight whilst there was little variability, the results did not see any decree in user satisfaction and enjoyment, only moderate increase. We would argue therefore that this a result of the depth of work that went into the application design combined with the nature of our participatory approach in informing each interaction of the application development was beneficial.

The next iteration of the application should look toward expanding this method training further. It should also be made available for free, to all.

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10. Attachments

- Appendix A - UX Pre-test questionnaire*
- Appendix B - Enclosed spaces assessment*
- Appendix C - The Teachers Toolkit*
- Appendix D - Principal Investigator's Contact Details and Bio*

APPENDIX A | UX Pre-test questionnaire

1- PRE-TEST BACKGROUND

YOUR BACKGROUND

- | | | | |
|-----------------------------------|------------------------------|---|--------------------------|
| 1. Gender | <input type="checkbox"/> | 3. Employment | <input type="checkbox"/> |
| Male | <input type="checkbox"/> | Student | |
| Female | | <input type="checkbox"/> Part-time | |
| | | <input type="checkbox"/> Full-time | <input type="checkbox"/> |
| 2. Age | <input type="checkbox"/> 18- | Academic | |
| 23 <input type="checkbox"/> 24-30 | <input type="checkbox"/> 31- | <input type="checkbox"/> Private sector | |
| 45 <input type="checkbox"/> 46+ | | <input type="checkbox"/> Other..... | |

3. Have you ever served in any of these roles at sea?
- | | |
|---|---|
| <input type="checkbox"/> Deck Cadet – Phase | <input type="checkbox"/> Engineer Cadet – Phase |
| <input type="checkbox"/> OOW | <input type="checkbox"/> 3 rd Engineer |
| <input type="checkbox"/> Chief Officer | <input type="checkbox"/> 2 nd Engineer |
| <input type="checkbox"/> Master Mariner | <input type="checkbox"/> Chief Engineer |

4. How much experience do you have in each of the roles that you ticked? (Years /Months – Y/M))

Role.....Y/M.....

Role.....Y/M.....

Role.....Y/M.....

Role.....Y/M.....

5. How would you rate your understanding of the general layout and equipment found on a ships bridge?

- ☐ Beginner
- ☐ Intermediate
- ☐ Advanced
- ☐ Expert

6. How would you rate your understanding of the general layout and equipment found in a ships engine room?

7. Have you ever used/tried virtual reality before?

- ☐ Yes
- ☐ No

7a. If yes, how would you rate your knowledge about virtual reality?

- ☐ No experience
- ☐ Some experience
- ☐ VR Guru

2 - USER EXPERIENCE FEEDBACK

For the assessment of the system, please fill out the following questionnaire. The questionnaire consists of pairs of contrasting attributes that may apply to the system. The numbers between the attributes represent gradations between the opposites. You can express your agreement with the attributes by ticking the circle that most closely reflects your impression.

Please decide spontaneously. Don't think too long about your decision to make sure that you convey your original impression. Sometimes you may not be completely sure about your agreement with a particular attribute, or you may find that the attribute does not apply completely to the product. Nevertheless, please tick a circle in every line.

Annoying	○ ○ ○ ○ ○ ○ ○	Enjoyable	1
Not understandable	○ ○ ○ ○ ○ ○ ○	Understandable	2
Creative	○ ○ ○ ○ ○ ○ ○	Dull	3
Easy to learn	○ ○ ○ ○ ○ ○ ○	Difficult to learn	4
Valuable	○ ○ ○ ○ ○ ○ ○	Inferior	5
Boring	○ ○ ○ ○ ○ ○ ○	Exciting	6
Not interesting	○ ○ ○ ○ ○ ○ ○	Interesting	7
Unpredictable	○ ○ ○ ○ ○ ○ ○	Predictable	8
Fast	○ ○ ○ ○ ○ ○ ○	Slow	9
Inventive	○ ○ ○ ○ ○ ○ ○	Conventional	10
Obstructive	○ ○ ○ ○ ○ ○ ○	Supportive	11
Good	○ ○ ○ ○ ○ ○ ○	Bad	12
Unlikable	○ ○ ○ ○ ○ ○ ○	Pleasing	13
Normal	○ ○ ○ ○ ○ ○ ○	Cutting edge	14
Unpleasant	○ ○ ○ ○ ○ ○ ○	Pleasant	15
Secure	○ ○ ○ ○ ○ ○ ○	Not Secure	16
Motivating	○ ○ ○ ○ ○ ○ ○	Demotivating	17
Meets expectations	○ ○ ○ ○ ○ ○ ○	Does not meet expectations	18
Inefficient	○ ○ ○ ○ ○ ○ ○	Efficient	19
Clear	○ ○ ○ ○ ○ ○ ○	Confusing	20
Impractical	○ ○ ○ ○ ○ ○ ○	Practical	21
Organised	○ ○ ○ ○ ○ ○ ○	Cluttered	22
Attractive	○ ○ ○ ○ ○ ○ ○	Unattractive	23
Conservative	○ ○ ○ ○ ○ ○ ○	Innovative	24
Uninspiring	○ ○ ○ ○ ○ ○ ○	Curious	25
Difficult to navigate	○ ○ ○ ○ ○ ○ ○	Easy to navigate	

Did you experience - General discomfort?	None	Slight	Moderate	Severe
- Headache?	None	Slight	Moderate	Severe
- Eye Strain?	None	Slight	Moderate	Severe
- Nausea?	None	Slight	Moderate	Severe
- Vertigo?	None	Slight	Moderate	Severe
How realistic did it feel?	Not real	Relatable	Familiar	Real
Did this help you comprehend a bridge's layout?	Not at all	Partially	Fairly well	Very well
Did the experience make you curious about maritime compared to a normal lesson or video?	No	The same as normal	More than normal	Very curious
How difficult was it to set up the app?	Impossible	Awkward	Fine	Easy

C – POST-TEST QUESTIONNAIRE

It is your personal opinion that counts. Please remember, there is no wrong or right answer!

1. What did you like most about this experience?

2. What did you dislike about this experience?

3. What suggestions or ideas do you have for improving the experience?

4. How long did it take you to get used to the controls?

5. Was there any material you found difficult to understand?

6. How would you compare the VR experience VR to being shown a deck through images/video?

7. What would make it feel more real?

8. Do you have any other general comments or observations?

Option: Based on your experience and personal preferences. Having now been in the virtual space, would you say that you would be drawn to any of the following; and if so, which one/s? Have your preferences changed or stayed the same??

1. Self-guided Exploratory Experience

The students are given guidance on their objectives, and left to explore and seek the required information themselves. The students have complete control over their location on the bridge, the information they see and the order in which they consume the information.

2. Teacher Guided Experience

The students have a degree of freedom in their interaction within the scenes, however the teacher channels their focus through the use of guided visual indicators.

3. Teacher Controlled Experience

The teacher has absolute control over the experience, changing the location of the users and highlighting and displaying text and images as they see fit.

APPENDIX B | Entry into enclosed spaces assessment

Entry into enclosed spaces

During your lesson we introduced you to the key points which should be understood when entering or working in enclosed spaces at sea. Now, we want to understand how much you were able to remember about the things that you learned.

Please can you answer the following questions in sections 1 to 5.

* Required

ENTRANCE INTO ENCLOSED SPACES



1. Name

2. During your confined spaces lesson, did the instructor use Virtual Reality as a teaching activity? *

Mark only one oval.

- ☐ YES
☐ NO

3. What are you studying? *

Mark only one oval.

- ☐ Marine Systems
☐ Nautical science / Deck Officer
☐ Marine Engineer

4. What year are you at in your studies? *

Mark only one oval.

- ☐ 1st year of study
☐ 2nd year of study
☐ 3rd year of study
☐ 4th year of study

5. Have you completed enclosed space entry training prior to this weeks lesson? *

Mark only one oval.

- ☐ YES
☐ NO

Enclosed spaces entry procedure

Put the following in the correct order from 1 to 6. Begin with the first task that should be completed prior to entering an enclosed space on board a ship.

6. Complete a permit to work *

Mark only one oval.

- ☐ 1st
☐ 2nd
☐ 3rd
☐ 4th
☐ 5th
☐ 6th

7. Ventilate the space *

Mark only one oval.

- ☐ 1st
☐ 2nd
☐ 3rd
☐ 4th
☐ 5th
☐ 6th

8. Perform risk assessment *

Mark only one oval.

- ☐ 1st
☐ 2nd
☐ 3rd
☐ 4th
☐ 5th
☐ 6th

9. Discuss the job with all parties *

Mark only one oval.

- ☐ 1st
- ☐ 2nd
- ☐ 3rd
- ☐ 4th
- ☐ 5th
- ☐ 6th

10. Secure the space *

Mark only one oval.

- ☐ 1st
- ☐ 2nd
- ☐ 3rd
- ☐ 4th
- ☐ 5th
- ☐ 6th

11. Test the atmosphere *

Mark only one oval.

- ☐ 1st
- ☐ 2nd
- ☐ 3rd
- ☐ 4th
- ☐ 5th
- ☐ 6th

Enclosed space scenario

Think about the following scenario, You are working in a party of two checking inside an engine room boiler for damage.

The entry is very straight forward and only requires stepping inside of the space. You are asked by the 2nd engineer to pass you a spanner which is within easy reach as you only have to climb just inside and pass it. You refuse but the engineer swears at you, and says hurry up and just do it! You're talking to the 2nd engineer so the space is perfectly safe.

12. What should you do?

Mark only one oval.

- ☐ Complete a new permit to work
- ☐ Ensure ventilation is in operation and then pass the spanner.
- ☐ Agree that you will test the space to make sure that it is safe to enter, Pass the spanner, but do not set foot in the space
- ☐ Call for a relief so that you pass the spanner
- ☐ Insist that the 2nd gets the spanner on their own.
- ☐ The Bosun just walks by, ask him to pass the spanner to the 2nd engineer.

Testing the space for safe oxygen levels

The oxygen level must be tested both prior to entering an enclosed space as well as during entry,

13. Which of the following oxygen levels would be outside safe limits? *

Mark only one oval.

- ☐ 19,6%
- ☐ 21,5%
- ☐ 22%
- ☐ 22,6%
- ☐ 23,6%

Emergency and safety equipment

What pieces of emergency and/or safety equipment should be ready and available for an enclosed spaced entry?

List as many as you can.

14. **1.**

15. **2.**

16. **3.**

17. **4.**

18. **5.**

19. **6.**

20. **7.**

21. **8.**

22. **9.**

23. **10.**

24. **11.**

25. **12.**

26. **13.**

27. **14.**

28. **15.**

29. **16.**

30. **17.**

31. **18.**

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 Google Forms

APPENDIX C | The Teachers Toolkit

Maritime Educators - A Toolkit for Integrating Smartphone based AR and VR into the curriculum

What is the difference between AR and VR?

With virtual reality, you can walk around a virtual engine room. And with augmented reality, you can watch an engine pop out of your business card. **VR** is more immersive, **AR** provides more freedom for the user.

What are the advantages of blending VR or AR into your teaching?

- The cost of physical field trips are expensive and ship visits are difficult to organise.
 - This technology helps students to engage in activities that might be impossible due to access, time, or even risk.
 - Blending VR or AR into lessons opens up wider opportunities for learner engagement for those who are more kinaesthetic.
 - Experiences can designed to make the complex idea or concepts, simpler.
 - VR and AR are both experiential and visual. Blending experiential learning into teaching helps students to relate there learning to real life at sea, improving attitudes to learning.
 - Blending experiences with instruction helps to immediately apply knowledge.
 - We can provide opportunities for real-time coaching and feedback.
 - During virtual assessments, performance and accomplishments are obvious and immediate.
-

What does the research say?

During field tests students who experienced blended VR into their lessons, performed twice as well compared to students who had not experienced the VR.

Okay, so what do I need to get started?

1. Smartphone

A smart phone - The phone must have a gyroscope and an accelerometer. Both android devices and IOS (apple) phones can be used to play the AR or VR on. You will need your own personal device. We found that most student's have compatible smartphones. However, if there aren't enough compatible smartphones in you class, ask if the students would be happy to work collaboratively.

2. A headset

This is used for the VR experience.

3. A lesson plan

Whilst AR and VR are great technologies, it is about blending this approach to learning into the curriculum. Therefore you will need a lesson plan to carefully integrate the VR to AR into your lesson. We have included an example at the end.

Lesson planning - How to integrate VR and AR into your lesson

It is important that AR or VR is seamlessly intergraded into the curriculum and not made the main focus. The assorted strategies used during the lesson are enhanced by VR not replaced. VR and AR are simply tools to enrich learning.

Your lessons should follow a consistent format, and be designed to engage your students, teach the content and improve their knowledge or skills, all while adhering to the curriculum and standards. Engage your students at the start of the lesson with a short warm-up to get them thinking about the topic and discussing. This can be done using a number of videos available by searching the youtube channel. Try asking your students to find some material.

Each lesson should consist of several different activities to differentiate the content and support students of all abilities. Possible activities include:

- Reading
- Writing
- Videos or pictures
- Discussions
- Bring your own device (BYOD) - 'Googling it'
- Subject Q and A WhatsApp groups

End the lesson with an activity for students to summarize and demonstrate their learning steps. For student teacher interaction try blending the use of some free online tools such as:

- Mentimeter (<https://www.mentimeter.com/>)
- AnswerGarden (<https://answergarden.ch/>)

Preparing your Lesson – The Lesson plan

We have included an example lesson plan on the final page of this document, but as a minimum you will need to define:

- The lesson overview, learning aim and learning objectives
- Student assessments strategies
- PowerPoint slides,
- Links to web resources or online learning tools e.g. answergarden or mentimeter
- You may also wish to include a differentiation strategy to identify how you intend to better enable different learning styles.

Student learning and assessment

During VR experiences/activities (we found) that students preferred to be self-lead or coached compared to the traditional teacher centric approach. However, what is still crucial, is that the educator carefully explains what the purpose of the experience is and what the student is expected to be doing. If students become unsure they quickly start to lose focus and disengage from the task.

For assessment, it is important to highlight that the choice of method very much depends on the type of training and the extent, as well as the depth of knowledge required, and the range of learning required. As we are only dealing with smartphone VR and AR, unless you are familiar with gaming engines such as unity or unreal, you will likely have to use worksheets combined with your web based free VR experiences.

For the beginner, methods of formative assessment can range from simple familiarisation and recall, to examination of virtually suspended equipment. For the expert it is possible to include much more complex assessment using algorithms, eye tracking or even heartrate monitoring. The most important thing however is that you are creative and don't be frightened to ask your students for advice! When starting out, it is best to begin by linking your VR learning and assessment methods to the following principles, as highlighted by the literature shown on the next page.

Virtual and Augmented reality facilitates the following:

- **Spatial knowledge representation.** Learning the physical dimension, size and layout of an environment or scene.
- **Experiential learning.** Content that requires a physical presence and active involvement to gain the required knowledge.
- **Engagement.** Improving the involvement of students in a lesson and their attention.
- **Contextual Learning.** Learning about a task or system in with appropriate context, such as the environmental conditions it is performed in.
- **Collaborative Learning.** Working together as a group to learn and engage in a lesson.

Finding VR experiences to blend in to your lessons - to create or not to create...

Currently there is a lack of VR content available for our maritime students, therefore it is important that we collaborate together as educators to fill this void. Ways in which to can collaborate include:

- Posting content on 360 YouTube Channels like LookSea VR
- Use your contacts and networks to share 360 lesson material between colleagues, locally, nationally and internationally.
- If have the resources and contacts at your institution, try to link up with your colleagues from computer science or computer programming to see how you might create some content.

In the meantime here are some application that you might consider using to get you started.

360 Degree Cameras to hire or purchase?

Garmin VIRB® 360



For 360 video capture we used the waterproof and rugged Garmin offering with 5.7K/30fps Resolution and 4K Spherical Stabilisation.

Visit: <https://buy.garmin.com/en-GB/GB/p/562010>.

Rocha Theta



- 360 degree spherical images at the touch of a button
- Take spherical videos up to 25 minutes long
- Live streaming of 360 degree images. Effective pixels - approximately 12 megapixels (x2)
- Transfer images to your Apple or Android device by WIFI
- Share your images and video on social networks, dedicated websites

Visit: <https://theta360.com/uk/>

SAMSUNG Gear 360



- With 4K 360° video capture life in high definition. Battery: 1,160 milli Ampere hour(mAh)
- Go live with Gear 360 - Broadcast live moments
- Samsung Gear 360 app allows you to switch up the view in a few taps, with multiple modes to choose from

- When you're ready to debut your new work, it's simple to convert 360 content into a standard video or photo format to upload wherever your audience is.
 - Gear 360 (2017), USB cable (Type-C), Strap, Pouch, Quick Start Guide
 - Smartphone compatibility: Galaxy S8, S8+, S7, S7 Edge, Note5, S6, S6 Edge, S6 Edge+, A5/A7 (2017) running Android 5.0 or later. iPhone 7, 7+, 6S, 6S+, SE running iOS 10.0 or later
- Visit: <https://www.samsung.com/global/galaxy/gear-360/>

VR Applications that you can use now...

LookSea VR®

Cost: Free

Summary: Dedicated to Maritime Education and Training: Database of experiences that can be used in VR, with oven ready lessons for download.

What we use it for?

Has a ship tour as well as a number of oven ready pre blended lessons. Very early days start up Is it good for learning in the maritime domain?

LookSea VR® 360 - youtube channel

Cost: Free

Summary: Dedicated to Maritime Education and Training: Database of experiences that can be used in VR to experience life at sea.

EON Experience VR – Pre existing material

Cost: Free

Summary: Database of experiences that can be used in VR, AR or Normal Mode

Aurasma – How to make your own material

Cost: Free

Summary: Scan images and make them interactive – make your own material

Discovery VR: Pre-existing material

Cost: Free

Summary: Discovery has added a VR app that allows you to experience your favourite Discovery programs, such as Deadliest Catch or Mythbusters in VR.

EON Reality: How to make your own material

Cost: Free

Students and teachers can create a blended-learning environment that allows creators to combine 3D with PowerPoint, notes, sound effects and more.

Immersive VR Education: How to make your own material

Cost: Free

Free education platform allows teachers to create their own lesson plans and immersive experiences.

Nearpod: How to make your own material

Cost: Free

This is a free-for-teachers VR-based curriculum.

Unimersiv: Pre-existing material

Cost: Free

This individualized and immersive learning platform releases content on a monthly basis.

zSpace: Offers different STEM programs, including Euclid's shapes or human anatomy at various prices.

Cost: Paid

Nautical Science



ENTRY INTO ENCLOSED SPACES T: 50mins

LEARNING LEVEL /PRIOR LEARNING

- Suitable for cadet level
- No sea experience required

LESSON OVERVIEW

Casualty estimates are in the dozens each year, therefore it is imperative that those on ships and offshore units learn at an early stage of the dangers of entering into enclosed spaces. The emphasize of the lesson is to highlight the dangers, reinforce correct process and instill the culture of safety first.

Students must understand how unsafe it can be to go ill-prepared into an enclosed space to assist a colleague as well as what to do when things go wrote. No enclosed space should be entered without proper precautions and training.

This lesson is suitable for introductory training at cadet level. Deck, Electrotechnical and Engineer.

LEARNING OBJECTIVES

- Understand the dangers and risks
- Understand personal responsibilities
- Understand the role of the responsible person
- Understand action to be taken in the event to emergency

ASSESSMENT STRATEGY

This lesson consists of two VR experiences.
Students

VR SESSIONS

This lesson consists of two VR experiences.
Students

RESOURCES AND PREPARATION

- VR Headsets
- Personal device with downloaded app
- Student devices - Download should preferably take place before the lesson begins. If not, Broadband will be required (Check the speed).
- PowerPoint slides
- YouTube Video – Enclosed space entry
- Google Docs assessment link
- Mentimetre questions and student links
- Computer
- Projector

LITERATURE / PREVIOUS READING

The Standard Club - A Master's Guide to Enclosed Space Entry

ENTRY INTO ENCLOSED SPACES

Scope and Sequence

6. Ensure students have downloaded both the VR app and Mentimeter app – Use the instructions given in the PP Slides.
7. Search youtube channel for Entry into Enclosed Spaces. An appropriate video introduction should last around 10 minutes.
Q1. Mentimeter – What is an enclosed space in a ship?
Q2. What is meant by an enclosed space?
8. Introduce the subject using the PowerPoint slides provided:



Formative VR Test Number 1 – The kit – (5 minutes)

Educator: Take the students through the equipment shown in the virtual room. You can use the numbers to highlight which piece of equipment you are referring to.

Students: In groups of two, review the equipment laid out in the virtual room. Ask them to identify the missing equipment from the list shown in the previous slides. One student's device is used to take turns in reviewing what's missing from the virtual room. The second student device is used to answer the mentimeter questions.

9. Continue with the lesson using the PowerPoint slides provided.



Formative VR Test Number 2 – First person entry and what to do in an emergency?

Educator: Explain the following to the students. We have just discussed the six basic steps which must be carried out before entry into an enclosed space can take place. Visit the virtual space and select the six options in the correct order. Once you have completed this task. Enter the space, and watch the person working in

the enclosed space. Remember, you are looking after their safety, so make the right choice when asked.

10. Continue with the lesson using the PowerPoint slides provided:



Formative VR Test Number 3 – Attendant responsibility - what to do in an emergency?

Final reflection

Reinforce the dangers of enclosed space entry. Reinforce the process required prior to entry into an enclosed space, the actions to be taken when something goes wrong.

Summative assessment

The assessment is prepared using Google docs. If time permits, wait until the next lesson to carry out a final test.

Assessment link:

<https://goo.gl/forms/6vpZ2eCZQ2Swi58B2>

Deeper Learning

Refer students to any of the P and I Club Publications. We used:

The Standard Club - A Master's Guide to Enclosed Space Entry

APENDIX D | Principal Investigator's Contact Details and Bio

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Gordon Meadow is committed to the development of Maritime Education and Training (MET). Formally an Associate Professor at one of the United Kingdom's leading maritime training institutions, Warsash Maritime Academy, part of the Warsash School of Maritime Science and Engineering at Solent University. Gordon is now Principal Curriculum Developer and founder of startup, SeaBot XR. SeaBot is a UK based company blending maritime training with smartphone based virtual reality, around the world. He is also Chair of the Institute of Marine Engineering Science and Technology (IMarEST) Maritime Autonomous Surface Ships Special Interest Group (MASS SIG). MASS SIG is considering skillsets for seafarers of the future in light of the growth of autonomy in shipping.

Following a career at sea in the commercial yacht market, Gordon moved to academia, specialising in navigational technology. He has taught at all levels in the UK Merchant Navy from new entrant cadet to master mariner, including undergraduate and postgraduate teaching, and was a visiting lecturer at MSTI in Hong Kong. He is an examiner for the International Association of Maritime Institutions in Navigation and Electronic Navigation.

He has presented internationally on his research interests in maritime education ranging, remote and autonomous shipping to technologically influenced pedagogy. He is an expert in the use of experiential learning for extended reality and he uses this expertise at SeaBot XR to blend maritime education with smartphone based virtual reality. He is an experienced researcher and was active in the Rolls Royce lead innovate UK MAXCMAS autonomous ships project as well as Principal Investigator for the Rolls Royce collaborative autonomous ship engineering project, IMAGINE. He was also principal Investigator on project WAVE, where he and his team, ranging four countries developed a best practice toolkit and prototype smart phone application for synthetic teaching and learning activities. Gordon is working with, a host of international partners on his better together initiative, with his goal to provide free for use open ready VR enhanced lessons to all maritime training institutions across the globe.

Gordon is married with two children and lives in a pretty Hampshire village on the South Coast of England.



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