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nDiVE: Development of an authentic training environment to support skill acquisition in logistics & supply chain management

Final Report 2016

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3 List of acronyms and glossary of terms

3.1 Acronyms

CS Frame	Carrot and Stick Framework
CT1/CT2	Short form for the container terminal scenario 1 and 2
Curtin	Curtin University
FPV	First Person View
HCI	Human Computer Interaction
HDR	Higher Degree Research
HMD	Head-Mounted-Display
L&SCM	Logistics and Supply Chain Management
OLT	Australian Government Office for Learning and Teaching
nDiVE n-dive:	Learning across all dimensions
TPV	Third Person View
UNE	University of New England

3.2 Glossary of terms

Artificial intelligence	the embodiment of intelligence in machines
Avatar	a 3D representation of a self in a virtual world
Bot	non-player character which is controlled by a computer
Head-Mounted-Display	device to allow 3D Visualisation of virtual content; user wears the device like goggles
In-world	in Second Life – in the virtual world/space/environment
Machinima	in-world video
Non-player character	an avatar being controlled by the computer
Participants	encompasses all stakeholders who participated in nDiVE
Second Life	one of more than 200 3D virtual worlds
Virtual world	3D immersive electronic presence that imitates real life
Unity	Software for developing games in a 2D/3D environment across platforms

4 Summary

While the higher education community has embraced the use of virtual worlds for teaching and learning, there are many hazardous situations where these virtual environments would provide benefits by enabling users to learn without danger. Meanwhile, the teaching in many of the subjects, involving students that work in these virtual environments, frequently fails to encompass suitably authentic activities and understandings of the nature of the environments. To address this, the nDiVE project explored authentic education in logistics and supply chain management scenarios as part of an Office for Learning and Teaching (OLT) two-year project grant. Unity, a game-based engine, was coupled with various immersive technologies such as the Oculus Rift head-mounted display (HMD), to create several detailed scenarios of operational working environments. Input from industry and academic stakeholders provided guidance in the development of the scenarios, making this an ideal platform for the development of further industry-focused, authentic, and immersive learning scenarios.

Four scenarios were created to thrust the learner into a range of hazardous environments, allowing them to become familiar with the risks and challenges of operating in these environments. Different cohorts of students and young people from a range of backgrounds were tested with this range of scenarios outlining different logistics and operational environments. Students and industry stakeholders participating in the experimental scenarios created a body of in-world data that could be analysed about their experience and perceptions of the environments. The results indicate that, while there are a number of design elements that can be improved and refined, nDiVE is a promising space for education and authentic learning for people who need to work in safe environments, even if the reality is hazardous.

This report draws on research conducted by project team members from Curtin University, Murdoch University, University of Wollongong, Auckland University of Technology (New Zealand), and Graz University of Technology (Austria) over two years from 2013 to 2015. Data was collected through experiments, surveys, observations, and discussions. The research aim was to develop and trial an authentic learning environment that will enable Logistics and Supply Chain Management (L&SCM) students to be better prepared for their professional life. The study set out to provide the higher education community with guidelines and recommendations to encourage the use of currently available immersive technology and virtual environments in logistics and engineering subjects.

The nDiVE environment is open-source and available for educational purposes. The usage of emerging technology and scenarios encoded with Unity requires that educators become familiar with the components prior to embarking on using nDiVE in their teaching context. This will enable them to overcome any technical difficulties they encounter. It is recommended educators consider the extensive documentation developed as part of materials dissemination (that is, scientific publications) and contact the relevant nDiVE team member for support, for example in organising workshops to introduce the philosophy of nDiVE, and induction to the development of new environments. Educators who are not familiar with Unity and the development of 3D scenarios are still able to take advantage of the developed framework, such as the Gamification concepts, the ideas on narratives with integrated Gamification elements, and the use of the emerging technology by applying off-the-shelf applications (or the nDiVE scenarios) to enhance teaching.

This report draws from the existing body of publications. This report is further limited in its scope by the need to comply with mandated report length limitations. Therefore reference to the nDiVE publications for further details is recommended

5 Executive Summary

The OLT project **nDiVE** (Full title: Development of an authentic training environment to support skill acquisition in Logistics & Supply Chain Management) addressed the failure of virtual environments to encompass suitably authentic activities and understandings of the nature of training in virtual learning environments. The research aim was to develop and trial an authentic learning environment that will enable Logistics and Supply Chain Management (L&SCM) students to be better prepared for their professional life. The study set out to provide the higher education community with guidelines and recommendations to encourage the use of currently available immersive technology and virtual environments in logistics and engineering subjects. nDiVE is an acronym representing the idea of

“n-Dimensions in Virtual Environments”

“n-dive: Learning across all dimensions”

(n-dive: enjoy and “dive” as in engagement, get started)

This project developed and trialled immersive virtual environments as an innovative and authentic approach to teaching and learning for practical skill acquisition, with integrated assessment and feedback. The project addressed the largely “inauthentic” pedagogical approaches currently used in classrooms and distance-learning environments.

In a nutshell, nDiVE analysed the short-comings of the virtual worlds, being state-of-the-art technology to implement virtual collaborative learning spaces in education, and advanced with the emerging trend of head-mounted displays for immersive virtual reality. Skill training in virtual worlds lacked a high-level of authenticity; i.e. with respect to control of the avatar and natural interaction with the environment. In a preliminary evaluation, nDiVE verified that technology like the Oculus achieved a full immersion in the virtual environment by eliminating distraction caused by the background, providing immediate replication of head movements, and observing the world from a first person perspective. The technology allowed us to develop an environment that can be self-explored creating unique narratives while scripted events guide the experience along a storyline.

The aim was to develop and trial an authentic learning environment that will enable Logistics and Supply Chain Management (L&SCM) students to be better prepared for their professional life. This requires to learn, practice, and manifest practical skills in a logistics scenario, such that the learner is able to understand the implications of errors. For example, not following protocols can cause harm and fatality to the own person or other colleagues in the environment like ignoring speed limits or placing objects at the wrong location. We demonstrate our “Carrot and Stick” framework on two examples: 1) Tasks on a Container Terminal and 2) Pulling a Bulldozer. In both examples, the learner is likely to fail during the first attempt; yet, there are guided to improve during following repetitions of the same scenario.

The project created multiple outcomes; among other a large number of publications, presentations, and artefacts. All developments are done with Unity and the Oculus Software Development Kit.

- Publicly-accessible environment for authentic education modules.
- Re-usable objects to support the creation of authentic immersive environments.
- Exemplary scenarios to demonstrate the utilisation of human-interaction in authentic immersive environments.
- Scenarios for higher educational institutions in Australia and worldwide.
- Publications describing the project outcomes

Our work on nDiVE led us to create two scenarios. The first one is a container terminal with multiple areas where the learner can possibly have a fatal accident if health and safety guidelines are not followed. The scenario was chosen with respect to L&SCM students to provide a safe side visit and to train correct behaviour in a shared (virtual) space. The second one shows a scenario from a mining site incidence where on bulldozer is pulled out of a mud area. While everyone of the non-player characters is performing according to their protocol, one person is dying. The learner can experience the event from different perspectives and, thus, creating a better understanding of how actions relate to each other.

The software for the the nDiVE environment is accessible through the project website. In addition, the publications and documentation we prepared a rich source that educators and developers can learn from and use to understand how to create an authentic learning scenario. The following documentation has been made available:

- Documentation of principle and guidelines to enable teachers to take advantage of nDiVE, explaining how to develop and integrate learning material and apply authentic teaching and learning strategies.
- Guidelines for effective teaching strategies and integration in the curriculum.
- Business use case of an industry application in health and safety training.

nDiVE was one of the very first projects in Australia using head-mounted displays in the field of Logistics & Supply Chain Management – and also over the wider field of education. The project was showcased through multiple public events of Curtin University and the associated research presented on conferences and workshops in Australia, Europe, and the U.S. We collaborate closely with, among others, Deloitte and Sentience Computing, to understand the industry needs in skill training and how this can be reflected and supported within a virtual space.

The key findings are shown below. We first address the research findings but also provide further insight from the lessons learnt to guide successful future developments.

Key Findings:

- Comparison of how different technology supports immersion.
Second Life (on a traditional computer monitor) and Oculus Rift (using the HMD) scenarios were different in terms of realistic, usable, interesting, engaging, and compelling. There was a statistically significant difference in all cases indicating the cohort strongly believed the Oculus Rift scenarios were better; these scenarios were perceived to be more realistic, usable, interesting, and compelling than scenarios presented in Second Life.
- Self-guided exploration.
Twenty-eight (53.9 per cent) of the participants in the experiment explored the virtual environment before finding the goal. The general feedback was that they enjoyed the opportunity to explore a space that is otherwise inaccessible in the real world.
 - This used gamification techniques and a ‘gamified nudge’ to keep participants ‘on task’ with the learning scenario.
 - Data analytics support this and enable development of formative assessment feedback.
- Large-scale events and a diverse set of participants
During the 2014 and 2015 Career Expo (Perth, Western Australia) many hundreds of

visitors used nDiVE; mainly students in their last two years of High School. This large sample confirmed the earlier findings, but with a much wider group of participants from a more diverse range of backgrounds.

Lesson learnt:

- Scenario design takes resources and time. This probably requires additional instructional designer support. Even relatively simple modifications of existing scenarios will require a reasonable level of technical competency.
- Learning curve associated with using the Unity engine (which underlies nDiVE) – it takes time to learn how to use this effectively. While this is negative over the short term, over a longer period the platform allows an experienced instructional designer to rapidly develop and modify scenarios.
- nDiVE uses short and immersive modules. These are best positioned as an extension of existing material within or in addition to existing curriculum. It is not best used as a replacement for large segments of existing curriculum.
- The possibility of “distraction by technology” was noticed when experienced for the first time. However, the “new factor” wears off within a short time. The design of the environment has to take this into consideration, for example by implementing the previously mentioned gamified nudge to bring students back on the task.

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7 About the nDiVE project

7.1 Introduction

The primary aim of the nDiVE project was to develop and trial an authentic learning environment which enables Logistics and Supply Chain Management (L&SCM) stakeholders to prepare, develop, and evaluate their skill acquisition in readiness for their professional career. The key factors for achieving the objectives in the project were the harnessing of emerging technology for human-computer-interaction (HCI), 3D immersive virtual environments, authentic education, gamification mechanisms, and computer-supported formative assessment. The chosen research methodology followed a pragmatic philosophy as core functionalities had already been developed for various applications. The nDiVE project aimed to synthesise and use these emerging technologies more effectively; that is, enabling the interdisciplinary character with pioneering applications in education. The project was embedded in an academic environment with the inclusion of current students in the classroom, but also future students at career expos and universities' open days; yet crossed over to an application in industry environments for training and learning purposes.

The main deliverable – an immersive environment and theoretical framework – is intended to be integrated into the educational material and teaching context as modules that allow the stakeholders to experience the practical implications of theoretical models or processes. The emphasis hereby is set on learning and training in distinct skills in an authentic scenario and situation, and to provide academic and training institutions with educational tools to enhance continuous learning and (professional) training. nDiVE is first demonstrated in the domain of logistics, yet the outcome is also intended to guide future developments of virtual environments in other industries. In the medium and longer term, this project aimed to develop and enhance pedagogical approaches in self-guided learning, game-based learning, understanding the perceptions of stakeholder and creating a direct impact on the learning retention through the provision of formative feedback, analysis of actions in comparison to other learners, and by that individualising the learning experience.

The project also aimed to develop good working practices to develop future environments and scenarios to engage learners in an immersive and authentic 3D virtual environment. The deliverables are designed to facilitate authentic teaching practice to embed in future curriculums as modules. nDiVE included early interested stakeholders from various disciplines, including operations management, construction, logistics, mining, and facilities management to receive timely feedback during the development of the environment. nDiVE used an iterative development process to create working prototypes. The prototypes were exhibited and verified at closed and public events across academic institutions and academic bodies. The explorative character of this study, with the inclusion of emerging technology required evaluation from a broad range of participants, resulted in the inclusion of a broad interdisciplinary group of researchers and participants. The research progressed with a multi-institution and researcher team, supported by a number of Higher Degree Research (HDR) projects and doctoral researchers (Marko Teräs and Ali Fardinpour). The research is continuing beyond the scope of the project as Marko Teräs progresses in his doctoral research (the anticipated duration of this HDR project is four years); as a result, only preliminary outcomes have been included in this report. See Section 13 for an overview of options to follow future developments and outcomes of nDiVE.

7.2 Project plan

To achieve the overall aims of the project, the research was segmented into the following stages. Note that some activities occurred over the whole project duration and are not explicitly stated. These are:

- Dissemination: Updates on social media and other online media, publication of articles in journals and at conferences, collaboration on international workshops, public events. A complete list is given in Section 12.3. Noteworthy are public events organised by the universities; including open days, post graduate expos, and career expos. We further achieved some non-academic publications demonstrating the project and research initiative.
- Meetings with the project team. These meetings occurred in person and online in various constellation depending on the given tasks in mind. Summaries and project updates were shared among the team.

7.2.1 Stage 1 – setup, refinement, status quo

- Project partners and manager meet to decide on the project coordination, communication, and organisation.
- Finding a qualified evaluator for the project.
- Refinement and finalisation of research goals and deliverables, including the vision of the final outcome and value for educational institutions and industry.
- Developing consensus amongst the partners on the pedagogical and assessment principles to guide the development process, selection criteria for technology, and options for the scenarios to evaluate the prototypes.
- Setting focus on authentic education, gamification, and technology-supported immersive environments for an engaging learning experience with high learning retention.
- Design for the implementation of initial prototypes to experimentally evaluate the acceptance of 3D virtual environments and, in particular, emerging technology to enhance the HCI and immersion of the learner.
- Establishing broad requirements for the scenario design with respect to the disciplinary learning objectives, the key skills required to acquire during learning sessions, and the explorative learning model. The learning objectives distinguished between educational and professional training expectations. Discipline experts as well as industry representatives were involved in this process to ensure authenticity and coverage of mandatory requirements.
- Definition of research tracks for HDR students associated with the project: 1) formative assessment of human actions in virtual environments; and 2) phenomenological study on perception of virtual training environments in industry training scenarios.
- Defining roles of the nDiVE team based on their skill and knowledge to support the progress of the project. See Section 7.3 for more details.

7.2.2 Stage 2 – Research, implementation, evaluation

- Reviewing literature on the areas of interest stated above.
- Establishing the research methodology for authentic education in the context of L&SCM. The ethics approval number for the project is **IS_13_10** (nDiVE-BOTS in educational virtual worlds, Curtin University), **IS_14_08** (nDiVE-DR on a Container Terminal, Curtin University), and **IS_13_12** (nDiVE-VR in educational virtual worlds, Curtin University).
- Designing authentic learning, teaching, and assessment scenarios.

- Implementation of the first scenario: Container Terminal (CT1).
- Designing authentic learning tasks.
- Creating technology to record in-world protocols for replay (resembling Machinima).
- Conducting experiment on CT1 with focus on explorative learning.

7.2.3 Stage 3 – Refinement, scenario, formative evaluation

- Implementation of the 3D virtual world and the agreed model with cohorts of students from the partner universities as well as industry stakeholders.
- Collecting data about the performance of CT1:
 - Internal data protocolled during the experiment (non-traceable to individuals).
 - Observation of the participants for areas of improvement.
 - Listening to participants during the experiment (loud thinking).
 - Inviting experts from educational institutions and industry for a round table talk. The discussion outcome was used to improve the scenario CT1, but also outline the refinement for the next iteration/version.
- Refinement of CT2 and expert evaluation, mostly performed in one-to-one settings as well as round table meetings.
- Continuous improvement of CT2 in an iterative process.
- Conducting experiments as part of the doctoral theses. See Sections 8.1.5 and 8.1.6.

7.2.4 Stage 4 – Analysis, reporting, and final evaluation

- Extensive experimentation with a large cohort outside of classrooms to receive informal feedback from non-biased groups.
- Demonstration and evaluation by experts with academic and industry background. Among others, this included external partner from Deloitte (Coert du Plessis), Sentient Computing (Doug Bester), and the HIVE at Curtin University (Andrew Woods, Joshua Hollick); but also national and international colleagues being invited to test and provide feedback on the development.
- Integration within the curriculum. This has been delayed due to lack of appropriate class and challenges with planning and resourcing. An ideal integration would be within a capstone unit; however this was not possible for organisational reasons.
- Dissemination in numerous articles and industry outlets. This was a continuous process extending throughout all stages.
- Final report on the project.

7.3 Project team and roles

The seed for the nDiVE project was planted in 2008 with the creation of container terminal mock-up development in Second Life to engage students in topics in the discipline of L&SCM. The project leader, Torsten Reiners, continuously explored related topics, yet the technological development to create authentic and highly immersive learning experience was not sophisticated enough until the time the project was proposed. Key arguments for a positive prospect of nDiVE were the successful development of tools in the VirtualPREX project, the technological development of programming tools for virtual environments, and the release of immersive technologies at consumer prices. Note that VirtualPREX refers to the finalised Australian Learning and Teaching Council-funded project, lead Sue Gregory, with the title “Virtual Professional Experience: Innovative assessment using a 3D virtual world with pre-service teachers”, see www.virtualprex.com for more information. The final puzzle piece was the initial collaboration with authentic education experts to create a team

with experts in all required disciplines to develop and implement nDiVE. While the project was carried forward by Lincoln Wood and Torsten Reiners, the success of nDiVE depends on the consultation and involvement of each team member, and especially the HDR students with their ongoing project support and engagement in their research topics.

7.3.1 nDiVE team members (core):

- **Torsten Reiners, Curtin University**
Lead, main developer, responsible for running demonstrations and experiments of nDiVE.
- **Lincoln C. Wood, Auckland University of Technology** (formerly Curtin University)
Co-lead, responsible for disciplinary knowledge and its implementation.
- **Hanna Teräs, Murdoch University** (formerly Curtin University, University of Wollongong, Tampere University of Applied Sciences, Finland)
Authentic education, game-based learning.
- **Jan Herrington, Murdoch University**
Authentic education, design of authentic learning tasks.
- **Vanessa Chang, Curtin University**
Experimental design, assessment, interactive learning experiences.
- **Sue Gregory, University of New England**
Distance education using virtual environments.
- **Christian Guetl, Graz University of Technology, Austria**
Simulation and game design, gamification.

The nDiVE project team was initially dispersed across Australia, Finland, and Austria, with the majority being located in Perth, Western Australia. The team members' location changed at multiple occasions:

- **Hanna Teräs** moved from Tampere, Finland to Wollongong (Year 1) then to Perth (Year 2).
- **Lincoln C. Wood** moved from Perth to Auckland, NZ.
- **Christian Guetl**, even though being generally in Graz, Austria, travelled regularly to Perth for research visits (two-month periods).

Due to the experience with virtual environments and communication through virtual means (Hangout, Second Life), a decision in favour of online communication and meetings was made over the otherwise required travel arrangements.

7.3.2 nDiVE associated PhD students

- **Marko Teräs, Curtin University (scholarship supporting nDiVE)**
The lived experience of an authentic context in virtual training environments in hazardous settings: Phenomenological approach
 - While many technologies can be used, the concept of “immersion” depends on the lived experiences of the people involved; two individuals with different backgrounds and philosophies can share a single experience but perceive it very differently. This project analyses the experience of individuals using a phenomenological approach to develop theories to support the further development of immersive technologies to ensure that they are more human-centred.

- **Ali Fardinpour, Curtin University**
Taxonomies for human behaviour, developing modules to evaluate the behaviour in the nDiVE environment and provide formative feedback.
 - Moving towards automated assessment, providing rapid and objective formative feedback for learners, requires substantial work in developing appropriate models. This work in developing taxonomies for behaviour supports further automated assessment and also provides a framework for manual assessment by experts.
- **George Coldham, Curtin University**
The effectiveness of “off-the-shelf” immersive technologies on the learning experience.
 - While there are many emerging technologies available, they are not all created equal, nor do they share all the same characteristics. This work evaluates a wider range of technologies and provides significant input into further development in the use of virtual immersive environments by generating a roadmap for further technology use.

7.3.3 Support at Curtin University and partner universities

Over the project duration, the project team received endless support from many professional and academic staff at Curtin as well as the partner universities. This list is long; however we highlight here the key people who had a major impact by taking much weight off our shoulders regarding administration, and supported us with countless invitations and opportunities to present the project.

- **Karen Clarke** for always being there if it came to budget and administration.
- **Julie Kivuyo** for outstanding support in intensive periods and provision of marvellous feedback on our writing attempts.
- **Natasha Petter** for supporting the team as a project manager in its first stage.
- **Sharon Iannello** for supporting the team on events at Curtin, such as the Festival of Learning stand.
- **Asha Selvandra** for support on events outside of Curtin such as the TEDx stand.
- The whole **HIVE** team, but especially **Joshua Hollick**, for support and “critical” feedback to our programming attempts.
- The **ORD** team for the support in their interface role.

7.3.4 The project nDive: Brief Introduction

“n-Dimensions in Virtual Environments”
 “n-dive: Learning across all dimensions”
 (n-dive: enjoy and “dive” as in engagement, get started)

This project develops and trials immersive virtual environments as an innovative and authentic approach to teaching and learning for practical skill acquisition, with integrated assessment and feedback. The project addresses the largely “inauthentic” pedagogical approaches currently used in classrooms and distance-learning environments. It proposes a methodology utilising existing and emerging technologies in creative and innovative ways. The simulation combines emerging technologies to project multiple business dimensions into one space, enabling students from different disciplines to observe, engage, interact, and participate in self-guided or group-based learning scenarios, receiving instant, multi-perspective, and rich feedback to support their learning, which enables iterative scenario-based training in a safe environment. Experiments and evaluations are executed on supply

chain scenarios where, in reality, business dimensions such as space or time impose difficulties in understanding impacts of decisions. The virtual space is a low-risk environment where there are no consequences in case of errors due to lack of skills, unfamiliarity with the environment, or exposure to unlikely situations.



Figure 1: Evolution of the nDiVE logo during the project duration.

The philosophy of nDiVE was an immediate dissemination of project findings to other academics and professional stakeholders. This sections show excerpts of the research over the past years, based on the published articles listed in Section 15.1. For further reading with a focus on nDiVE, refer to the cited articles [x] at the end of each section. Detail of the article can be then found in Section 15.1).

7.4 nDiVE environment and framework

This section describes the scenarios developed during the project. The description is kept non-technical to address a broader audience. The implementation of the scenarios with the exception of the Second Life scenario can be requested by the project team of nDiVE. Objects and algorithms are coded for reusability, thus future adaption and extension of the nDiVE environment was part of the development process.

7.4.1 Second Life warehouse

According to the proposal, the initial scenario is set in a warehouse and was created in Second Life. The design consisted of an enclosed space with three shelves, a selection of different fork lifters (with a variation in the maximum allowed load), a computer area, a gate with a waiting customer, as well as some container terminal actions being executed in the background. The user could explore the warehouse and interact with different objects, including selecting and driving the forklift, requesting the next order to process from the computer, and delivering a box to the customer. Caused by limitations of Second Life regarding the design and interaction with objects, the forklift was not able to pick objects from the shelf. Instead, driving in the correct aisle placed the order on the forklift.



Figure 2: Screenshot of the Second Life scenario “warehouse”.

Figure 3 shows the gold standard workflow for this scenario. Starting at position (0), the user has to access the computer (1) to receive the details of the order, including the shelf position, dimension, weight, and customer name. Next, the correct forklift has to be chosen (2), maximum weight limit must exceed the order weight), and driven to the correct aisle (3). Finally, the order has to be delivered to the customer (4).

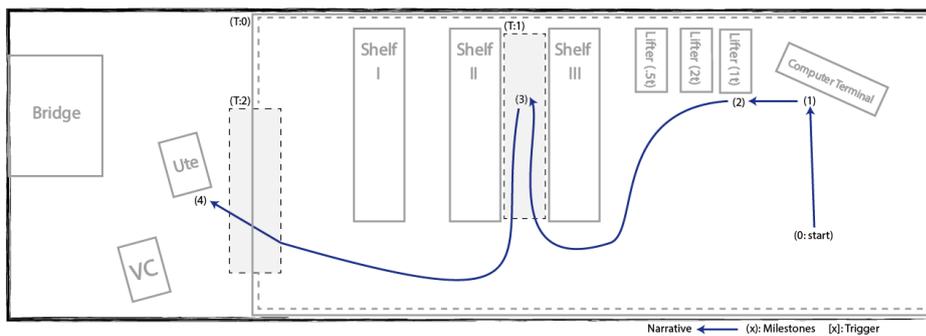


Figure 3: Gold standard of the workflow for the Second Life scenario “warehouse”

Annotation: The project team developed the warehouse scenario and used it in the “Technology Perception Experiment”. Yet, the main experiment about observing a larger cohort in this scenario (with respect to a self-guided exploration of the space and its functionality) had to be abandoned. The project used a provided space on Second Life’s “University of Hamburg” Island, but the administrator was not informed about the ending contract between Second Life and the University of Hamburg. The island – and therefore all its content – was deleted without warning. Furthermore, Second Life does not provide backup functionality, therefore the project was not able to regain access to the data. In addition to the outcome of the experiment, this event was considered as a strong argument to shift towards Unity and non-server based development.

Figure 4 visualises observations made during other experiments. In contrast to the ideal process in Figure 3, the initial exploration of the space seems unstructured, with only a few reoccurring patterns. This is, attraction to the forklifts and the gate, where they received some indication (1) to focus on the given task to look up the order (2) and deliver it to the customer. The further process included the selection of the wrong forklift (3), driving to the wrong aisle (4), not being able to pickup the order due to weight limits (5), having to come back (7) with the correct model (6) to finally serve the customer (8). The set of observations resulted in the design of the container terminal scenario as well as the self-guided exploration of the space with some guidance; that is, gently pushing the learner in

the direction of the next step.

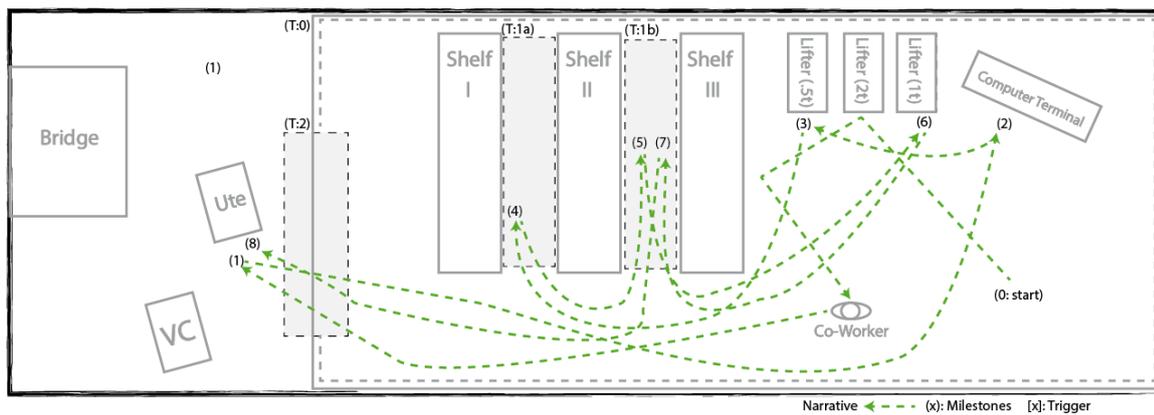


Figure 4: Observation of participants made during experiments using the Second Life warehouse scenario

7.4.2 nDiVE container terminal – version 1 (CT1)

The objective of the scenario CT1 relates to the identification and comprehension of occupational safety and health risks within a container stack on a terminal. Figure 5 shows the layout of the scenario, and Figure 6 indicates the type and context of the eight potential safety and health risks designed for the self-guided exploration of the virtual learning spaces experiment.

This choice of risk types is based on discussions with experts as well as previous projects conducted by team members. The scenario is intentionally designed to cover only a small area to allow full exploration; artificial boundaries are used to restrict learners' freedom to relevant areas. This is feasible and represents the focus of the inspector during the investigation. The following list explains the risks (numbering refers to Figure 1) in greater detail, focusing on how the participants can identify hazards and report them. Note: These eight risks represent general categories, instantiated to the container terminal, and are later reused in variants of the scenario. An instantiation within a different disciplinary context is considered and anticipated.

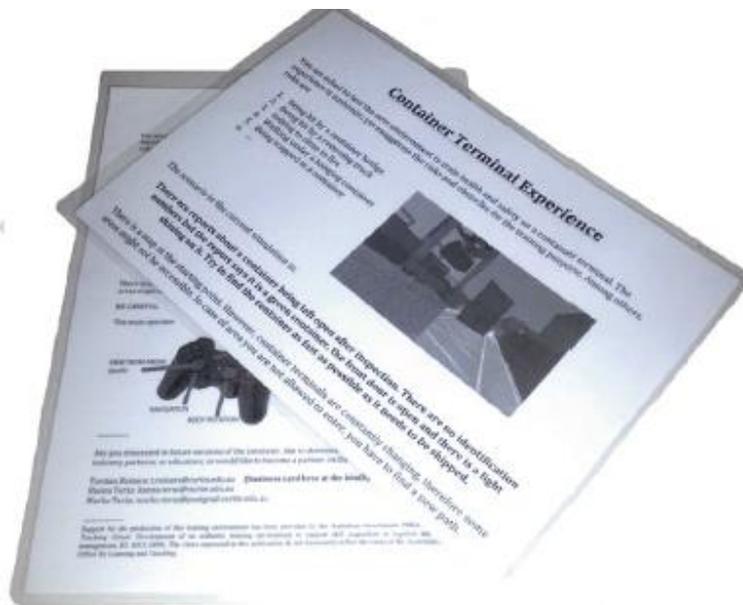
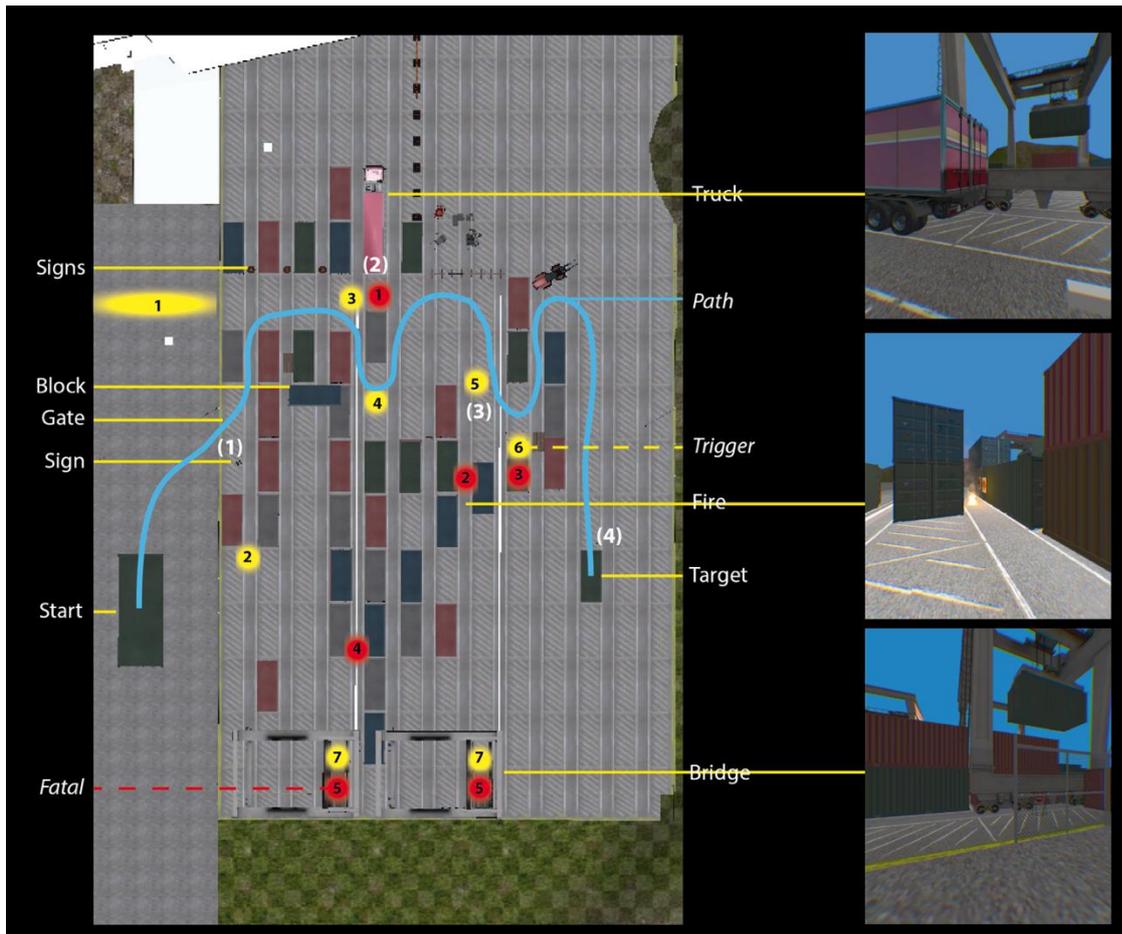


Figure 5: The layout of the scenario (top) shows the fixed setup to direct the participant towards an ideal pathway (shown during the induction (before wearing the HMD) on a paper-based map (bottom). The yellow triggers are used to pass messages to the participant (for example, 1 - heading off in the wrong direction) or initiate actions (for example 3 - start reversing the truck). The red numbers represent potential risks of getting injured or killed and generally resulted in a failure of the scenario.

1. **Being hit by moving objects while emerging:** Missing floor markings can lead a worker to believe that it is safe to continue walking. If the worker continues to walk, the forklift will hit and injure the worker.
Outcome: Injury or death.
Method of prevention: Stopping at the end of the aisle and looking for traffic.
Identification: Centering the view on the area with the missing marks and taking a photo/screenshot (built-in camera).
2. **Hit by a moving object in a restricted space:** Cranes and straddle carriers operate in container stacks and the view into an aisle may be blocked during operation as the operator does not have clear view at all time.
Outcome: Injury or death.
Method of prevention: Contact should be established with the operator via radio before entering the aisle.
Identification: Use either the radio to report the hazard or the computer to mark the aisle as blocked so that operations in the area are placed on hold.
3. **Crushed under an object:** While moving in the container stack or accessing a container, the crane might place a container on you due to poor visibility.
Outcome: Death.
Method of prevention: Contact the operator via radio before entering the apparently empty area.
Identification: Use either the radio to report your location or the computer to check on operations in the area.
4. **Faulty material:** Cable or locking bolts might fail if regular maintenance was not undertaken. Here, the cable snapped and the container dropped at a location deemed to be safe.
Outcome: Injury or death.
Method of prevention: Prioritise maintenance and check for irregularities; for example, sounds or suspicious configurations.
Identification: Use the computer to check maintenance dates and report suspicious sounds/sights.
5. **Dangerous Goods:** Dangerous goods require special handling and may not be located within certain proximities to some locations or objects. Failure can cause tremendous danger and damage, for example, if containers are broken and contents emerge.
Outcome: Injury or death.
Method of prevention: Verifying content and location before placing the container, inform appropriate co-workers about health and safety issues regarding container classification.
Identification: Centering the view on the area with the labels while taking a photo/screenshot.
6. **Error by humans:** Even after identifying and marking the risk areas, risks remain in most environments. One immediate problem is human error, for example, incorrectly estimating the height of the container stacks resulting in one container knocking another off the stack and onto a passing worker.
Outcome: Injury or death.

Method of prevention: Stay alert and observe the surroundings. Have someone else to support you doing this.

Identification: Writing a report identifying additional risks. Taking a photo/screenshot of the area that is associated with the report.

- 7. Endangering a colleague:** Inspection of containers requires workers to open and enter containers. Non-communication can cause a colleague to close an open door, whereby their colleague may be trapped inside.

Outcome: Psychological harm (to co-worker), injury or death (to yourself).

Method of prevention: Inspecting the container before closing the door. Colleague might not react to your voice as they may be wearing “noise-cancellation” headsets. Instead, use visual signals such as a flashing light. Require employees to indicate with a sign when someone is in the container.

Identification: Centering the open door while taking a photo/screenshot.

- 8. Being trapped:** Similar to scenario seven (“endangering a colleague”), but in reverse, where a colleague endangers the learner.

Outcome: Psychological harm, injury, or death.

Method of prevention: Stay alert and observe the surroundings. Have someone else outside monitoring activities.

Identification: Writing a report identifying additional risks. Taking photo/screenshot of the area that is associated with the report.

Other features include:

- Restricted time to solve the task, visualised in the upper right corner.
- Recording of all events in a log-file in a defined time interval (default: 0.25 sec). This includes time index, current position, direction of the body, vector of the head, current object in the centre of the view, messages to the participant, special events.
- Trigger causing a visual or audio feedback, for example, showing a message in the display or playing a sound. Furthermore, trigger causing other objects to move or process a fixed set of activities.
- Observation of the activities on a screen to provide interactive feedback.
- Non-context related object to create points of interest/distraction (for example, signs) or pure decoration (for example, objects in the background).

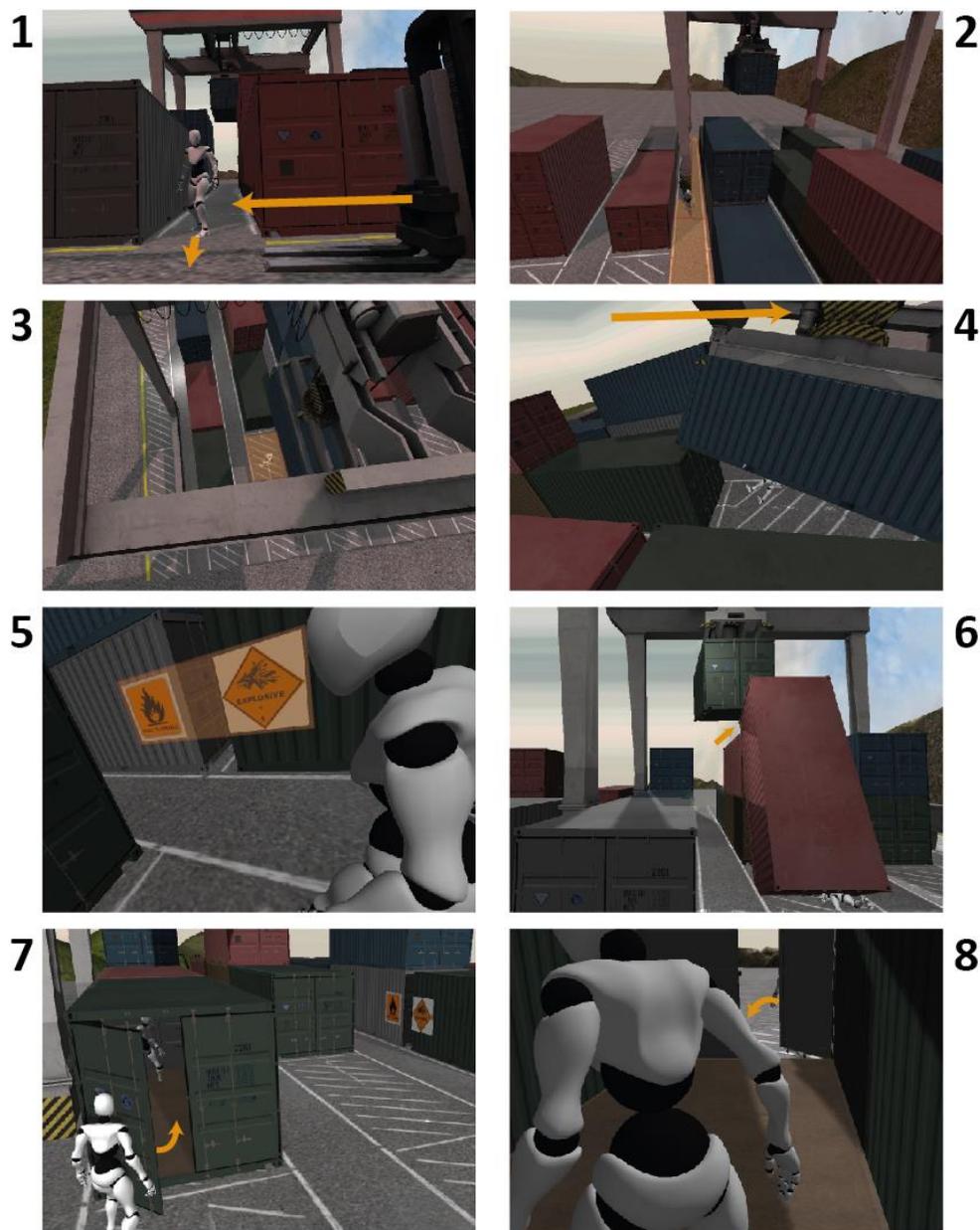


Figure 6: Visualisation of the different situations on the terminal. (1) hit by emerging vehicle, (2) hit by crane in aisle, (3) crushed under container, (4) faulty material, (5) dangerous goods, (6) error by humans, (7) endangering a colleague, (8) being trapped

7.4.3 nDiVE container terminal – version2 (CT2)

The feedback on CT1 from different stakeholders (that is, students, academic staff, industry experts) resulted in the following changes in the design:

- The first scenario did not use a visualisation of the body. Thus, participants felt disconnected with their avatar when looking down during the experiment using the HMD. It was decided to use the featureless avatar shown in Figure 6: Visualisation of the different situations on the terminal. (1) hit by emerging vehicle, (2) hit by crane in aisle, (3) crushed under container, (4) faulty material, (5) dangerous goods, (6) error by humans, (7) endangering a colleague, (8) being trapped, to prevent gender discussions in the experiments.
- While the default camera position was first person view (FPV), with camera

positioned relative to the eyes' locations, a significant number of requests were made during preliminary runs to allow a third person view (TPV) as well. Here, the camera is static a short distance behind the avatar (1m behind and 20cm above the head). The TPV was only activated on request.

- The first scenario excluded a visualisation of the dying sequence, but displayed a message about the cause. The message was replaced in the following way: In case of a fatal accident, the camera is shifted from FPV to TPV such that the participant can see the avatar dying. The message itself is placed outside of the participant's view to force an active move of the head see it. This enabled a brief moment of reflection about the cause of the death rather than being confronted immediately with the result.
- Failure does not result in a stop of the simulation as was the case in the scenario CT1. Here, the avatar can be resurrected (resulting in a penalty for the final result) and continue with the objectives.

The layout of the scenario is not fixed but based on initial layout descriptions. Figure 7 shows the layout used in the experiment. The yellow markers show risk areas, some of them being on the anticipated pathway according to the provided map and information from the bot. The other markers indicated risks in areas used for distraction from the objectives, as well as reminders on the need to follow instructions as deviation might have severe outcomes.

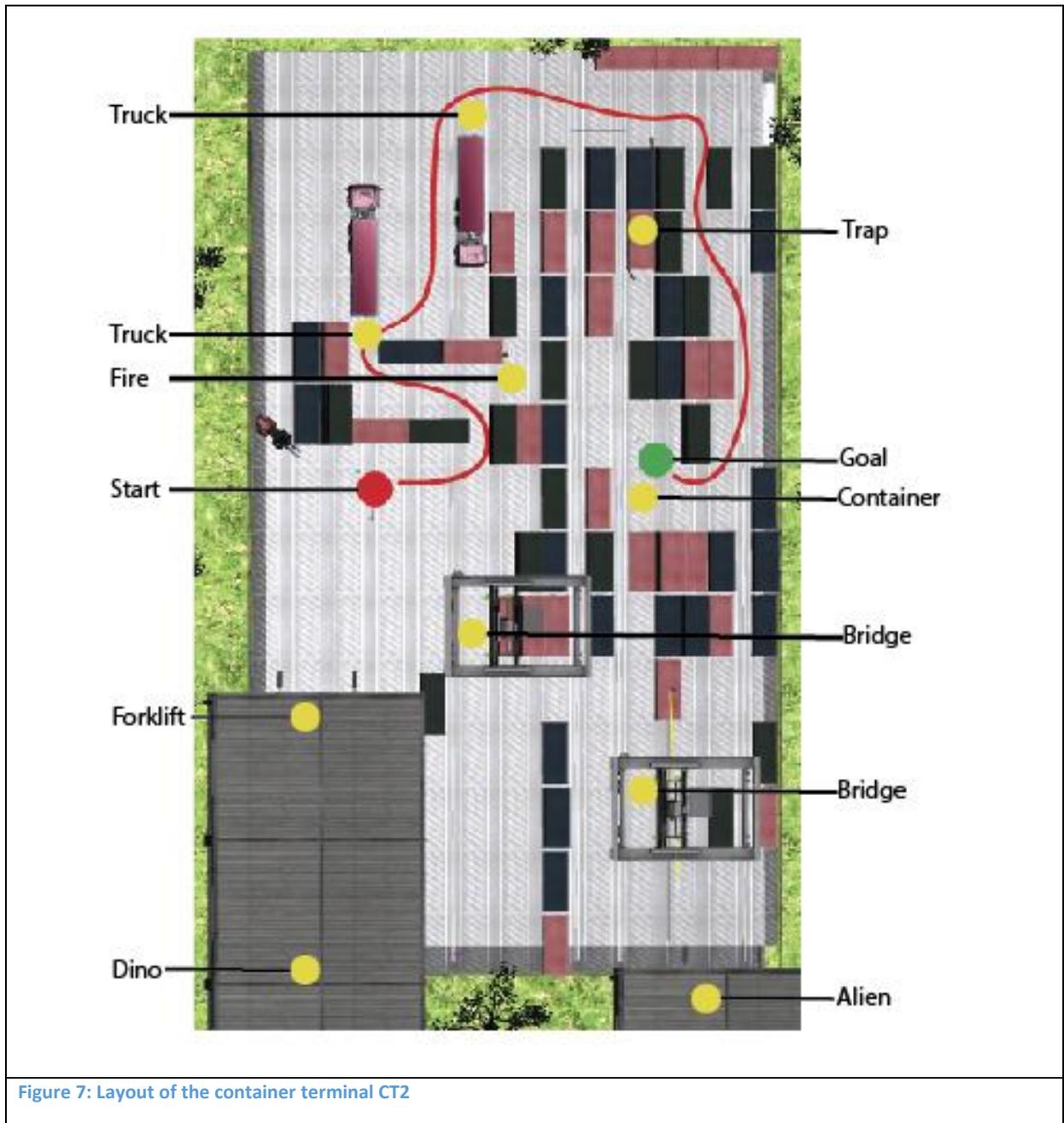


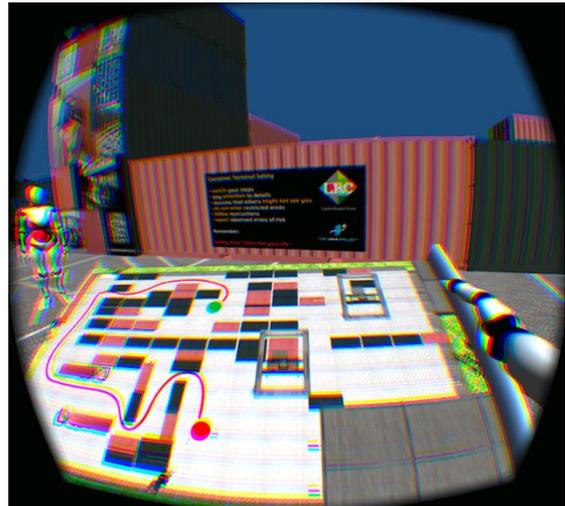
Figure 7: Layout of the container terminal CT2

The guidance and support in the environment were changed to have an increased level of support as well as tools to navigate around the terminal. Figure 8 shows some examples: (1) integrated reminder of risk situations (here a reversing truck), (2) advanced information about the layout and current location on a map (unfolded by the user via the controller), (3) bots provide guidance on request and information boards remind of the objectives and instructions, (4) information about the cause of death, (5) higher fidelity and realism of operations (container bridges shift containers according to a working plan) and (6) “easter eggs” as part of the gamification.

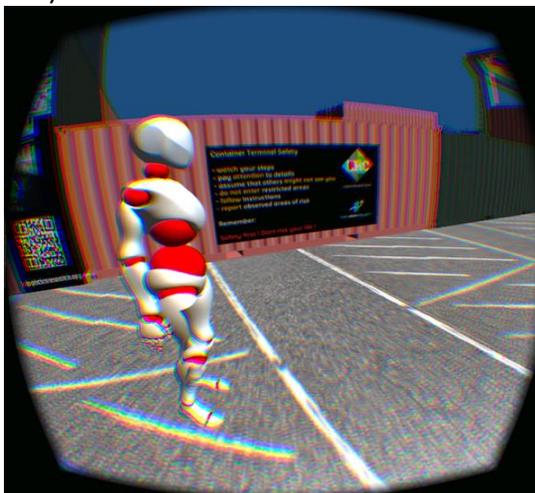
1) Reminder



2) Interaction, Information, Map



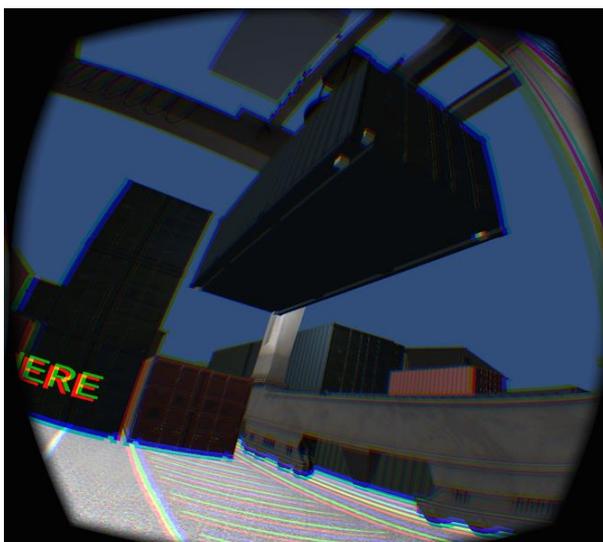
3) Bots and information boards



4) Cause of failure



5) Higher Fidelity and Realism



6) Gamification

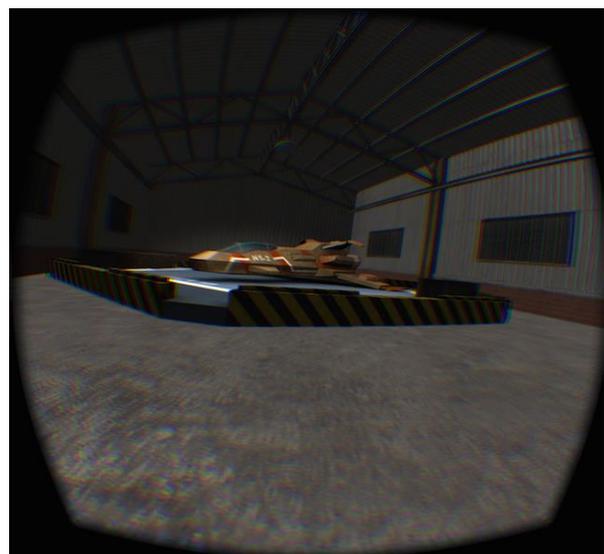


Figure 8: Examples for the scenario CT2. Note: the distortion and false colour results from the screenshot of the HMD version.

From a technical perspective, CT2 is a complete redevelopment of CT1 with focus on reusability of objects for simulations in other disciplines. This includes in particular the following components:

- Advanced avatar that can be controlled using various input controls (PlayStation controller, keyboard, mouse, Razer Hydra) and output channels (Oculus 1, Oculus HD, monitor in 2D), different animations for dying and interaction, visualisation of maps, arm and hand control using the Razer Hydra, FPV and TPV, and walking in all directions including backwards.
- Advanced logging of events, including all objects, coordinates of avatars, location and direction of the Oculus, object in the view, interactions, messages, trigger, and environmental changes.
- Simplified trigger system to integrate interaction in the scenario.
- Generator to setup scenarios based on a layout description file.

7.4.4 Bulldozer recovery

The bulldozer recovery scenario results from the project's collaboration with Deloitte and re-creates a real-life scenario. The given challenge was the transfer of a training video to an interactive module using the HMD and an educational context to be used as an induction training module. Re-using modules from nDiVE and the Unity object library, the project team was able to develop the scenario within 48 hours for a demonstration at Deloitte.

The scenario has the following steps, where four workers are involved (W1-W4) in the recovery of the green bulldozer (GB) using the yellow bulldozer (YB) to pull with a rope.

- Each worker is positioned to the original real-world scenario. W1 is responsible for the connection of the rope at YB, W2 is operating YB, W3 is waiting at the side to check GB for damage. W4 is not involved and mainly observing.
- W1 connects the rope and signals W2 to move forward.
- W2 moves forward until GB is out of the mud area.
- W2 stops the engine.
- W1 tries to detach the rope.
- W3 walks to GB and checks the chains.
- W1 is not able to detach the rope and signals to stop the engine.
- W2 misinterprets the signal (or does not see it) and moves forward.
- W3 is caught in the chains and killed as GB rolls over W3.

During the induction, different modes can be played.

- Take the role of any worker and keep this during the whole simulation.
- Take the role of the currently active worker, with an automatic switch of roles.
- A trainer is making the switch in roles while explaining the situation.

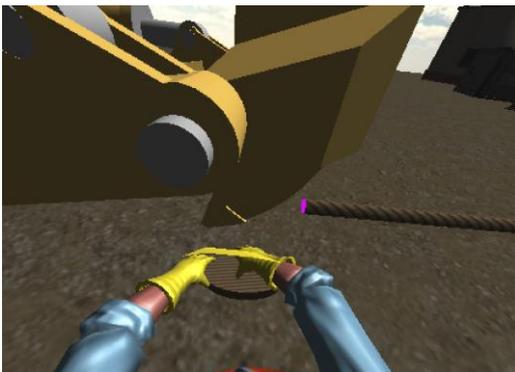
The strength of the HMD implementation vs the video is in the limited view of each worker. While the video is showing every activity from a distant perspective, including coloured areas to point out blind spots, the simulation with the HMD feels realistic as no artificial marker indicates a concern or supports the decision-making process. In the role of W2, the user realises the difficulty of turning around and identifying the signal made by W1. This restricted view was intensified when the moveability of W2 was further restricted in such a way that W2 behaves as if wearing a safety belt.

The most intensive experience happened with W3; that is, if no more was explained in advance than the objective of W3 (checking the chains), users were surprised when they realised their mistake of going to the GB without confirming safety.

1)



2)



3)



4)



1. Initial scenario setting with the green bulldozer in the mud area and the yellow one being ready to pull.
2. Worker is connecting the rope to the bulldozer.
3. The yellow bulldozer is pulling the green one out of the mud area.
4. The worker, who began inspecting the green bulldozer, was fatally injured after the rope could not be disconnected and the yellow bulldozer kept moving.

Figure 9: Screenshot for the bulldozer-scenario

7.5 nDiVE: Background and Further Details

The causes of the existing skills gap between the qualification of graduates from educational institutions and industry expectation have many dimensions. Among others, the classroom faces students from diverse backgrounds and sometimes with dissimilar needs (Wood & Reefke, 2010). Learners are individuals with unique behaviours, skills, experiences, and effective learning approaches are required to teach how to process information and acquire knowledge that is needed to make sophisticated decisions in known and, especially unknown, situations. The individual must be acknowledged for an effective and efficient learning process, a condition that is generally not achievable in classrooms or on-the-job training with respect to available resources such as time, staff, and generalised learning material that must be *fit-for-all*, and not *made-for-individuals*. In addition, classrooms lack authenticity. Learning from a book or video does not necessarily prepare a student for the tasks and challenges they are likely to experience in their professional life. Instead, many students struggle to go from the “academic” understanding of theory to an understanding of “practice”.

The moment of truth for a learner occurs when the acquired knowledge and trained skill-set has to be recalled, practised, and performed outside of the safe environment found in the classroom. Reality is not providing the corsage of experimental setups where the experiment serves the demonstration of learnt theory, but includes all the side effects that influence the outcome. The guidelines in textbooks, or instructions in the classroom, are replaced with an unsupervised environment where decisions include the selection of tools and methods as well as further attributes such as sequences, colleagues, safety, resources, effectiveness, or efficiency. In a real-world setting, failures can result in serious consequences; there is no reset button or option to go back in time for another run.

7.6 Terminology and embedding into literature¹

In this report, we restrict the discussion to the authenticity, immersion, and gamification in the context of virtual environments as an extension to the traditional utilisation of virtual environments in the teaching context (for example, Second Life). For more details on the current state of the art on virtual worlds and virtual spaces in education in Australia, please refer to the publications in the Australian Virtual World Working Group (www.vwwg.info), state of the art publications by Gregory et al. (2013, 2014, 2015) published annually at the *ascilite* conference, and other publications (for example, Callaghan, McCusker, Losada, Harkin & Wilson, 2013; Huber & Blount, 2014; Gregory & Masters, 2012; Jarmon, 2012). nDiVE is being designed to build on experience and knowledge in virtual environments and authentic education held by the project partners, developing an environment to evaluate the advantage of immersive and authentic virtual environments and its efficient and effective integration in the classroom.

7.6.1 Immersive learning environments²

Immersion is “the subjective impression that one is participating in a comprehensive, realistic experience” (Dede, 2009, p. 66), whereas the experience does not depend on how or with what means the immersive presence was created. In this research, the project team further advanced the perceptual immersion (Biocca & Delaney, 1995), by using head-mounted displays such as the Oculus Rift (Oculus, 2013) to submerge a user into a virtual environment. nDiVE acknowledges a broader understanding of information such as the

¹ For further reading on the general theme of nDiVE: [20, 25, 26].

² Further reading on immersion: [2, 6, 11, 13, 20].

ability to “draw people in” (Jennett, Cox, Cairns, Dhoparee, Epps, Tijs, & Walton, 2008, p. 641) using a technology-generated immersion (Palmer, 1995), as well as basic psychological immersion using a gamification mechanism as an incentive to create deep engagement in the scenario (Witmer & Singer, 1998; Brown & Cairns, 2004). Brown and Cairns (2004) report that players use immersion as a term to describe three levels of involvement with games – engagement, engrossment, and total immersion. They noted that “each level of involvement is only possible if the barriers to the level are removed” (Brown & Cairns, 2004, p. 2). The convergence of video games and immersive virtual environments, namely, game design mechanics used in immersive virtual environments mediated by a head-mounted display and other controls promoting more embodied user experience, is taking research into new directions.

7.6.2 Authentic education and realism³

Authenticity is the representation of real-world tasks. When these are re-created in virtual environments, realism (exactness in visualisation) and fidelity (exactness in functionality), become essential as authentic activities mirror the “kind of activities people do in the real world” (Herrington & Kervin, 2007, p. 223). In authentic learning activities, students find and solve problems with the “complexity and uncertainty of the real world” (Herrington, 2006, p. 3). Simulations and virtual environments provide spaces for authentic learning experiences to occur where real-life costs and consequences are avoided (Gregory, 2011). The authentic simulations should be realistic and the relevant activity emerges due to the interaction between the participants, the simulator, and the context (Rystedt & Sjoblom, 2012, p. 785).

It is imperative to ask the following question which is driven by emerging cost-sensitivity in most educational environments: How much authenticity and realism is “enough”? This is an important question addressed in nDiVE as there is still little understanding of the level of authenticity and realism required within such environments to sufficiently deliver the learning material. High fidelity means that the environments resemble real life to a high degree or duplicates it (that is, if a very realistic simulation is used). Low fidelity environments and tasks are frequently good enough; learning environment and tasks can be simplified as long as they meet the same tasks criteria (that is, the same output and results are expected), the same social context (is the task in cooperation with certain stakeholders or not?) and the same physical objects (which objects are available in normal life). The degree of fidelity influences the depth of immersion. Immersion means that “the greater the participant’s suspension of disbelief that she or he is ‘inside’ a [...] setting” (Dede 2009, p. 66) the more immersed they are. Distinctly, there is perceptual immersion: “the degree to which a virtual environment submerges the perceptual system of the user” (Biocca & Delaney 1995, p. 57) and psychological immersion, the degree of feeling of involvement and enthrallment caused by stimuli (Palmer, 1995). Realism is about the *perceptual* immersion and the authenticity is often related to *psychological* immersion; however, some moderate degree of fidelity is likely to be required. But how much? The greater the fidelity, the greater the perceptual immersion is likely to be, and therefore, supporting the immersion and engaging in the learning process.

Technology support is often considered to raise the level of realism in the classroom, even though the focus is mainly on course management, monitoring data, or managing students. Rather than being used as a support for improved learning, it is often incorporated simply as a platform for a teacher-centric method of information delivery to students. In this mode, the adoption supports a low-level of cognition, with a strong focus on remembering information and impeding higher levels of cognition (Anderson & Krathwohl, 2001). The

³ Further reading on authenticity and realism: [5, 6, 11, 14, 20, 21].

project team asserts that technology must be used to push towards learner-centric classroom environments, such as, supporting the HCI-like head-mounted displays (HMDs) or gesture recognition systems.

In nDiVE, the focus is set on authenticity by technology support; creating a replica of the real-world reduced to its core functions and objects interacting with each other. Even though authenticity is not requiring high-fidelity and realism, the enhancement in technology resulted in a steady convergence of virtual and real-world look-and-feel.

7.6.3 Gamification in authentic environments⁴

There are now many definitions of gamification, however some are too concise (fun, play, passion) or too specific with strong reference to gaming mechanisms (Deterring et al., 2013, 2011; Kapp, 2012; McGonigal, 2011; Zichermann & Cunningham, 2011). For nDiVE, a simple, comprehensive definition was proposed, unrestricted in its application, environment, or discipline: *“Gamification is a designed behaviour shift through playful experiences”* (Reiners & Wood, 2015).

Gamification and the incorporation of game-based elements are particularly useful within authentic learning environments (Wood, Teräs, Reiners, & Gregory, 2013). Together, they can complement authentic assessments to help learners develop complex and valuable skills and encourage greater self-directed learning to take place. In this way, the project team considers that Gamification within authentic assessment represents a leap ahead of traditional assessment mechanisms. Complex assessment practices present a significant barrier to adoption of greater authenticity in assessment. While simple multiple-choice questions can be automatically assessed, evaluating the capability of a learner to manage a disparate series of tasks in a virtual environment is not a simple undertaking (Fardinpour, Reiners & Dreher, 2013). The complexity of the assessment task returns to the establishment of the framework for the virtual environment. While educators agree that the deployment of “artificially intelligent” bots would be useful, large-scale adoption remains some way off and is limited by technology, institutional resourcing for changes, and training in instructional design and implementation (Reiners, Wood, & Bastiaens, 2014). However, effective design of a range of bots can be guided by developed frameworks, minimising the effort required to develop support for particular learning activities (Wood & Reiners, 2013).

The primary challenge of incorporating gamification into assessment revolves around the feedback mechanisms. There are two approaches. First, feedback can be provided by an instructor viewing and monitoring in-world activities. This has the benefit of expert instruction, but clearly requires significant time investments on the part of the instructor. Second, expert performances can be captured through evaluation of “perfect” attempts at a task. This provides the learner with a framework of what they should be aiming to achieve, but not necessarily feedback on how they can improve parts of their performance to get there. Third, peer-assessment can take place, with other students tasked to provide guidance and feedback to the student.

Gamification can form an adjunct to existing authentic environments by helping to create a more motivating situation and encouraging the desire for further self-directed learning by students outside of their regular educational boundaries.

⁴ Further reading on Gamification: [21, 28, 29, 14, 10, 9, 8, 7].

7.6.4 Context: Skill training in virtual environments⁵

The research on nDiVE indicated the extension of the focus on higher education and especially classroom integration to the following roles: 1) *demonstrator* between theory and practice to learn the impact of the lack of applied knowledge/skills; and 2) to train and re-train professional workers regarding their skills for a workplace. The first workshops organised with industry resulted in positive feedback, collaborations, and an extended phenomenological study among workers using virtual training environments. nDiVE relates to an innovative and authentic approach to teaching and learning for practical skill acquisition, thus we selected a current area of interest in the field of L&SCM; i.e. in the mining, construction, and logistics industry. Here, workplace health and safety is eminent concern being reported in government reports (see reference below) as a result of limited workplace skill development and training. An area where education can have a major impact on the society.

- In 2009-10, 337 people died in Australia from work-related, traumatic injuries.
- Australia possesses a shortage of highly-skilled workers and apprenticeships, but employees have 20 per cent less skill than required for their job (Department of Education, Employment and Workplace Relations, 2012).
- Well-educated workers may lack practical skills (Jackson, 2009), and many workers are not trained to deal with complexity and uncertainty of larger systems (Department of Education, Employment and Workplace Relations, 2012).
- Work practices often encourage shortcuts to meet targets, with many employees believing managers accept these behaviours, while adequate recognition of danger and safety from managers may encourage them to take precautions; meanwhile, training and handling of written procedures declined from 1998 to 2002 (Mine Occupational Safety and Health Advisory Board, 2002).
- Employees are strongly impacted by incapacity or death, while the community is strongly impacted by medium- or long-term absence; minor incidents affect employers more greatly [6, 8]. Work-related injuries and fatalities costs rose to \$60.6b in 2008-2009, accounting for 4.8 per cent of GDP as 392,700 workers received assistance (Linacre, 2007; Safe Work Australia, 2012). Younger workers, with less experience and training, have higher rates of injuries (Linacre, 2007).

The significance of health and safety training and the interest in nDiVE by the industry shifted the focus from a purely classroom integration concept to a modular system with modules addressing students for intensifying and applying theoretical knowledge in a safe environment, promoting the connection between higher education and industry especially for *close to graduation* students, and providing a virtual environment to conduct health and safety training for industry, such as in the case of induction and refreshing training.

7.7 Project deliverable and impact

This section outlines the impact and deliverables according to the proposal. Changes to the proposed deliverables are discussed in Section 9 (as part of the experimental outcome) and result from the technological development since the original proposal documentation was written and the experimental results regarding their effectiveness. The changes inherit the underlying aims of the proposed deliverables as such, and remain true to the expected outcome of the project.

⁵ Further reading on skill training in virtual environments: [26, 25, 13, 11, 8, 2].

7.7.1 Virtual environment, scenario

- Publicly-accessible environment for authentic education modules.
- Re-usable objects to support the creation of authentic immersive environments.
- Exemplary scenarios to demonstrate the utilisation of human-interaction in authentic immersive environments.
- Accessible activities for higher educational institutions in Australia and worldwide.

Preliminary evaluation of user perceptions in using virtual environments resulted in shifting from Second Life to Unity. Key arguments were the ease of interaction (that is, movement), integration of HCI technology, and the realistic simulation of real-world parameters (that is, gravity and object interaction). nDiVE is focused on human interaction rather than communication, therefore the competitive advantage of Second Life as a communication platform had relatively low relevance for the project and anticipated outcome.

nDiVE is demonstrated using two scenarios (container terminal – two versions CT1 and CT2 – and the warehouse), each scenario modelled with respect to training processes, and health and safety training in particular. While these implemented scenarios are stand-alone modules to support self-explorative learning, further frameworks and narratives were developed for an interconnected supply chain covering all stakeholders and addressing different disciplines. This report briefly describes the design of learning material (instructional design) for units in L&SCM and skills training, and a more detailed description can be found in other reports (see Reiners & Wood, 2013; Reiners, Wood & Bastiaens, 2014; Wood & Reiners, 2015).

Interactive, autonomous bots were proposed, and the project team published multiple papers about the design and its functionality (Riedmann, Venable, Chang, Reiners & Gütl, 2013), however the bots were excluded in favour of data analytics on recorded data during the explorative learning to generate formative feedback. While mock-up bots are in the environment to provide information, interactive bots without user control were too unreliable in terms of intelligent reactions (see Wood & Reiners, 2013; Riedmann et al., 2013). The interaction of the environment with the user adopting triggers and other means of recognition closely resemble the functionality intended with the bots.

7.7.2 Guidelines and framework

- Documentation of principle and guidelines to enable teachers to take advantage of nDiVE, explaining how to develop and integrate learning material and apply authentic teaching and learning strategies.
- Guidelines for effective teaching strategies and integration in the curriculum.
- Business use case of industry application in health and safety training.

Originally, the project planned to integrate the environment into the classroom to define best practice guidelines. Changes in the curriculum, low alignments of nDiVE examples and unit content, time constraints on extra sessions in units, and availability of technically-equipped classrooms altered the source of data collection to define principles and guidelines. Thus, nDiVE used seminars, workshops, open events, and experts from multiple disciplines to execute experiments and demonstrations to collect data and fine-tune the design of the environment as well as the activities. The teaching strategies and guidelines for educators are deducted from the collected data and verified in sessions with teaching staff and students.

The proposal considered Machinima, an edited recording of the action in the virtual environment, as part of the learning experience. However, we decided in collaboration

with the industry partner *Sentient Computing* (<http://sencom.com.au>) to incorporate a recording of the learning experience while using the Oculus Rift to allow a seamless replay of every action in either the Oculus setup or in other contexts, for example, the HIVE as described in Section 8.1.1. As part of the project, we developed the tools to record and replay actions; yet could only run preliminary experiments within small groups. Note that the development is done for Unity.

7.7.3 Gamification

- Critical discussion of gamification and best practice guidelines for integration in the curriculum regarding virtual environments for learning and training.
- Demonstration on how nDiVE is using gamification to their advantage.

Gamification gained more attention in the project than originally planned. This resulted from the increased media coverage during the start of the project as well as the first demonstrations of the nDiVE environment at academic events. This impact was elaborated on in the project team's dissemination strategy (edited book and publications).

For more details on gamification in nDiVE, see Section 7.6.3.

7.7.4 Dissemination Means

The project followed different dissemination strategies, with a focus on academic publications and collaborations. The project received further attention from industry through collaboration with Deloitte, and participation in events with the Australian Computer Society (ACS). The following list is a short overview:

- All developed tools, objects, and environments are shared through CreativeCommons. This includes any future developments, modifications, and extensions if related to the original project in writing and thought.
- Dissemination used shared drives, collaborative tools (for example, Google Office, Dropbox) and in-person meetings.
- The project team favoured a continuous publication of milestones and experiments instead of limiting the publication of a final project publication. See Section 15.1 for a list of currently published articles and books.
- nDiVE was intensively promoted in events organised by university, industry, societies, and other non-academic bodies. See Section 12.3 for a detailed list.
- nDiVE is being used by Curtin University as an example of some of the cutting-edge innovative learning and teaching projects (See, for example, the article "*Changing the Game*" in the *West Australian* 24 August, 2015 as well as the list of reports about nDiVE).
- nDiVE organised multiple workshops and attended (international) conferences to present the outcome of the project.
- Dissemination through social media, blogs, and website.

7.8 Exemplary scenarios and proposed activities

The research proposal suggested a container terminal, warehouse, and production facility as examples to demonstrate the functionality and authenticity of discipline-specific scenarios. The warehouse was implemented as a first prototype and mock-up in Second Life (See Section 7.4.1 for some screenshots and design notes on the scenario). However, this was later replaced in Unity with a real-life scenario for higher authenticity. This example is described in Section 7.4.4 and is about the activities in a vehicle recovery leading to a fatal incident. The final scenario was not implemented as a result of the

additional impact experienced with the container terminal scenario (dissemination, presentations) and the requirement for additional implementations. The production facility, as well as two further scenarios, are part of the PhD/MPhil projects. An additional scenario in the context of automated formative assessment (preliminary development of taxonomies for human behaviour to support the assessment) is developed by Ali Fardinpour. The scenario trains health and safety requirements in an engineering context.

Conducted experiments used the developed scenarios as well as other available open-access demonstration environments to test the effectiveness of immersive technology with various cohorts of students, academics, and practitioners. See a list of events and experiments in the next Section. Design science research was adopted to guide the nDiVE project through the cycles of action, analysis, reflection, and re-action. Both qualitative and quantitative data were collected in multiple experiments, supported by independent peers and experts in the field of education and logistics to ensure accuracy and alternate explanation.

8 Evaluation of the nDiVE environment

8.1 Experimental designs

8.1.1 Technology used for nDiVE

This list is a complete collection of used technology with regard to creating the HCI. General hardware and software such as computers notebooks, and classic monitors are not listed. Furthermore, it should be emphasised that every participant received a short introduction to the technology if required.

Table 1: Technology used in the nDiVE project

Item	Description	
Unity	Unity , even though a 3D gaming engine, is one of the best choices as it allows the creation of scenarios, the linking of multiple stages, simulation of real world processes with the correct physic engine (for example, gravity), visualisation emulating different fidelity levels, easy programming with access to many developers around the world, and availability on all devices including mobile computers. The idea of providing induction on the way to the mine being on a plane is achievable if you see modern mobile phone having quad core, 64bit, 2.3 GHz with high-end HD graphics. And this would have a “selling” point as it does not rely on fixed locations for the setup of specialised hardware.	
Oculus Rift DevKit 1	Head-mounted display developed by Oculus VR as part of a Kickstarter campaign. The set was one of the very first in Western Australia and attracted wide interest in our community. Even though the resolution is low, the display resulted in a strong immersion into the virtual space. The project adapted to the technology after running a preliminary experiment to verify its usability, perception, and acceptance.	
Oculus Rift DevKit 2	This model is the next version and comes with higher resolution besides the improvement of the sensor, usability, and driver software. The difference in perception of the 3D space is very significant and improved especially the side effects of the previous version, for example nausea and exertion of the eye.	

<p>Razer Hydra</p>	<p>This controller by Razer is a “motion and orientation detection game controller” to transfer the position and rotation of arm and hands into the virtual environment. The device has limitations due to the connecting cables (causing restricted movements) and no finger simulation, but has some buttons to perform grasping and other simple hand gestures. The advantage of this device is about not having a barrier to the 3D space as with a desktop mouse, but using the hands as would happen in the real world. The device was very well received by the participants, and it was noticed people juggled objects after even a very short introduction phase.</p>	
<p>PlayStation controller</p>	<p>The classic controller. This input device was chosen due to the familiarity among the participants in cases where the hand movement was not necessary (for example, most of the examples in the container terminal).</p>	
<p>HIVE</p>	<p>The Curtin HIVE (Hub for Immersive Visualisation and eResearch) is an advanced facility designed to support researchers in the fields of visualisation, virtualisation, modelling, and simulation. The HIVE hosts a range of activities including multidisciplinary research projects, workshops, and visiting speakers. Driven by high-performance computers, the HIVE enables a new and improved capability in the interpretation, presentation, and communication of research data. For more information see http://research.humanities.curtin.edu.au/projects/hive</p>	

8.1.2 Technology perception experiment

In order to identify the perception of different technologies for the later implementation of the nDiVE environment, a pilot study on campus with staff and student was undertaken from different fields; the majority from the School of Information Systems in the area of Supply Chain Management. The participants were asked to partake in seven short experiments, each with a varying form of immersion, for example being in control or in the passenger seat, and having 3D on a traditional monitor or using the Oculus Rift. After each scenario, short interviews were conducted using a schedule as a general guide to ensure consistency over the interviews and to reach the main objectives of this experiment as well as the objectives for each scenario. This structuring ensured that the interviews remained focused on the exploration of phenomena of interest. The schedule was used to initiate questions and discussions, allowing the participants to express their own concepts,

interpretations, and perceptions about immersion. Open-ended questions and Likert-type scales with five levels were used to rate the scenario (in terms of realistic, useable, interesting, engaging, and compelling) with seven levels of agreement from strongly disagree to strongly agree (see Section 9). Observations were made of participants' gestures and comments during the scenarios. Six scenarios were used in this experiment: 1) Warehouse as proposed in the project proposal, 2) self-controlled exploration of a building structure using the Oculus Rift, 3) Oculus Roller Coaster scenario, 4) car driving simulation on a normal monitor (self-driving), 5) Oculus Rift Driving Simulator (self-driving by the participant), and 6) Oculus Rift Driving Simulator (driven by the experimenter).⁶

During the experiment, only the participant and organiser were in the room to minimise the disturbance, as voices from outside of the virtual space would decrease the effect of immersion. The participants were asked to restrict the time spent in each scenario but were not rushed through the experiment, so they had adequate time to adapt and explore the space. The average planned time for each scenario in the experiment was six minutes including the interviews, a total of approximately 40 minutes per participant.

The project team conducted the interview questions, questionnaire, and took notes about their gestures and comments while the participants were in the VR scenarios or at the completion of each experiment. The questionnaire segment relating to Second Life was administered following the segment of Second Life-based scenarios, and similarly the questionnaire segment relating to Oculus Rift was administered following the segment of Oculus Rift-based scenarios. A small sample size (N=13) has been used and it is important to note that data from the questionnaire are not intended to be used for inferential statistics, but only to provide an approximate quantitative guide to the experiences, which is supplemented by the interviews; thus, the small sample size is reasonable given the early stages of this research stream.

8.1.3 Self-guided exploration of virtual learning spaces

The experiment was conducted with the aim to evaluate how a learner explores the virtual learning space based on a general induction to the objectives. A container terminal scenario was used, with a fictional background story about customs having to inspect a specific container and having forgotten to secure it according to safety guidelines. The participant in this study is asked to go to the container within a time limit, preventing any incidents. The experiment began with an induction explaining the risks of getting injured or killed, using different examples. Furthermore, a printed map is used to explain the layout and the position of the container. It should be pointed out that the container terminal was unrealistic as it contained an unusually high number of dangerous situations. During the actual experiment, the learner is wearing the Oculus Rift with headphones for a high degree of immersion, while using a PlayStation controller to move and turn the avatar. The head and viewing direction is aligned with the movement of the Oculus Rift. The player starts outside of the container terminal in a room where the controls are explained and a video about the objective is shown. There are three dominant points of interest: the warehouse on the left, a large building ahead, and the container terminal. The given task, as well as an open gate, increases the attraction for the latter point of interest. In this experiment, options to stray from the ideal were left open so the participants' behaviour could be investigated, however visual hints (signs) were provided, as well as points of attraction (open areas, gaps), blocks (a container blocking a path), or dynamic actions (a moving vehicle, a fire) to direct the participants in the desired direction. While the learner

⁶ The selection of experiences is done based on the context of Supply Chain and Logistics; however, we wanted to apply the technology in a familiar environment to allow to focus on the technology rather than mainly on the scenario. The roller coaster was selected as a passive, the driving as an active application.

is unable to pass through a container, signs are indicators and do not actively block exploration. The focus of the experiment was on whether the scenario design enabled participants, without detailed instruction, to acquire necessary information and complete desired tasks while understanding the inherent dangers of the scenario.

8.1.4 Impact of distraction in an explorative virtual learning space

The experiment used the next version of the container terminal including, among others, the following changes:

- Size was approximately doubled, and the layout provides more guidance as well as risks.
- Fully operating container bridges shifted containers. On the one hand, this increased the realism of the terminal, but also increased the risk of getting either hit by the bridge or by a placed container. In addition, the operation was used in one scenario as the movement of containers also opens passages.
- The risk areas (for example, reversing trucks, a fire, a container dropping) feel more natural than being placed in the scenario for the purpose of injuring the participant.
- More support and help messages were integrated.
- Other avatars that functioned as contact points were included for support. Note that these are not bots as there was no further functionality or intelligence implemented.
- A visual avatar was included.
- Capability to look at a map as a support for the navigation. The map was part of the environment and showed in the hand of the avatar.
- The phenomenology study of virtual training sessions revealed the effect of glitches (events or occurrences that behave different to the expectations) like walking through wall or being teleported to another place, for example, the roof of the building. We identified a stronger memorisations of the glitch and its surroundings compared to other parts of the experiment. We designed a simple experiment by adding a point of “distraction” – do learners stick to the task or follow the distraction. The dinosaur was depicted by coincidence as the object was available, one of the least likely objects to be found on a container terminal, and the sound created awareness from larger distance.

Besides the updated environment, the experimental design was kept the same to allow for comparison. Each participant received an induction to the technology (HMD, Playstation controller) and the objective of the scenario. A printed map was used to point out the starting location as well as the location of a contact person. The participant was asked to keep to the objectives, yet was not required to follow the suggested path. During the induction, some of the risks were pointed out (for example, container bridges, not entering containers), yet some of the more intuitive risks were kept out of the induction to verify that 1) messages in the environment are recognised (warnings), and 2) participants paid attention to the environment while pursuing the task. Furthermore, some parts of the environment like the warehouses and their contents were not mentioned. We used this part to identify if unexpected events cause distraction from the intended tasks and if the unexpected events have a stronger memorisation effect than the original learning material and tasks. Another point of interest was the perception of signs and how they are processed; for example, if there were two doors with visual signs, would the participants choose the one they have the permission to enter, or was there a general attitude to ignore this in a virtual environment without consequences other than the avatar dying. Screenshots showing the layout and some impressions can be found in Sections 7.4.2 and 7.4.3.

8.1.5 Phenomenology study on user perception of virtual spaces

The experimental design described in the previous sections addresses the observation of the participants in the study regarding their behaviour and interaction with the environment. Data on activities was collected, the degree of immersion based on physical attributes was measured, and these were considered as classification of the virtual embodiment in the developed scenario. At the same time, the participants were expected to make an objective reflection of themselves while their real-world body is still “under the influence” of the received sensory information. Therefore, the research in nDiVE was extended to include an experiment to create a rich description of the phenomenon of “virtual embodiment” by an extensive literature review and, more importantly, a phenomenological analysis of how employees working in actual hazardous settings experience their work context in virtual safety training environments.

Phenomenology was chosen as the methodological approach because it can be used to examine specifically the meaning a phenomenon has for individuals. This allows finding rich, unexpected, descriptions that would not be found for example with a questionnaire containing predefined questions, even if open-ended ones. Phenomenology is a systematic study of how phenomena are given to us in consciousness (Giorgi, 2012). Examples for phenomenological analysis include a wide range of lived experiences such as educational computer use in leisure contexts (Cilesiz, 2008), alternative forms of human-data interaction (Hogan, 2015), and the experience of telepresence in video conferencing (Friesen, 2014), to name a few.

In these experiments, we collected qualitative data through interviews and analysed these using a phenomenology approach. Findings from the qualitative phase are used to form the suggested framework; i.e. inclusion of distraction elements, and to create a comprehensive understanding of how authentic context is realised in an immersive virtual environment-mediated safety training event. The interviews were conducted with 5 mining employees who conducted a health and safety training in a virtual environment setting, which was provided by Sentient computing. The detailed results are planned to be published in 05.2017; as the experiments are part of the sponsored PhD thesis that Marko Teräs conducted as direct part of the OLT-funded project.

8.1.6 Evaluation of automated formative assessment support

The major disadvantage of self-guided explorative environments is the lack of sophisticated formative feedback. Learners in these environments are free in their decisions, and can explore the space within the given scope to achieve the objectives. The common practice of feedback is based on whether the final goal was achieved (yes/no), time, and maybe the number of failures and their nature. However, other feedback concerning the performed actions, such as inspecting objects, learning the structural composition of the environment, or performing extra activities is generally ignored in automated feedback. The research for nDiVE was extended with the doctoral thesis of Ali Fardinpour with respect to developing a method to provide formative feedback in virtual environments. As described in Section 9.5.2.3, the nDiVE environment was exploring a milestone-based feedback accumulating relevant measurements; yet this experiment was using individual human actions to reflect on the performed tasks, but allowing a comparison with a gold-standard performance by experts. The core research hereby is on the development of a human taxonomy, the encoding of human action sequences, and the comparison of performed sequences against an expert sequence. The outcome of the comparison can be used to formulate structure yet formative feedback in the form: “The experts suggest the step *put on gloves* before *operating machine*. You are missing the step *put on gloves*. The experts considered all sequences without *put on gloves* as failed”. The developed taxonomy is validated in

multiple experiments including card-sorting algorithms, encoding of examples using the taxonomy, and interpreting encoded sequences of human action with respect to their information accuracy. The detailed results are planned to be published in 02.2017; as the experiments are part of the PhD thesis that Ali Fardinpour conducted as direct part of the OLT-funded project.

8.2 Participants in the nDiVE project

The proposal identified a number of potential stakeholders in terms of participation (students, staff, industry, and funding body) as well as later users of the nDiVE environment (institutions that will be able to access and share these resources, academics and teaching professionals able to benefit from a safe and risk-free simulation environment, businesses and not-for-profits that need to train workers quickly, effectively, and safely).

The participants for the experiment varied in their composition. While the first experiment (Section 8.1.2) was conducted using students and professional as well as academic staff, those constraints were removed for the ongoing experiments (self-guided experiments on the container terminal) to increase the number of participants, but also to boost the non-requirement of skills or other background experience. The only specific question for participants was about their gaming experience (serious gamer on a PlayStation vs. never touched a game) to understand the speed of adapting to and usage of the HMD and input controller. Finally, the scenario defined the context, yet the project was interested in a general perception independent of the disciplinary background than limiting itself to supply chain students.

Experiments in the industry were in general related to the context of either mining, construction, logistics, or supply chain as a result of existing connections with industry partners. However, the conducted experiments (despite the experiments conducted as part of Marko Teräs PhD project) addressed general features of the technology and the perception of the virtual environment itself; and while the L&SCM context was always the scope of interest, we did not specifically require stakeholders from the field but only asked for a general understanding of the scenario itself (for example, container transportation or warehouses). If possible, we collected data about the participants, but some experiments we did

8.3 Relevance of industry

Section 7.6.4 demonstrated the current impact on society of either not having the right skills or not getting the sufficient training. In a number workshops and business meetings (see Section 15), the current situation with respect to training was discussed, primarily the willingness of organisations to provide the resources for training (time off, travel cost, living cost, salary), but also the willingness to participate in training units. Often, workers considered training as wasted time with no or minimal impact on their work. One often stated argument was that they were hired to work in the mines, not to sit in rooms to look at slides.

The shift from traditional seminars to on-the-job-training or virtual environments is a trend observed over past years in Western Australia. The close collaboration with Sentient Computing showed the interest of companies in mining, oil and gas, and construction to extend the training options towards virtual environments as an alternative. Arguments given include the option to set up spaces on site to minimise impact on the work (that is, in case of general computer equipment), positive feedback from workers in the mining industry about satisfaction, and the authenticity and realism provided in these logistics and supply chain scenarios.

Finally, nDiVE demonstrates an option to support the transit of higher education graduates to the workplace by providing hands-on examples without leaving a safe environment and facing the risk of being injured onsite before receiving proper training. Another argument mentioned by some organisations was the training of terminology, activities, and workflows before being enrolled in hands-on training courses.

8.4 Iterative development and expert evaluation

The first experiment was conducted to evaluate the perception of different technological options to develop the nDiVE environment. The project invited different user groups to experience the different environments and provide us with feedback (speaking out loud). With nDiVE, a general audience with no defined background, qualifications, skills, experiences or beliefs regarding the concept or technology was targeted. Thus, the project concentrated on ad-hoc given feedback while the user was immersed in the environment. All reactions, observations, and spoken words were recorded (protocols were validated by the user afterwards). The analysed feedback data from the “technology perception experiment” was used to design and implement the first version of the container terminal environment (CT1).

Refinements to the nDiVE environment design were undertaken from CT1 to CT2 as a result of feedback from the participants, academic and industry stakeholders, and the project team (see Section 8.1.4 for a detailed list of major changes). The most requested changes were directly related to the perception of immersion: 1) Being able to see a form of embodiment in the virtual world – in scenario CT1, a user looking downwards had a weird feeling that there was nothing holding the camera, neither a human avatar or other artificial body; in a certain sense a discontinuity of authenticity and realism. 2) Being able to see the dying sequence rather than a message box. 3) Having better sounds for the objects. Note that no team member is a sound expert and that the first version consisted of non-realistic sounds, especially for the container bridges and container movements.

9 Results

The challenge of the OLT project nDiVE was the creation of authenticity in a field relying on transportation hubs, warehouses, and complex work environments, all with parallel and interacting processes. nDiVE is exploring the “fun and passion” aspect commonly associated with Gamification, creating a learning environment uncommon in the classic approach taken in Business Schools. The concept immersion is considered to be essential in enabling Logistics and Supply Chain Management (L&SCM) students; not necessarily to create an authentic learning environment but to recreate complex work environments and understand the interaction and effects among stakeholders and objects (that is, each action has a reaction and therefore the potential of a major (negative) impact). In this section, the key outcomes of nDiVE are described: the explorative but guided learning process using emerging technologies. The first experiments showed that virtual worlds lack authenticity for skill training and, therefore, we explored first alternatives to create an authentic and immersive learning environment. The chosen technology was combined with self-exploration to allow the learner to create their own narrative while guidance supported the telling of a specific story (lesson). The combination of technology and environment establish an authentic experience, where the outcome of decisions is reflected in events; either on the learner itself (for example, virtual death) or other objects and actors (damage or injuries). Overall, nDiVE achieved a new way of approaching L&SCM education by making the learner part of the scenario rather than demonstrating simulated reality in the classroom. Note that this environment is not necessarily unique to L&SCM; thus a later application in other contexts like construction, engineering, or event planning is possible and anticipated.

The results shown here are a selective sample to demonstrate major outcomes of the experiments. Further details are published in journals and conference proceedings or as part of the PhD theses which were part of nDiVE. Further details can be found in the referenced articles and requested by the authors of this study.

9.1 Technology perception experiment

This experiment had a significant impact on nDiVE despite its general design. The philosophy of nDiVE is to immerse the learner in the scenario, and the extended use of emerging technology might cause rejection not related to the content. Second Life “seemed” to be a perfect choice in the early stage (given the team’s previous experience), but the introduction of the Oculus required verification. Finally, the results demonstrated the early stage of the technology and the steps that had to be taken to proceed with adopting nDiVE. These are the results are from an initial experiment, updated with the continuous demonstration of nDiVE and observation of the engaged users over the project lifetime.

9.1.1 Experimental outcome

The results represent a preliminary study to evaluate the potential of an emerging VR technology. The participants elected to partake in the experiments, therefore, it was anticipated there would be a higher affinity for new technology than would have occurred through a random selection from the cohort. On a five-point Likert-type scale (from 1=no to 5=extensive), the participants (N=13) were asked about their gaming experience (M=2.85, SD=1.46) and virtual world experience (M=2.23, SD=1.23), with a correlation of 0.39. All participants had heard of head-mounted devices, and only two were not aware of other VR-devices, such as haptic VR gloves. A seven-point Likert-type scale questionnaire was used (from 1= strongly disagree; 4=neutral; 7=strongly agree), and each participant

was asked how strongly they agreed with the statement: “The [Second Life or Oculus Rift] scenario was highly” realistic, useable, interesting, engaging, and compelling. In each case, there was a significant difference with participants favouring Oculus Rift rendered scenarios. In all cases there was also greater convergence (most participants rating it as Agree or Strongly Agree each time), reflected in the lower standard deviations (see Table 1). One participant insisted on reducing his high ranking of Second Life by two points after the experience with the Oculus Rift scenarios, mentioning that not knowing the technical options caused an overestimation favourable to Second Life. Paired t-tests were conducted to compare whether there was a difference between whether the cohort believed that the Second Life and Oculus Rift scenarios were different, using the terms of realistic, usable, interesting, engaging, and compelling. There was a statistically significant difference in all cases, indicating the cohort strongly believed the Oculus Rift scenarios were better; these scenarios were perceived to be more realistic, usable, interesting, and compelling than scenarios presented in Second Life. There was greater convergence (that is, a lower standard deviation) for the Oculus Rift scenarios (Table 1).

Table 1: Second Life (SL) compared to Oculus Rift (OR) use in scenarios. Note the p-values showing a very strong result. This was partly anticipated as the technology is innovative and providing a strong visual effect for the user; however it confirms the correct selection of the technology for nDiVE.

	SL	OR	T(12)	p
Realistic	M=5.30, SD=1.25	M=6.8, SD=0.44	5.0257	0.00015
Usable	M=4.08, SD=1.75	M=6.8, SD=0.38	5.3176	0.00000
Interesting	M=5.30, SD=1.25	M=6.8, SD=0.38	4.3818	0.00045
Engaging	M=4.70, SD=1.32	M=6.8, SD=0.38	5.5268	0.00000
Compelling	M=4.70, SD=1.25	M=6.7, SD=0.48	5.3258	0.00000

The Second Life scenario began from the first person perspective in the warehouse. Participants were asked to move and look around and to use the forklift. In accordance with their experience with either virtual worlds or 3D games, expected aptitudes were observed in handling the mouse and keyboard for navigation. Nine out of 13 (69 per cent) demonstrated accuracy in navigation (that is, not running into objects and arriving at the expected destination), while the others overreacted, demonstrating poor control of the avatar. There was no significant correlation between gaming experience and the participants’ capability to move around in Second Life.

In the other scenarios, participants put on the Oculus Rift HMD. While the project had not invested time to make nuanced adjustments of the device for a perfect fit (for example, by adjusting straps, distance to the eyes, and distance between eyes), most found the device comfortable and lightweight. Participants were asked to keep their eyes closed until the scene was completely loaded. All participants showed clear indication of surprise, excitement, and fascination. This was demonstrated by their verbal expressions, including: “Oh my god”, “this is crazy”, “impressed, this is real good”, “Wow, this is new, never had an experience like this”. There were many comments like “Wow!”, “freaky”, and many participants laughed. There was also a tendency to maintain the familiar perspective of looking straightforward onto a monitor while working with monitor, reducing the field of experience to merely the part that would be visible on a monitor. Noticeably, one experienced gamer intensively used the head movement as long as he did not include the mouse for changing the direction of view as it is done in games. Some participants pointed out that they can feel immersed even just using monitors, but often drop out as soon as they turn their head, react to noises, or notice movements and lights in their field of view. This “drop out effect” is not apparent with the Oculus Rift. The immersion was further increased through standing and not touching objects or using the keyboard; both would conflict with the visual experience and cause detachment from the virtual space. Further

observations were recorded for the physiological intensity of the HMD. This outcome is significant as it demonstrates the correct selection of technology to be used for recreating the reality as a learning environment.

9.1.2 Feedback used for technology selection

The participants could see a strong potential for integrated immersive environments such as nDiVE supported by HMDs in education, training, entertainment, and tourism (order indicates the relevance stated by participants). It would be valuable for “places you could not go otherwise”, which could be real locations. HMDs allowed greater immersion than the same experience on a regular 2D computer monitor. Participants (70 per cent) investigated scenarios with more care and attention; 77 per cent believe that using the HMDs for an induction to an industry site (for example, demonstrating possible incidents that can occur on this site that may lead to injury) would create greater awareness and thus more care while in the real environment. HMDs may have applications in “hazard perception tests”, as the HMD would result in “motivation to identify all risks to look out for later at the location.” The majority of participants mentioned that it would add value to classroom experiences.

Some suggestions for improvements were recorded, as well as negative comments about hardware, dizziness, and usage. The current version of the Oculus Rift (used in nDiVE) is a developer kit, and the final consumer version will feature improved image resolution, lower weight, and better design. The present resolution was initially of little concern (“the experience is just too intensive to care at all”), however with more time participants noted that in slower scenarios the resolution was insufficient to study details in the environment around them.

Another disadvantage of the low resolution used in the HMD models used during the project was a tiring effect on the eyes – none of the participants could imagine using the Oculus Rift for several hours without a break. The effect is partially affected by the display, as their reaction time is low and can cause blurry effects on moving while there is exclusion of sensory information from physiological balance sensors, similar to the reverse effect of getting seasick on vessels. It is important to note that these issues are being addressed in the more recently released virtual reality HMDs. Furthermore, the project’s intent is to use these scenarios for short periods of time, avoiding physiological effects of long-term use. In addition, the cables connecting the HMD proved to limit freedom of movement and was very restrictive in reducing the radius and distance.

While it is immersive, users of HMDs can still be distracted by external factors. The Oculus Rift covers vision (output) and head movement (input), however, the participants noted that it does not entirely eliminate external distractions (for example, there is no 3D sound within the virtual space). This could be rectified using virtual mobile devices, or speakers integrated with the environment and placed physically around the user. Further space to move and the entanglement with cables can be overcome with adjustments to the setup, or by using wireless technology.

Despite these drawbacks, the key advantage of the Oculus Rift is its simplicity and fit with the consumer market; adding more technology and increasing the software complexity may be counterproductive and lead to replication of existing approaches, for example Caves. The open source community is currently exploring HMD technology and is extending the authenticity and immersive experience, particularly in new and more natural ways of sensing, moving, and interacting in the environment, such as using the Razer mouse and Kinect. Participants knowledgeable with Second Life emphasised the emptiness of the nDiVE environments and the lack of social interaction.

Finally, two participants noted that the immersion is both a strength and a weakness; being unaware of the activities and behaviours of bystanders in the physical space was seen to be a risk. Therefore, using VR devices requires a protected space and trust in the people nearby, especially as any sudden interference can cause intense reactions. Participants should have a signal in the virtual space that someone from the real world wants to communicate.

9.2 Self-guided exploration of virtual learning spaces

The aim of this experiment was to observe if participants were able to perform a self-guided exploration of a learning scenario under the following constraints: 1) the environment provides indicators, signals, and indirect messages to *push* the participant in the right direction, 2) the participants receive a brief induction without revealing too many details, and 3) the participants are not from the discipline or trained in the scenario. The last constraint reflects that it is a common situation to have visitors on site to perform contractual work who are not necessarily accustomed to the environment, such as emergency workers on a rescue mission, maintenance teams, or higher management. Therefore, the team used the invitation to demonstrate the nDiVE project at a Curtin University event with external visitors (Festival of Learning; www.curtin.edu.au/learningfortomorrow/festival-of-learning.cfm). Guests of the exhibition could select from a portfolio of applications, including the container terminal scenario. With respect to minimising the external effect on the participant of being aware of the experimental design, the experiment was disguised by using a cover-up story of using a game in a prototype stage. In addition, participants' identities were kept completely anonymous, no personal information or biodata was recorded at any time, the data was recorded using a random user identifier, and no time codes that would allow a reconstruction of the order of the participants' participation. The introduction to the scenario included a short explanation of how to navigate with the PlayStation controller, their overall task to find the one container, introduction to the map outside the start location, and outlining risks at a container terminal.

Figure 4 shows two “heatmaps” (showing a visual aggregation of overall movements) based on the recorded results, the left map being an example of one participant successfully finding the container, the map on the right showing overlay of all the participants in the experiment. It shows the variety of paths chosen, with a clear indication of the main and also anticipated path leading to the container. Of the 52 participants, 36 (69.2 per cent) moved directly towards the gate, while four (7.7 per cent) walked briefly past the gate but realised immediately that they had to go back. Eight (15.4 per cent) chose to explore the house despite the given tasks; four (7.7 per cent) walked in a completely different direction). Only 20 (38.5 per cent) finished the task by arriving at the specified container, while 22 (42.3 per cent) died in the process (the most frequent cause of death was the falling container, as it was overlooked, closely followed by being locked in a container when participants ignored the “no entry” sign). Twenty-eight (53.9 per cent) explored the virtual environment before finding the goal. General feedback was that participants enjoyed the opportunity to explore a space that was not accessible in the real world. Only six (11.5 per cent) had to stop the experiment early as they felt light dizziness.

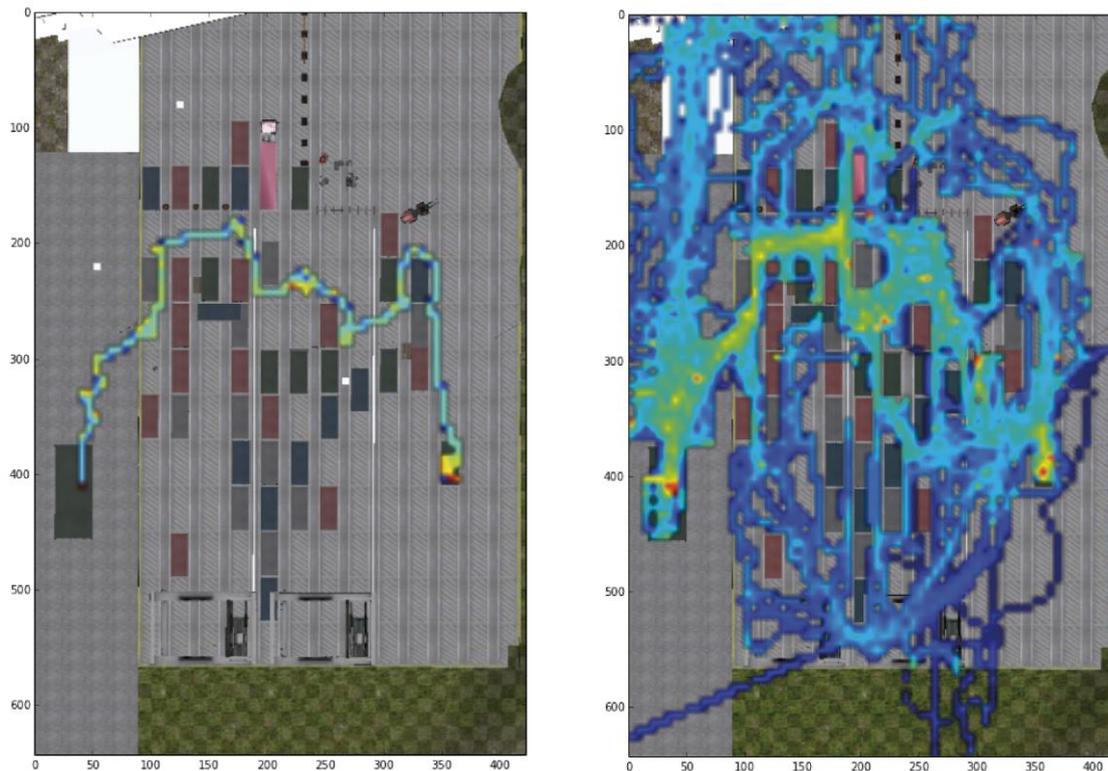


Figure 10: Heatmaps showing the path of one participant (left) and all participants (right). The intensity is based on a log-function (to emphasise areas of interest) over the accumulated time that an avatar was at a certain position. Note that a brighter colour indicates a higher intensity.

This experiment was used to understand how learners address an unknown virtual environment, that is, something outside their expertise. A container terminal scenario was used, one which most participants know of, and have a rough understanding of the processes that could occur. The short introduction let them know about risks (most of them are common knowledge as they included fire, vehicles, and other large objects), with no special training. All but a few of the participants had not experienced HMDs, which added to the novelty of the experiment. Observations supported the abovementioned experiment regarding the usability and immediate capability to navigate in the virtual environment, an experience that was not observed in other environments such as Second Life. Physical reactions were recognised with some participants, but were less intensive compared to scenarios such as the roller coaster and racing simulators. Feedback after the experiment suggests that this lessened physical intensity was related to the real world application of the scenario and the focus on the task as a subliminal distraction. The analysis of the individual heatmaps showed that most participants were following given attractors to choose their paths and also focused on getting to the final destination. Note: The low success rate, as well as the large number of deadly accidents, demonstrated that container terminals are not safe environments and training and extensive induction should be undertaken.

9.3 Feedback to refine the learning scenario

Project team members attended several large-scale events where the nDiVE technology and scenarios were presented to the public. Most importantly, the 2014 and 2015 Career Expo with many hundreds of visitors, mainly students in their last two years of high school. This large sample confirmed the earlier findings, but with a much wider group of participants from a more diverse range of backgrounds. Due to the operational pressures of discussing the scenarios with a large number of people while operating with three users

simultaneously, it was not possible to record detailed verbal feedback. However, the anecdotal comments picked up included phrases such as:

- Awesome.
- I got killed a lot ... but solved the problem.
- This is the most intensive game ever played.
- I wish learning would always be like this.
- Totally cool.
- I did see the warning and restricted area sign, but I did not care as it is not dangerous for me in the game.
- I never thought that container terminals are so big.
- I want to drive the container bridge.
- I have to get my friends ... they have to try this.
- This is logistics ... I want to study this.
- University creates this. I thought that this was a game.

Observation of the participants further showed the need to change details in the layout (as the intended barriers/guidance were not effective), minor programming errors, that the objective was at times forgotten, more gamified nudges were needed as an incentive to focus on the objectives, and some consideration of authenticity (“I thought that would be different in the reality”) and realism (“the container is floating, I do not believe this”). The data of the Career Expo (2015, CT2) is still being analysed, however the first results confirm earlier findings.

Working with Deloitte and their panel of experts at different occasions, the project team re-confirmed that the recommended changes from Section 7.4.3 were important, relevant, and valuable. What was suggested there was confirmed by these industry experts as being valid and reliable. This provided triangulation of the findings.

9.4 Stakeholder feedback

Input and feedback from a range of academics and industry professionals helped to inform the nDiVE project over the project duration. First, a range of feedback was received from academics around Curtin University, the University of Tasmania (during a one-day workshop), and other events as listed in Section 12.3. Their insight and input was valuable in terms of learning how to best accommodate the practical requirements of other educators when developing the nDiVE materials further.

Second, nDiVE worked closely with a number of industry stakeholders. In the early phases of the grant application development and early specification of project parameters, this included input from managers at Rio Tinto (a major mining company), SKM (providing engineering services in a range of working environments), and GS1 (the global information standard organisation). In later phases of the work, the project team engaged with Deloitte, participants at the Careers Expo, and industry representatives who contacted the nDiVE team following presentations and exhibitions.

The feedback was always useful and informative and provided substantial direction to the project.

9.5 Formative assessment

Storytelling is an ancient profession to create an illusion to immerse the audience in a fictional or non-fictional space. The storyteller orchestrates words, gestures, expressions, and other stylistic means (such as suspense) to create a draft framework, which is padded by each listener in a (slightly) different way. The story defines the space and its objectives, the narrative, or the path to reach these objectives, and should involve an individual's experience and knowledge, allowing one to explore the space and use creativity to find solutions (Reiners, Wood, & Dron, 2014).

This section summarises the key findings of nDiVE and provides a framework of components and philosophies to guide the development of future authentic immersive learning scenarios. However, it can only cover a fraction of the outcome of a two-year project. For more detail refer to Section 15.1 for an overview of publications and Section 12.3 for other dissemination means. This section continues with a brief discussion on project decisions.

9.5.1 Explorative learning vs. Machinima vs. data analytics

The project team explored a number of methods for providing overviews for participants before they began a scenario. One of the most obvious options to provide this overview was to use in-world cinematic video clips on the gaming and media streaming website Machinima. However, early experiments and feedback from participants indicated that in terms of the immersive experience the project was seeking to develop, Machinima was an option that was less immersive and more challenging to create than simply providing a “fly-over” experience of the scenario (whereby the user can see everything and the overall layout) with a narrative.

From past professional experience (including experience with other OLT projects), the project team knew that while Machinima could be visually appealing, in-depth, and detailed, there were significant costs. It takes substantial development time to create a professional product that addresses all requirements, making it a relatively time-consuming and cost-inefficient approach to supporting the learner. In addition, there was limited transferability between learners, thus, while it may be perfectly suited to some learners, it may be less useful to others.

A final argument against Machinima was the loss of immersion that was created with the use of HMD and specially-designed scenarios. Therefore, a collaboration with Sentient Computing integrated a recording functionality: each object and its parameters in the scenario were recorded and written to a document so that it could be played again. The further advantage was that the recording could be limited to certain objects, and that the environment allowed interaction during the replay. Thus, this feature could be used not only as a Machinima, but also to walk through a scene and discuss the recorded action in real-time.

Finally, Machinima was not storing any valuable information about the activities within the product. Recordings on the other site reflected the explorative nature of the environment by tracking all relevant information for recreation. This rich dataset can be used for later analytics about the learning retention by finding clusters of learners with similar behaviours and outcomes.

9.5.2 “Carrot and stick” framework (CSFrame)

Many commonly-used educational practices focus on implicitly coercive approaches to encourage student compliance with educators’ wishes – applying a “stick” approach. However, the term “carrot and stick” implies both a threat of punishment coupled or used in conjunction with something tempting dangled in front of the student in order to motivate them. While some elements may be used as an extrinsic motivator of this sort, the use remains somewhat limited, with most practices designed to punish non-compliance. Effective education may require application of sticks, but there is increasingly room to include carrots.

With self-directed learning, the focus shifts further away from the use of punishments and coercive acts to ensure compliance, while enabling the student to engage in their self-directed study. A self-directed study suggests design with greater reliance on intrinsic motivation, and may be supported by self-determination theory as an approach to create more powerful forces that encourage instincts supportive of learning (Ryan & Deci, 2000). Note that a “carrot” by nature is a reward, however we tend to think of this as a purely extrinsic motivator; make progress and you are rewarded.

Within a self-guided learning environment, sticks can be as simple as providing fewer points or perhaps explicit penalties where points are deducted. The extrinsic carrot may involve rewarding progress towards objectives, for example, by allocating points to specific tasks in a way that also provides feedback on overall progress in the learning scenario. The intrinsic motivator carrot includes many of the contemporary gamification mechanisms to create and support intrinsic motivation to support tasks. The use of multiple lives or save-points enable experimentation and trials to take place without negative consequences for the student, encouraging a range of actions to be attempted, and enabling the sating of curiosity about a particular situation. The use of leaderboards can provide a learner with an overall perspective of success and how they are faring against others in a way that motivates them to continue as they collect points, rather than becoming frustrated when being penalised for failing tests (McGonigal, 2011). The use of ghost or shadow images (Hebbel-Seeger, 2013) or other comparative techniques enables observation and reflection on performance with the ability to learn from others, or from oneself, or from the difference in previous attempts in comparison to the attempts of others.

Gamification processes can aid the shift away from extrinsic motivators as carrots towards developing intrinsic motivation. Application of appropriate gamification design can increase the propensity of a student to engage in self-directed learning. In this way the carrot can become a multi-dimensional or multi-layered approach to developing, encouraging, and supporting the students’ willingness to explore and engage in the learning environment. The ultimate focus is to shift the development of motivators away from extrinsic to intrinsic motivators over time, while increasingly reducing the use of sticks in the environment (Landers, Bauer, Callan, & Armstrong, forthcoming); in this way, gamification can be supportive when designed to run in parallel with authentic learning (Wood, Teräs, Reiners, & Gregory, 2013).

The following components are considered to be essential in CSFrame to guide the development of learning scenarios:

- Understand what should not be done or where the user should not go. Movement into these areas can be dis-incentivised with a range of automated prompts in the environment – this is a “stick” that can help guide the user back to more useful areas.
- Providing positive, formative, feedback with automated approaches can enable users to respond and do more of what is required to complete the scenario – this is a “carrot” that incentivises further work.

- Provide additional bonuses for improved performance, incentivising greater consideration and effort in improving overall performance.

The following sections cover the core principles of the nDiVE findings to develop authentic, immersive, virtual environments targeting self-guided explorative learning.

9.5.2.1 Storytelling and narratives

In all experiments, participants were generally observed to enjoy the freedom and delight of influencing the activities and the event as a whole. For example, chess has strict rules regarding the use of pieces and how they interact, yet players have a high degree of freedom as each move branches into one of the almost unlimited narratives, where one decision can be countered by the opponent in many ways. An even higher degree of freedom for the participants is achieved in various role-games with co-creative elements, where the game master establishes the outline of events that constitute each “quest” that the participants are involved in and largely control.

Providing an open space for learning, despite boundaries to maintain the user within the scope of the learning objectives, supports intrinsic motivation, creativity, and in-depth understanding in case of integrated failure of possibilities to explore boundaries. Users can deviate in the open space. It is all about achieving the outcome, not necessarily *how* this is achieved. Moving a box from the twentieth floor can be accomplished by dropping it from a window, yet, using a pulley and rope would cause less damage and lowers the risk of hurting innocent people. Still, it is the learners’ choice to pick from valid methods such as pulley, lift, carrying, cranes, or helicopters, as long as the aim of the scenario is fulfilled. On completion, the result is assessed by criteria such as time taken, cost, or damage, thus, while a helicopter ride may be fun it is not the most cost-efficient solution in a commuting problem, and therefore maybe not preferable over others. Recorded variables such as completion time are used to calculate a score, which the learner can improve on in further runs. If a learner gets themselves “killed” or makes a “fatal mistake”, only points are deducted instead of having an impact on the actual person or the person’s avatar. Virtual learning environments enhanced with gamification enables learners to repeat situations over and over to discover the correct solution to improve their score (McGonigal, 2011). When playing games, there is a very high percentage of failure rates on initial attempts of approximately 80 per cent (Fujimoto, 2012); yet, where the player is engaged to master the activity and complete the task, the overall fail rate drops precipitously. This type of repeated attempt is something highly discouraged by our educational systems; educational institutions promote success and focus on a “single-shot” assessment with extremely low fail rates but low grades, rather than having learners repeat to improve and intensify the learning experience as well as learning outcomes. The traditional classroom setups seem to be a fail-safe environment where failure and negative experience is disregarded.

9.5.2.2 Gamification and gamified nudge

The quests in games such as Dungeons & Dragons are established by objectives, goals, and loosely structured stories that the game master (the Dungeon Master or DM) controls. The DM is able to slow down or speed up the progress of the party, or change the environment by introducing new objects such as traps or treasures. With players being in control, it is important to ask what happens if the players become “side-tracked” by something that is less relevant? The DM merely convinces them to re-focus on their main objective. There are a number of ways of achieving this, but gentle persuasion is usually adequate. Similarly, in professional games such as Grand Theft Auto, the players are “gently encouraged” to return to the storyline by increasingly strong “hints” that are dropped in the guise of being part of the game and environment. The result is that players have a sense of freedom. They

are able to explore, examine, learn, and interact with the world around them. They can follow their heart's desire, but only up to a point – we still have a story to tell them! The use of these hints, or “nudges” enables the native interest, curiosity, and enthusiasm of a player to be encouraged and incorporated into the situation.

The tension remains, however, of encouraging an “open” exploration of spaces while being conscious of the fact we need a “closed” focus on a particular outcome or result. Similar to the effect when we pull a rubber band between two hands, the further we pull, the greater the force that attempts to correct the situation. Similarly, an open space can have mechanisms built in to “pull” a player back to the path.

The implementation of a pull or nudge can be difficult to implement; while a DM can use observation and human intelligence, it can be difficult to “codify”, and thus use technology to automatically see what must happen, when, where, and by whom, in a way that all actions can be monitored and the scenarios adapted automatically. This is even more problematic under limited resources to develop scenarios. Careful design of the learning spaces can result in a gentle set of guides to assist a learner in navigating through a scenario. Tracking and analysing the data of the learner in the environment allows the design of a space so that learners’ time is primarily spent in areas (location) or narratives (objective) that they need to be in to complete the learning activities. The following list shows some examples that were evaluated as most promising in this project to provide a “gamified nudge”:

- Static information integrated into the environment to direct the learner (for example, signage).
- Dynamic information that fits within the context (for example, traffic lights for flow-control, TV screens for messages).
- Participants being forced to respond to triggered events in the immediate vicinity (for example, a reversing truck blocking a passage).
- A constantly changing environment that adapts to the learner (for example, container transports on a container terminal).
- Chatbots using (basic) artificial intelligence (Wood and Reiners, 2013).
- Allowing participants to respond to external incentives (for example, a monetary bonus).
- Allowing participants to respond to intrinsic motivation induced by their sense of fun and passion to solve the task and achieve the goal.

Furthermore, such a “gentle” guide requires little in the way of narrative or instructions. Preliminary work indicates that a simple set of instructions provided during an “orientation to the technology” session can also encompass a basic idea of what to do within the environment. That, coupled with the “natural attractors”, gives the participant the basic outline of what to accomplish. Thereafter, the design and setup of the virtual environment should occur in such a way as to keep them on track while also encouraging the desired behaviours. Experiments indicate that the design of interactive spaces can occur in such a way that prominent features act as “magnets” for user attention (Reiners, Wood, & Bastiaens, 2014; Reiners et al., 2014). People are by nature curious and inquisitive, and do take the time to examine the spaces they find themselves within. Therefore, something which appears different or unusual tends to attract their attention and hold it. In this experiment, a short but reasonable scenario was developed to be readily understood by someone generally not familiar with the context of a container terminal, therefore users need no prior exposure to the particular business or operating environment. The project observed a high affinity of participants with the story line, where other areas that could be of interest and were accessible did not side-track them. Even in the case of early failure to proceed with the task, participants asked for support as they realised they were lost but still wanted to return to the narrative or story in which they were participating. Further, a

comparison group who did not receive an objective, were observed to feel engaged but not motivated in pursuing a specific (self-made) objective. Furthermore, the experiment showed that the warnings about dangerous elements in the virtual environment (for example, those situations that kill the avatar and stops the experiment) increased the participants' awareness of their surroundings, such as awareness of signage such as notices telling them "do not enter" the area, and warnings of heavy traffic nearby.

The experiment confirmed that stories and storytellers (here, manifested indirectly through signage or directly by scripted events) are valid tools to engage learners with the learning task, but also to keep them interested in exploring the space to find an answer. Deterding (2014) showed that the incentives (or challenges) must change over time to prevent frustration (for example, where the task is too challenging) and boredom (for example, where the task is too simple given the skill set of the learner). The story can, as described below, include gamification elements to adapt the environment to the skill set; these elements include semi-intelligent bots, changing environments, or challenges involving other learners.

9.5.2.3 Data analytics for automated formative assessment

The feedback during the experiments showed that immediate formative feedback was one of the most important components in a self-explorative environment. As described above, guidance, visual feedback, and messages in case of failures were important, but limited the understanding to a very specific point of time and the current surrounding or environment. Further discussions on a broader context or analysis against the outcomes by experts can be found in Reiners et al. (2014) and Fardinpour et al. (2014). nDiVE explored two methods for formative feedback, see below for an example of analysing collected data and deriving assumptions for the feedback. The second method is part of the doctoral research by Ali Fardinpour, and incorporates the encoding of human actions in a specialised taxonomy (BEHAVE) and the Action-based Learning Assessment Method (ALAM) to compare human action sequences against each other.

To explain the use of recorded data, the following milestones (triggers) were used in the container terminal scenario as part of the expected solution to fulfil a given objective, in this case the finding of a specific container. Numbers refer to the numbers in brackets in Figure 11 and represent the narrative of the expert:

- **Walking through gate (1):** Entering the actual scenario space; the passage of time or distance walked until the trigger was activated could provide an indication of how quickly the learner understood the task (reading maps or instructions) or found the relevant area.
- **Passing the truck (2):** Indication that the learner walked in the correct direction, did not follow a path that was indicated as a no-entry zone, and did not get hit by the truck. The milestone is reached if the learner turns right before the truck; the alternative of passing quickly behind the truck is considered as not safe.
- **Passing the fire (3):** This milestone is either walking the northeast loop or waiting for the fire to extinguish and the explosion to be detonated.
- **Finding the target container (4):** Reaching and entering the container that was indicated on the map as the final destination.

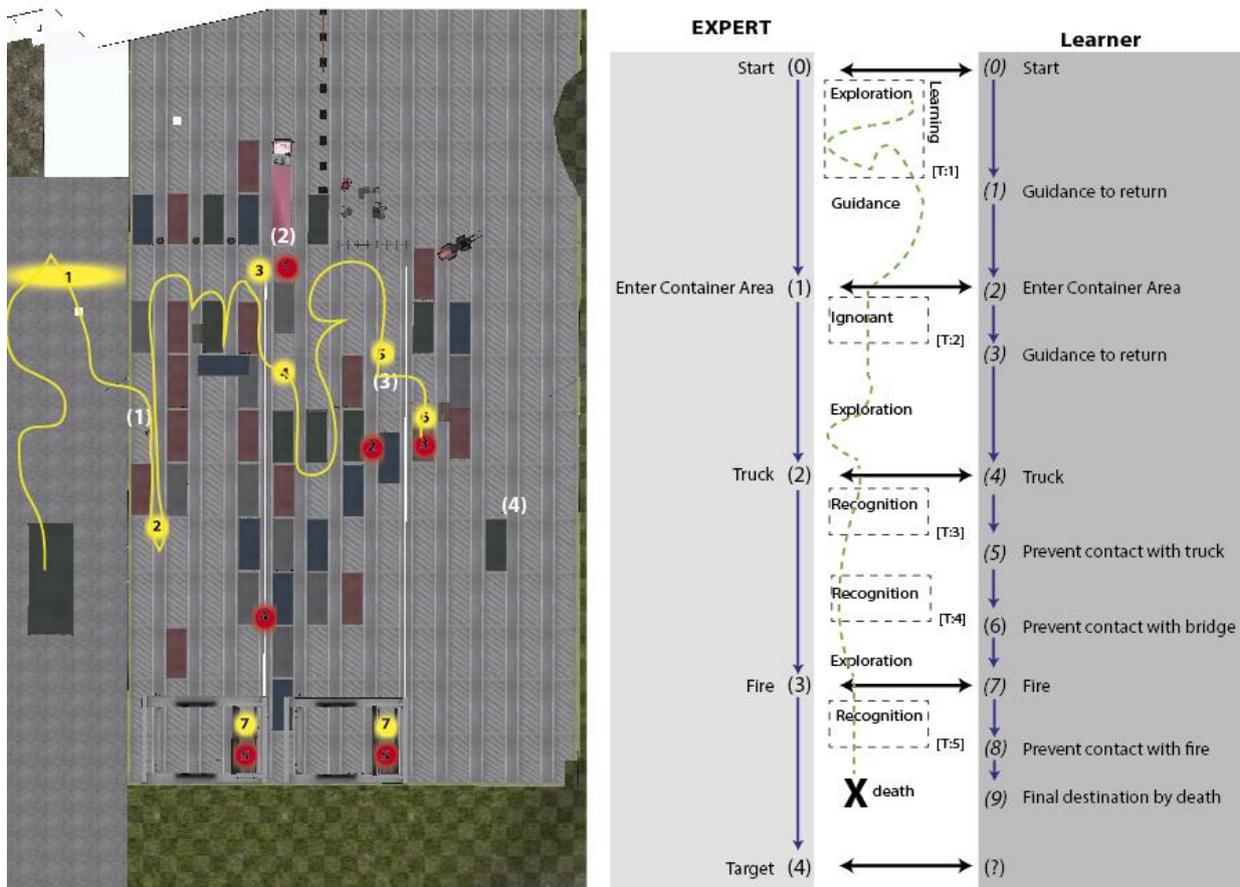


Figure 11: Comparison of narratives – expert and learner

Figure 11 shows the comparison of narratives completed by the expert (not shown in the figure) and learner (shown with a yellow path in the figure). The first step is the alignment of matching milestones; for example, expert (1) (referred to as e1) and learner (2) (referred to as l2) for entering the container area. Even up to this point in time, the expert and learner followed different narratives, for example the learner triggered [T:1] and walked further. This variation allows us to deduce feedback for the learner based on predefined templates associated with triggers and analytics of the collected data as described above. The milestone (l1) is created by trigger [T:1], which is associated with walking in the wrong direction. The immediate feedback is a message (voice or text) about the objective and where to go (guidance); furthermore, the analytics shows larger travelled distances than expected, which may indicate an exploration of the environment or that the learner is lost. The information with additional hints can be passed to the learner (“You walked in the wrong direction [template] and covered a distance of 250m instead of 180, requiring 30 per cent more time than expected [analytics]. Please go back and use the gate to the container area [guidance]”). The relatively straight walking line shows that the guidance helped to get back on track and reach the milestone (e1). A similar strategy is used in the following steps, whereas *ignorance* indicates overlooked signs/restricted areas, *recognition* indicates the awareness of danger (no dying), and *exploration* indicates a longer walking distance than expected. In this example, the learner died by walking into a container that was ready to be closed and shipped. The framework focuses on milestones and the deduction of what happened in between by using collected data and/or information from triggers and other objects. The team does not describe the behaviour or gestures of avatars in detail; see Fardinpour and Reiners et al, (2014) for some examples on how an analysis of human behaviour can be further processed.

The training scenario is gamified in several ways. First, feedback on performance relative to previous experiences and overall outcomes is provided based on records of sectors defined by milestones and time. Second, the quality of the experience is indicated by an overall score; that is, based on time, absence of errors, and most importantly, not running into a deadly situation. Accuracy (short distance), time, or recognition of danger are positive (to get a carrot), while other situations are punished (stick) by adding penalty points. Third, additional gamification elements include rewind functions allowing learners to reinspect a situation, competitive incentives, and being in an authentic environment.

Note that in this case, gamification was being used to support summative and formative evaluation. Scores, while usually used for summative feedback, can in this situation be used to provide immediate and specific feedback on the tasks that the learner is undertaking, presenting a powerful formative feedback tool. While the guidance form of the mentor/teacher in learning is crucial, where the training of skills is required comprehension of the task and intense feedback is helpful. Under these circumstances, the provision of automated feedback is helpful, but it is stressed that learners should always be able to request additional support from a mentor or teacher. nDiVE facilitates this by providing records and playback functionality, enabling a mentor to “dissect” a past attempt by the learner, and provide additional feedback and commentary.

This provides a safe environment where the student is able to attempt a range of actions and experience the outcome. There is no harm to the learner or real environments, therefore learners need not be afraid of failure and can instead attempt different approaches to the problem and learn from their mistakes and the feedback provided.

9.5.2.4 Technology-focus only in learning modules

Due to the nature of the technology and the logistics and supply chain curriculum, some opportunities and limitations were noted in how the nDiVE project is used. This is a technology-enabled supplement to existing pedagogical approaches – it complements them but does not replace them. The project team believes that it will be most useful to create small, specific, and focused modules, carefully concentrated on key lessons, and use this as an add-on to existing modules/units in the curriculum. Feedback from industry representatives provides evidence that this approach can act as an excellent “bridge” between the classroom theory and the real-world activities. Therefore, nDiVE modules might be effectively positioned as part of a capstone module in the curriculum.

nDiVE created multiple objects, algorithms, and other modules to support the development of future environments. However, the research project was unable to provide the resources to create finalised, off-the-shelf modules using plug-n-play interfaces (which would enable instant adoption by other educators). Therefore, others wishing to use nDiVE materials will need to contact the nDiVE team and arrange an introduction to the materials, underlying code, and a discussion on how they can adapt existing materials to accommodate their own scenarios.

Through the nDiVE environment, there are multiple opportunities to provide feedback. While the experience for an individual learner is within a closed environment with limited interaction with their teacher, they can get no immediate feedback from the expert. This can be partly mitigated by created expert-recorded training sessions, and using contemporary visual display technologies (for example, using Curtin’s HIVE and 3D Cylinder display), to project the recorded sessions for multiple (and simultaneously present) observers. In this way, the expert can navigate through their session in a way that is similar to a movie, while also pausing and changing their perspective or camera angles, providing the opportunity to interact with the learners and work with them to help them comprehend the nuances of a specific situation that they are discussing. Surveys on this approach are planned for June and July in 2016.

10 nDiVE against Australian National Professional Standards for Teachers

The project team emphasises that the use of technology creates opportunities, but also barriers. While a very broad acceptance of the technology used in this project was discovered, limitations in the applications were also noted. For example, if someone is not capable of seeing 3D (for example, he or she have only one eye), then the HMD cannot be used and traditional 2D monitors must be used as an alternative. It was not in the scope of the project to evaluate the fitness of people to nDiVE; however, participants in the larger experiment included participants with disabilities (including autism, and mental or physical disabilities), multiple religious' backgrounds, nationalities, cultures, minorities, social standings, and qualifications. Observations showed that no learners felt excluded, but all rather felt curiosity and a desire to share the experience.

We adapt the seven standards by the AITSL National Professional Standards for Teachers (<http://www.aitsl.edu.au/australian-professional-standards-for-teachers/standards/list>) to outline how nDiVE can support teachers facilitate the attainment of the standard. We acknowledge that nDiVE is intended to be applied in Higher Education, however experiments at career expositions and other public events demonstrated the application potential and the value for inclusion in school teaching. Further, the standards are valid for teaching in general and thus provide further understanding of how to utilise nDiVE.

Table 2: AITSL Standards mapped against nDiVE for learning and assessment

Domains of teaching	Standards	Use of nDiVE
Professional Knowledge	Standard 1: Know students and how they learn	<p>The project team sees nDiVE as an extension to the standard curriculum, where knowledge and acquired skills are tested in a game-based environment. With more than 500 high school students testing the container terminal scenario, no fear of contact with technology, was observed, but there was strong interest in the tasks. The short (time-wise) but intensive learning units (information and activities) were acknowledged as an ideal concept matching the game-based trend of short levels or progressions between events. With game consoles and smartphones, the technological divide was minimal and appeared to be a good match to participants' physical, social, and intellectual development and characteristics, especially when we consider students in higher education.</p> <p>Another positive aspect is that (correctly designed) games are robust relative to participants' cultural, religious, and socioeconomic backgrounds, and often provide a common denominator for disparate groups. During public exhibitions, nDiVE was used by people with diverse backgrounds of varying culture, religion, and physical capability. Participants' individual experiences provide additional opportunities to discuss and share within groups. The objectives in all tasks were defined to be fair and achievable; there was no "punishment" for additional attempts, as a replay allowed learners to correct mistakes.</p> <p>The collected data enables replay (with a function to freeze a situation) of the simulation under guidance of the teacher. This supports a detailed discussion of how the situation evolved and what can be done to avoid this in the future. The communication of skills and knowledge is visualised and therefore prevents misunderstandings.</p>
	Standard 2: Know the content and how to teach it	<p>nDiVE is a collection of tools, objects, and code modules. These resources allow the teacher to re-create visualisations of their learning material. The inclusion of nDiVE in the curriculum enables the development of skills and the understanding of context knowledge and relation between events. It also supports the step from memorisation to application, validating understanding rather than regurgitating what has been memorised. Finally, nDiVE supports the teaching of industry-relevant knowledge by using real-world examples, and it therefore prepares students for their post-graduation experiences.</p>

Professional Practice	Standard 3: Plan for and implement effective teaching and learning	<p>nDiVE scenarios consist of multiple stages. The induction provides information about the environment and the objectives. Learners must read and understand these to plan their tasks during the simulation. Within the environment, the inclusion of multiple sensory input requires the learner to stay focused to provide the appropriate actions at any time, responding to a range of stimuli. The chance to correct failures by immediate repetition helps to understand the cause of the failure and ensures less disruption of the learning process.</p> <p>nDiVE shows strong similarities with games, where studies demonstrate acquisition of advanced skills (for example, multi-tasking, decision-making, and communication).</p>
	Standard 4: Create and maintain supportive and safe learning environments	<p>Professional training often relies on internships and practicum, where the student is embedded in the authentic working environment. However, many business sectors have unsafe environments that are unsuited for those without qualifications or inductions. nDiVE maps real-world scenarios in an authentic and realistic way, while being safe in terms of experiencing limits and boundaries of the environment as well as developing individual skills. If action leads to failure, the action can be reversed without enduring harm. Teachers' guidance can provide additional explanation and mentoring in preventing the failure the next time. Regarding the intensity of the HMD and visualisation, all environments can be shown on and used with traditional 2D monitors and the visualisation is configurable, for example accidents can either be depicted or may be blocked and represented by a floating text message inside the environment.</p>
Professional Engagement	Standard 5: Assess, provide feedback and report on pre-service teacher learning	<p>nDiVE inherits mechanisms to provide immediate feedback and create detailed reports for analysis. Moreover, the doctoral research being undertaken by Ali Fardinpour addresses the recognition, encoding, and assessment of human actions to provide formative feedback, extending current evaluation approaches by using milestones and collected data about the learners' behaviour in the environment.</p>
	Standard 6: Engage in professional learning	<p>nDiVE can create recordings of all activities, and these recordings can later be used in a replay mode. This allows students and teachers to reflect on the process and outcome. With nDiVE being positioned as an interface between theory and practice, it further supports professional training in the discipline.</p>

	<p>Standard 7: Engage professionall y with colleagues, parents/ carers and the community</p>	<p>nDiVE integrates emerging technology that engages the learner in a highly interactive learning session. Project observations over hundreds of runs show that nDiVE created a strong attraction factor to observe, participate, and later share experiences. The use of the technology is designed to provide a multitude of sensory inputs, creating a state of excitement comparable to an exercise or fun activity. This momentum supports the community of sharing.</p>
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11 Reflections on success and limitations

11.1 Factors that were critical to the success

The results indicated that nDiVE is promising as a space for current, future, and past L&SCM students to practise their skills and build their confidence before going out on professional experience placement. The participants enjoyed the immersive scenarios and the opportunity to experience authentic activities in the virtual world, and felt that it would be beneficial in their preparation for professional experience. They also enjoyed the immersion in and authenticity of the environment. There were a number of factors that were critical to the success of the nDiVE project:

- The project was led by Torsten Reiners and Lincoln C. Wood, both in L&SCM and Information Systems. The project was, therefore, dependent on the education experience and expertise of the other project members. The inter-disciplinary exchange of information and knowledge enabled the team to embed innovative ideas that would be unlikely in a single, disciplinary-derived team.
- The focus on emerging technology to implement the proposed deliverables resulted in unexpected yet positive resonance from academic as well as industry institutions. The overwhelming interest in the project was an additional motivator to spend the extra time on realising additional depth in outcome and in demonstrable scenarios.
- The excellent support of stakeholders in the field of education (Curtin Teaching and Learning), visualisation (Curtin's HIVE), and health and safety training organisations (such as Sentient Computing). The team was always able to find support when it required additional knowledge, for example regarding technology and programming.
- The support from the Curtin School of Information Systems in numerous situations, as this provided a platform for presentations and finding additional workload-relief during work-intensive times.
- The social component, working and discussing as a team, outside of the workplace and (ironically) with a non-virtual environment, often over team BBQs.

11.2 Factors that impeded the nDiVE project approach

Any plan for a two-year research project is likely to face new and unpredictable challenges; such as when the scope is addressing emerging technologies with focus on education in the L&SCM discipline with a multi-disciplinary team spread over two continents. Summarising the last year's work in this area, we learnt that visions have to be constantly modified to keep up with both the development of new technologies and also the realities of changing demands of teaching and learning at universities and industry organisations. These included:

- The underlying technology experienced a quick turnaround in updates and new versions. HMD technology is in its prototype stage and not yet established as consumer-ready products. While it was possible to adapt nDiVE to the newest versions, it also involved a significant time allocation.
- Proprietary software (for example, the commonly-used virtual environment *Second Life*) created significant risks as export of items created in the environment was often not supported, and other parties could influence success and failure of projects by discontinuing access and support.

- The challenges in identifying and locating the most appropriate combination of technology and software to achieve the research objectives had an impact on the project timeline in the first 6-8 months (this was due to the significant shift in underlying technology that occurred during this period). Despite this, the project team caught up and continued to track well against with the project plans, and anticipates no significant delays in outcomes and timelines.
- The administrative process to get the project started was underestimated; that is, the internal process for document creation and approval took substantially longer than expected.
- The administrative overhead and timely process; that is, with respect to lengthy processes, paperwork, and the demonstrated risk-aversion to innovative approaches.
- The implementation of software was slower than expected. The evaluation for its eligibility for the project was time-consuming and required a steep learning curve regarding programming.
- The need to be flexible to accommodate team members' busy work schedules.
- The academic management activity of "reshaping" at Curtin University (a fundamental strategic change that had significant repercussions at the operational level) detrimentally impacted the project. Research allowances were decreased and the teaching load was increased, reducing the time allocation for the project lead. Furthermore, reshaping caused an environmental instability and reduced staff engagement and morale from the end of 2013 to mid-2014.
- Curtin University, the lead university, changed the structure of the Office of Research and Development to a "hub and spoke" architecture. While this will be supportive for future projects, during the transition it appeared to create a "vacuum" in administration during the changeover and therewith delayed project control and reporting procedures.
- Even though the responsibility lies with the lead, the time allocation in the proposal for the team member did not reflect the true requirements. For better project progress, a smaller team with more time allocation per team member is preferable (under constraints of the budget).
- We required multiple changes in the project management, an issue that could have been prevented by the lead university hiring an external project manager.
- Initially, we had anticipated working with current students to conduct experiments, however we found that there was limited support for this. The lack of support was due to the changing balance of research and teaching at Curtin University, the increasingly compressed teaching cycle, and limited time availability in the new modified course content which did not allow for the integration of intensive experiments.
- Unexpected non-availability of curriculum units (where the unit content matched the developing nDiVE scenarios, as this is where the experiments were planned).
- Finding a competent and available evaluator for the project. The team sent requests to several qualified evaluators but received negative feedback (primarily citing a lack of time due to other commitments, or lack of knowledge of either emerging technologies or logistics). The team finally secured Professor David Gibson, who has research interest in Learning Analytics and Game-based Learning.
- Finding students: The initial phase for preliminary experiments with students was unfortunately in the semester break (caused by a delayed start to the project). Preliminary experiments could only be concluded in Semester 1, 2014.
- Finding a PhD candidate who was qualified, had the requisite background, and was able to start his doctoral research at Curtin University. After assessing and supporting two applications from candidates with an excellent match of skills to project requirements (for example, they had extensive experience with virtual environments, authenticity, and education), the applications were unsuccessful as they had insufficient IELTS scores, or were unable to fulfil visa requirements, and the search needed to continue. Note that the project leads both conducted lengthy and

intensive interviews to verify the suitability and technical qualifications of the candidates beforehand, but were surprisingly confronted with the insufficient outcome in relation to the IELTS. In the end, a qualified PhD candidate (Marko Teräs) was found, who began in February, 2014. The PhD is fully-funded by Curtin University with support from the OLT grant.

- A number of team members changed institutions or their role during the life of the project. This had varying effects including having less time available to work on the project due to new commitments. This was partly addressed by additional support from the School of Information Systems.

12 Evaluation

Throughout the project the project team engaged in both self-evaluation and independent evaluation.

- Team meetings via Hangout – during the course of regular meetings, team members constantly checked with each other on project timelines and goals and ensured that the project was on task.
- Face-to-face meetings – goals were set at these meetings and revisited to ensure that the project was able to meet outcomes and deliverables.
- An independent evaluator undertook summative and formative assessment of the project (the report is available in Appendix 1).

12.1 General impact of nDiVE

Note that some of the impact was indirect as other parties learned of the project and the topic. For example, the special issue invitation was granted after hearing about the project and its current outcome.

- Special invitation to participate at the Festival of Learning being celebrated at Curtin University 10-12 March, 2014 (www.curtin.edu.au/learningfortomorrow). The general invite included the following line: *“Some of the confirmed activities include the opportunity [...] to trial the Oculus Rift 3-d goggles and scenarios specially created by our resident expert Torsten Reiners.”* Furthermore, the project presentation was invited to the evening stakeholder event with representatives from universities, industry, and government present. This allowed for a high visibility of the project and potential interest for further opportunities to apply the concept and later implementation.
- Promotional Video Curtin: <https://www.youtube.com/watch?v=zWffkKomR2Q>
- Special invitation to participate at the Big Day Out.
- Special invitation to present at the Academic Board Meeting (May 2014).
- Special invitation to present at the Career Expo (May 2014, May 2015).
- Special invitation to present at the Curtin Open Day (August 2014).
- Special invitation to present and run a one-day workshop at the University of Tasmania’s Australian Maritime College, on gamification and virtual environments (17 November, 2014).
- The Business Development Manager of the IP Commercialisation Group of Curtin University contacted us after presenting the project idea and first demos at multiple events. The current communication is about how the project could proceed in the future and funding be guaranteed. A business model was developed to present the ideas to a committee to secure two years of funding of AUD\$80,000 p.a. (that is, to create a commercial product from the artefacts). An initial seed of \$16,000 has already been received for a workshop with industry stakeholders. It is important to note that the Business Development Manager is aware of the OLT requirements to ensure that project outcomes remain available to all educational institutions in Australia without charge and limitations, and advised that this is not an issue of concern. It was decided to follow up on this idea in August 2015 after the OLT project is finalised.
- Constant interest is received in the project and how the technology is being used, and in the developed software to improve skill training. This is across the involved universities but also with respect to external partners and industry.
- Invitation to submit a proposal for the *ascilite* conference 2015 in Perth, with support from Jill Downie (Deputy Vice Chancellor, Education, Curtin University) and Sara de Freitas (Pro Vice Chancellor, Professor of Learning and Teaching, Murdoch University) to be governors on the proposal.

- The nDiVE project is cited in a special Curtin University edition of the *West Australian* under the category “Changing the Game”.
- The nDiVE project is cited in different industry journals, including (among others):
 - *Business News*: [hwww.businessnews.com.au/article/Meet-the-parents-boost-safety-with-goggles](http://www.businessnews.com.au/article/Meet-the-parents-boost-safety-with-goggles)
 - *Cannings Purple*: www.canningspurple.com.au/News/1407-DEL
 - *Australian Mining*: [hwww.australianmining.com.au/news/virtual-reality-as-a-training-tool-for-mine-site-w](http://www.australianmining.com.au/news/virtual-reality-as-a-training-tool-for-mine-site-w)

12.2 Limitations of nDiVE

- There is a learning curve associated with using the Unity engine (which underlies nDiVE) – it takes time to learn how to use this effectively. While this is negative over the short term, over a longer period the platform allows an experienced instructional designer to rapidly develop and modify scenarios.
- Scenario design takes resources and time. This probably requires additional instructional designer support. Even relatively simple modifications of existing scenarios will require a reasonable level of technical competency. (As an example, development of the scenario in Section 7.4.4 was completed over a 48-hour period around existing work.)
- nDiVE uses short and immersive modules. These are best positioned as an extension of existing material within or in addition to existing curriculum. It is not best used as a replacement for large segments of existing curriculum.
- The possibility of “distraction by technology” was noticed when experienced for the first time. However, the “new factor” wears off within a short time. The design of the environment has to take this into consideration, for example by implementing the previously mentioned gamified nudge to bring students back on the task.

12.3 Events, Presentations, and Publication for Dissemination

Details of events held during the period. Events include workshops, forums or colloquiums involving participants outside of the project team. Note that the numbers are estimated, therefore the number of higher education institutions and other institutions represented are included:

Event Date	Event title, Location (city only)	Brief description of the purpose of the event	Number of participants	Number of higher education institutions represented	Number of other institutions represented
May 17, 2013	Auckland University of Technology, NZ	Presenting the project to find collaborators.	10	1	1
May 29, 2013	Workshop ACS, Bunbury	Reiners was Invited as an expert on gamification and designing learning units using virtual worlds.	15	1	10
July 1-4, 2013	HERDSA, NZ	Conference paper presented by Wood.	30	Many	Many
July 15, 2013	Invited talk, Coventry, UK	Presenting the project, establishing collaborative projects with the Serious Games Institute.	13	1	3
Nov 28, 2012	ITS 2012, Perth	Conference paper on gamification by Reiners.	>40	Many	Many
Nov 28, 2012	ITS 2012, Perth	Conference paper on nDiVE by Wood.	>40	Many	Many
July 12, 2013	The Learner 2013, online	Conference paper on new landscapes by Bastiaens (collaborator on this paper about nDiVE).	>50	Many	Many
July 12, 2013	The Learner 2013, online	Conference paper on design perspectives of bots by Wood.	>30	Many	Many
July 12, 2013	The Learner 2013, online	Conference paper on mobile applications for virtual environments by Reiners.	>40	Many	Many
July 12, 2013	The Learner 2013, online	Conference paper on new landscapes by Bastiaens (collaborator on this paper nDiVE).	>30	Many	Many
Sep 17,	ACS Meeting,	Invited talk about	80	Many	Many

2013	Perth	gamification.			
Sep 20, 2013	HERDSA Rekindle in WA, Perth	Conference paper re-presented in Perth by Reiners.	30	6	2
Sep 21-23, 2013	SLAction, online	Conference paper presented by Fardinpour and Reiners.	20	Many	Many
Dec 1-4, 2013	Ascilite 2013, Sydney	Conference paper by Gregory.	>60	Many	Many
Dec 1-4, 2013	Ascilite 2013, Sydney	Conference paper by Fardinpour.	>20	Many	Many
Dec 1-4, 2013	Ascilite 2013, Sydney	Conference paper by Reiners.	>30	Many	Many
Jan 30, 2014	TL Forum 2014, Perth	Conference, demonstrating T+L achievements in Western Australia. Presentation by Reiners on chatbots.	45	Many	Many
Jan 30, 2014	TL Forum 2014, Perth	Conference, demonstrating T+L achievements in Western Australia. Presentation by Reiners on nDiVE.	50	Many	Many
Jan 31, 2014	TL Forum 2014, Perth	Conference, demonstrating T+L achievements in Western Australia. Presentation by Fardinpour on human behaviour in virtual environments.	30	8	2
12.3.14	Festival of Learning, Perth	Promoting nDiVE and the future of learning at Curtin University. Afternoon for lecturers and students, evening for external stakeholders.	>400	>20	>50
Mar 12, 2014	Radio Interview	Promoting nDiVE and the future of learning at Curtin University. Afternoon for lecturers and students, evening for external stakeholders.	>100k	Many	Many
Apr 14, 2014	MHMK, Hamburg, Germany	Project presentation, invited for collaboration.	>100	Many	Many
Apr 17, 2014	FernUni Hagen,	Project presentation, invited for	19	1	1

	Germany	collaboration.			
Mar 23, 2014	Graz University of Technology, Graz, Austria	Project presentation, invited for collaboration, EC proposal.	21	3	2
Apr 1, 2014	Presentation at Deloitte	Skill training.	>40	0	10
Apr 11, 2014	Presentation at Deloitte	Skill training.	5	0	2
May 15-18, 2014	Career Expo	Representing Logistics for Curtin University.	>400	Many	Many
May 20, 2014	Academic Board Meeting	Representing nDiVE for Curtin University.	80	Many	Many
Jul 23-27, 2014	Ed-Media 2014, Tampere, Finland	Conference presentation, presenting nDiVE.	>30	Many	Many
Sep 2014	CHNM2014@Curtin	Invited presentation.	50	Many	Many
Nov 2014	Ascilite 2014, Dunedin	Conference paper presentation.	30	Many	Many
Mar 2015	Dunedin	Discussion, collaboration.	12	2	0
2015	Connecting Industry to Research through Innovation	Invited presentation.	60	Many	Many
May 2015	Career Expo	Representing Logistics for Curtin University.	>500	Many	Many
June 2015	Presentation Tampere	Meeting regarding collaboration with University of Tampere.	11	2	0
September 2015	HIVE Photo-shooting	Project was selected to be included in advertisement material for the L&SCM courses	-	-	-

12.4 Resulting Outcomes and Linkages

In addition to the reported outcomes and collaboration mentioned earlier, the project received multiple invitations to participate in EU proposals, unfortunately not successful or still under evaluation, and received multiple grants or project approvals. Among others, these outcomes are:

- **HORIZON 2010 proposal**, lead TAMSK in Tampere, Finland – unsuccessful
- **ARC Linkage grant 2013**, lead Curtin – unsuccessful
- **COST TDP**, partner, lead iLab.o - iMinds Institute – unsuccessful
- **Transformation Training Centres proposal**, partner, lead Curtin – unsuccessful
- **Australia-Germany Joint Research Cooperation Scheme**, lead Curtin – under review

- **HIVE Proposal:** Intelligent “Spying” on closed 3D spaces. This project proposal was *granted* and provides us with HIVE time and support with programming.
- **Marco Teräs** received multiple awards for presentations (poster, paper) during Curtin events.
- Marco Teräs received a research grant (\$8,000) from Curtin to extend his work on the project with partners in Trondheim, Norway.

The invitation and participations in the proposal are related to the success and dissemination the project team experienced. The collaborations are still active and used for PhD programs.

13 Future directions

The nDiVE project has developed and pilot tested the nDiVE system and learning support materials in a range of teaching settings, both vocationally focused and at the university level. These tests show that the environment and the learning approach are valuable resources. The next stage of development is to move these resources into the curriculum and have them actively used and developed by members of the educator community. To this end, the following steps in the project will be:

- Assess new technology releases to evaluate how they support the sense of immersion.
 - Develop specifications for a fully immersive visual, audio, and unrestricted movement set of equipment to be used in nDiVE.
- Develop more taxonomies on learner behaviours and human action recognition. These taxonomies will build into patterns of actions required to completed tasks. This approach will support both manual and automated assessment of tasks.
 - Develop assessment frameworks using the taxonomy, intended to support expert assessment of performance in the virtual environment.
 - Extend assessment principles to an automated assessment environment, enabling rapid provision of formative feedback.
- Enhance teaching support material to show how a range of scenarios can be modelled in the immersive environment.
- Follow on the concept of intelligent guidance systems (bots) to enhance the asynchronous and self-guided learning within the nDiVE environment.
- Widen the audience and potential users of the nDiVE environment by developing industry “on-boarding” modules, and working with industry representatives to build these into the platform more completely.
 - Development of use-cases with close collaboration with industry representatives.
- Open up nDiVE to a broader audience. nDiVE is currently used in multiple institutions, for example at the HIVE at Curtin for demonstrating immersive learning, the School of Information Systems for demonstrating L&SCM to K-12 students, and at Sentient Computing as part of the collaboration with nDiVE. One limitation to broadening the audience is the required development time to setup other scenarios, a common concern with virtual environments, including Second Life.
- In collaboration with the HIVE, develop a network component to allow multiple learners to be in the environment. This includes the design of learning objectives with the need for teamwork, communication, and information sharing.
- Meet a major request for an increased integration of game-based components, merging learning with game playing. The objectives were occasionally considered as too simple or “real work and not a game”. Further research is planned on the benefits of video games and how components can be transferred to the nDiVE environment without losing the educational focus.
- Support for the separate theses of George Coldham and Marko Teräs. Both began as part of the nDiVE project and their results will be later integrated into the project.

13.1 Conclusions

The nDiVE project has developed several immersive virtual environments for learners to develop and enhance their skills in simulated training environments, working either synchronously or asynchronously. Existing virtual environment and control technologies have been integrated to increase immersion and allow students to undertake authentic assessments. Scripts and scenarios have been created for use in both formative and summative assessment to support self-, peer-, and teacher-assessments.

Using the nDiVE portfolio of scenarios and teacher-support materials enables educators and businesses to rapidly develop immersive activities that enable authentic assessment of user capabilities. This provides additional elements that are not otherwise available through traditional examinations of user comprehension of hazardous working environments. Students in the classroom can be exposed to challenging or dangerous working environments – and can explore using a range of responses to developing situations – without endangering life or taking the risk of a financially devastating mistake.

Dissemination of this project can be found at ndive-project.com, including information on how to get started using these resources already created. The public availability of these resources enables a range of educators and instructors to develop and build on the nDiVE scenarios and materials for use in classrooms and training situations.

14 Suggestion for future research

Throughout the project, the discussions and reflections amongst the nDiVE team provided ample opportunity to evaluate what were seen to be the successes and difficulties faced. This led to three key suggestions in terms of team structure and future research directions.

First, a key suggestion that emerged is that in future, an education researcher should hold the lead role. It was felt that this would provide a stronger opportunity to ensure that the project would follow the requirements and philosophies of education-related research stronger. In addition, it is believed that a smaller team with greater time allocations would prove beneficial; while the project benefited from the inclusion of a range of international experts, the time allocation and supporting resources proved generally insufficient.

Second, future research directions include closer partnerships with industry representatives to develop materials and approaches that bring the working environment even more closely to the classroom experience. While the current project worked towards this, there is still substantial work that can be undertaken in this area. The key benefit and outcome is to deliver greater authenticity as reflected in the skills and capabilities that the students would demonstrate in the simulated experiences. In particular, this would push the current project towards greater inter-personal discussion, communication, and collaboration within each scenario.

Third, we identified that the (research) ambitions being stated in the proposal did not reflect the need during the actual development including the work conducted by HDR students. The preliminary test resulted in a partial refocus of the project, not in its nature but its implementation needs. While this is expected in projects and potentially addressing the explorative nature of research, certain circumstances could not be predicted. Among others; the shift of technology at the starting time of the project (Virtual World to true Virtual Reality) and the time required to find an adequate candidate for the HDR student. The time-frame of the grant was to complete the project in a two-year period. However, when the team worked to embed HDR students into the project, providing the opportunity for them to embed their work into the larger research program of the project, this created difficulties. The MPhil program is of a shorter duration than the grant, and a PhD program is of a substantially longer duration. A further challenge was the difficulty in finding a person who is an appropriate match with the project requirements. In many cases it will take more than a single year to locate someone, enrol them, get them through their initial/candidacy seminar, and perhaps pick up some additional research methods units if required. This leaves only a single year of time for them to work on the project before the conclusion of the grant.

15 Publications and Collaborative Activities

The nDiVE team have disseminated various publications through journal articles, book chapters, conference proceedings, workshops, and presentations, which are detailed below. These can also be found on the nDiVE website, which will continue to be updated beyond the lifetime of the project.

15.1 Publications

1. Gregory, S., Gregory, B., Wood, D., O'Connell, J, ... Irving, L. (2015). **New applications, new global audiences: Educators repurposing and reusing 3D virtual and immersive learning resources.** In: T. Reiners, B. R. von Konsky, D. Gibson, V. Chang, L. Irving and K. Clarke, Globally connected, digitally enabled: Proceedings ascilite 2015 in Perth. Australasian Society for Computers in Learning and Tertiary Education (ascilite), Perth, WA, Australia, pp. 121-133.
2. Reiners, T., Wood, L. C., Teräs, M., Gregory, S., Teräs, H., Chang, V., ... Guetl, C. (in press). **Self-guided Exploration of Virtual Learning Spaces.** In S. Gregory, D. Wood, & S. Scutter (Eds.), *Virtual worlds: facilitating student engagement, creativity and intercultural awareness through authentic learning experiences.* Springer.
3. Fardinpour, A., Reiners, T., & Wood, L. C. (in press). **Action-based Learning Assessment Method in Virtual Training Environments.** In S. Gregory, D. Wood, & S. Scutter (Eds.), *Virtual worlds: facilitating student engagement, creativity and intercultural awareness through authentic learning experiences.* Springer.
4. Teräs, H. (2015). **You are Your Avatar is You: Phenomenological Literature Review of Virtual Embodiment in Virtual Environments.** CBS HDR Colloquium Curtin University.
5. Teräs, H., Teräs, M., & Viteli, J. (2015). **Authentic context as a foundation for Gamification and game-based learning.** In: T. Reiners, B. R. von Konsky, D. Gibson, V. Chang, L. Irving and K. Clarke, Globally connected, digitally enabled: Proceedings ascilite 2015 in Perth. Australasian Society for Computers in Learning and Tertiary Education (ascilite), Perth, WA, Australia, pp. 566-570.
6. Teräs, M., Teräs, H., & Reiners, T. (2015). **The Lived User Experience of an Authentic Context In Virtual Environments: First Steps of a Phenomenological Analysis in a Safety Training Setting.** 26th Australasian Conference on Information Systems. <https://arxiv.org/pdf/1606.01363.pdf>, pp. 1-6.
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8. Reiners, T., Wood, L., Gregory, S., & Teräs, H. (2015). **Gamification design elements in business education simulations.** In M. Khosrow-Pour (Ed.), *Encyclopedia of Information Science and Technology* (3rd ed., pp. 3048–3061). Hershey: IGI Global.
9. Gregory, S., Reiners, T., Teräs, H., Teräs, M., & Wood, L. C. (2015). **Gamification and digital game-based learning in the classroom.** In M. Henderson & G. Romeo (Eds.), *Teaching and Digital Technologies: big issues and critical questions* (pp. 127–141). Cambridge University Press.
10. Wood, L. C., & Reiners, T. (2015). **Gamification.** In M. Khosrow-Pour (Ed.), *Encyclopedia of Information Science and Technology* (pp. 3039–3047). Hershey, PA: Information Science Reference (an imprint of IGI Global). Retrieved from <http://goo.gl/N8vihL>
11. Wood, L. C., & Reiners, T. (2015). **Storytelling to immersive learners in an authentic virtual training environment.** In T. Reiners & L. C. Wood (Eds.), *Gamification in Education and Business* (pp. 315–330). Cham, Germany: Springer. Retrieved from <http://www.springer.com/economics/game+theory/book/978-3-319-10207-8>
12. Wood, L. C., Reiners, T., & Bastiaens, T. (2014). **Design Perspective on the Role of Advanced Bots for Self-guided Learning.** *The International Journal of Technology, Knowledge and Society*, 9(4), 187–199.

13. Reiners, T., Wood, L. C., & Bastiaens, T. (2014). **New Landscapes and New Eyes: The Role of Virtual World Design for Supply Chain Education.** *Ubiquitous Learning: An International Journal*, 6, pp. 37–49.
14. Teräs, H., Teräs, M., & Reiners, T. (2014). **Giving virtual worlds a pedagogical boost with gamified authentic learning design.** In *Proceedings of World Conference on Educational Multimedia, Hypermedia and Telecommunications 2014* (pp. 1688–1693). Chesapeake, VA: AACE. Retrieved from <http://www.editlib.org/p/147703/>
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The project further received two internal research grants (each \$5,000) to upgrade two conference publications for high ranked journals by collecting data and extending the implementation. Both research grants are part of nDiVE; see also below.

- Journal of Vocational Education and Training (ABDC: “A”, in preparation)
- Manufacturing and Service Operations Management (ABCD: “A”, submitted)

Other publications in process and to be submitted in the near future:

1. Working title: “Innovative Authentic Education in Logistics and Supply Chain Management: A n-Dimensional Immersive Virtual Environment (nDiVE)”. nDiVE core members. Contract with Springer.
2. Summarising article in a higher-ranked journal; covering the nDiVE project and its conclusive outcome (including the experimental results).

The research on gamification within nDiVE resulted in an invitation to submit an edited book with Springer Verlag, published in 2015: Reiners, T. and Wood, L.C. (2015). *Gamification in Education and Business*. Berlin: Springer. The book covers theory, education, business, and use cases; all in the context of gamification:

- 58 proposals submitted.
- 34 chapters in the final book.
- 66 international authors.
- 798 pages.
- 119 figures, 84 in colour.

15.2 Collaborations

nDiVE resulted in multiple collaborations with academic institutions and industry partners. The nature of the collaborations varies from short-term discussions to ongoing projects and established long-term relationships. This list shows a selection. Further information can be provided on request. The list does not distinguish between active and past collaborations.

15.2.1 Academic collaboration in relation to nDiVE or closely related topics

- **Nina Sellars**, School of Arts, Curtin University
Simulation of the transport of human organs for transplantation. This project is initiated; due to resource limitation it is now postponed until nDiVE is finalised. This project is the first external project to apply the nDiVE methodology, guidelines, and technology in a new context. The project is also bridging the virtual environment and real object display for a comprehensive immersive experience.
- **Sara de Freitas** (former Associate Deputy Vice Chancellor, PVC Education)
Serious games, improvement of engagement in the classroom.
- **David Gibson** (Director Learning Engagement), Curtin University
Learning analytics using big data.
- **Brian von Kinsky**, Curtin University
Visualisation of data. Topic: Immersive technology to explore data.
- **Mikhail Fominykh**, Molde University.
Immersive virtual learning environment to simulate training environments.
- **Tom Willans**, Serious Games Institute, Coventry University
Emotion induction using immersive technologies.
- **Michael Steurer**, formerly Technical University of Graz
Collaboration in virtual environments, learning analytics, heatmaps for learner tracking.
- **Fraunhofer Austria**, Visual Computing, Graz Austria
Collaboration to evaluate the deviation in presence using the Oculus Rift vs. CAVE
- **Students at the Graz University of Technology**
Primin Riedmann, Lisa Tomes, Karin Wildings.

15.2.2 Industry collaboration and support

The project team remains in close contact with various industry partners to later conduct industry experiments on skill training using the nDiVE environment. These are, among others:

- **Sentient Computing** (Doug Bester, Managing Director)
The company is working with Woodside on 3D training units in the context of mining.
- **Deloitte** (former lead partner Coert du Plessis)
Skill training using immersive and authentic environments. Deloitte is facilitating the contact with other industry partners, for example Rio Tinto, Woodside, and Australia Post.

Marko Teräs and George Coldham collaborate with multiple companies to conduct interviews and benchmark the nDiVE technology. The team appreciates the support for the nDiVE project and our PhD students from, among others, Woodside, Rio Tinto, and Sentient Computing.

Other collaborations include:

- Graz University of Technology, Austria
- FernUniversität Hagen, Germany
- MHKH Hamburg, Germany
- Büro X, Hamburg, Germany
- University of Athabasca, Canada

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(see also 15.1 Publications for further references)

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External Evaluation Final Report of the OLT Funded Project: nDiVE

October 2015

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A handwritten signature in black ink, appearing to read 'David Gibson', with a long horizontal flourish extending to the right.

EVALUATION REPORT: EXECUTIVE SUMMARY

Purpose

This evaluation is aimed to monitor project progress, provide formative input towards supporting the project to achieve its intended aims; and provide a summative view of the project's capacity to achieve the project aims and intended outcomes. It is not an evaluation of the impact of the project outputs.

Key findings

The project was closely followed, monitored, and consulted in the best interest of achieving not only the project's aims and deliverables, but also to sense changes and new directions in technological development, its educational implication of the technology, and its practical implementation. The project achieved a strong awareness in the participating universities but also among the different academic and industry communities. The project team had robust project processes considering the participating researcher's time commitments for teaching and administrative work. At the same time, the project experienced several challenges that are faced by many distributed collaborative research projects: multiple events that impacted timeliness, such as finding PhD students, dealing with changes of affiliation, changes of teaching focus, which impacted in-class experimentation, and other administrative impacts. Key evaluation findings include:

- ◆ The development of resources that can be used in education of logistics and engineering professionals through a range of both synchronous and asynchronous activities
- ◆ The development of resources that can be used to support teaching and learning
- ◆ The development of assessment activities and guidelines to support the implementation of nDiVE or similar virtual environments in this discipline
- ◆ Pilot testing of the resources in a range of settings
- ◆ Several awareness-raising dissemination activities that included conference presentations, seminar presentations and journal articles
- ◆ Many invitations to present on marketing events, inclusion in marketing brochures and industry articles
- ◆ Focus on the dissemination of results, testing and evaluation of environments, and strong connection with industry stakeholders
- ◆ Framework (carrot and stick) to support the development of learning material based on storytelling, narratives, gamified elements for engagement and technology-integrated learning
- ◆ Identification of the value of the technology in a learning context (e.g. replacement or integration in a traditional teaching unit)

In summary, the project resulted in a strong 'proof of concept' technology that was collaboratively developed and broadly shared and at the same time, illustrates how early-stage technological innovations can be challenged by the difficulties of setting up a novel environment for development, testing and research evaluation. The project shows the potential for a new form of virtual logistics training and has uncovered several key

characteristics for success in future similar research settings.

EVALUATION REPORT: BACKGROUND

The nDiVE project grew out of international collaborative and collegial research partnerships among people who shared an interest in applying technology in new ways to improve training, content delivery, and the impact of technology on learning. The essential shared vision of the group is that technology offers new affordances for learning that have the potential to make higher impacts on students via immersive digital experiences that embody authentic psychological and physical triggers for the learning experience, and that this immersion in authenticity in a safe, scalable and highly documented environment will provide several benefits. Chiefly those benefits potentially include more impactful learning (e.g. longer or more deeply retained knowledge, more deeply felt experiences than with reading or watching a video, but with more safety than a real-world apprenticeship) with access to higher resolution data that documents learning, and a higher safety, lower-cost way to provide highly impactful authentic decisions that are known to develop heuristic knowledge. The research project explored a variety of questions within this space and has made significant contributions to knowledge.

Project aims

The nDiVE proposal aimed to:

- Innovation and development in learning and teaching, including in relation to the role of new technologies.
- Facilitates multiple emerging technologies for cyber environments in an integrated framework to bridge theoretical and practical skills acquisition as preparation for real-life, capable of decision-making considering risk and financial impact.
- Develop and trial an authentic learning environment which will enable Logistics and Supply Chain Management students to prepare, develop, and evaluate their skill acquisition in readiness for their professional career
- Harness the emerging 3D immersive virtual environments, gamification, and mobile technologies to facilitate innovative authentic education and then making the outcomes accessible across the higher education sector
- Develop an immersive environment accompanied by a theoretical framework and practical guidelines based on authentic education. This outcome represents an exemplar for future developments of virtual environments in other industries
- Provide tools and guidelines to condense multiple dimensions into a restricted immersive virtual environment to demonstrate, simulate, and control real-world situations, allowing students to grasp the highly complex and interwoven processes.
- Provide guidelines for developing immersive scenarios that can be used to increasingly improve student skills in real-working environments
- Build and evaluate the use of an scenario-based training environment with emphasis on joint learning opportunities in an authentic learning environments in Australian higher education institutions.

Project deliverables

The key deliverables as stated in the project report were:

- 1) Innovative nDiVE (3D logistics training) environment

- 2) Resources and new framework to support immersive, gamified learning and teaching
- 3) Evaluation reports
- 4) Publication of results

The major **project deliverables** are:

- D1. The nDiVE environment in the established and real software environments of Second Life (with backups in OpenSim); with a prototype developed in OpenWonderland.
- D2. Resources to support learning and teaching:
 1. Authentic learning and assessment material for three scenarios (container terminal, warehouse, and production facility); accessible independently but also interconnected as a supply chain. The base scenario was also used for a second case, illustrating the re-use of key background, processes and artwork for a quick turn-around new learning environment.
 2. Scripts to animate the scenarios (including bots) and drive interactions with the learner
 3. Implemented recording of scenes and events as a resource for authentic learning and assessment
 4. Guidelines to enable teachers to take advantage of nDiVE, explaining how to integrate learning material and demonstrate authentic teaching and learning strategies; how to use nDiVE
 5. Principles and guidelines for developing and implementing formative skill development and assessment in a 3D virtual world based environment
- D3. Evaluation of:
 - Survey results and analysis
 - The usefulness of nDiVE
 - Self- and the potential for group-learning in nDiVE
- D4. Final reports and dissemination of results:
 - Workshops.
 - Journal publications.
 - Conference presentations.
 - nDiVE website
 - Blogs, and other publicly accessible web-based dissemination
 - Protocol and guidelines for sharing future use and development of nDiVE

External evaluator

Associate Professor David Gibson, a serious games researcher, developer and author with knowledge of learning theory, psychology of learning, educational technology innovations, and simulations, provided early-stage formative feedback on the research design, processes and theoretical development and an appropriately distanced summative evaluative perspective on the team's work. Gibson serves as Director of Learning Futures at Curtin University and is involved in advanced analytics, serious game and simulation development, and strategic innovations in e-learning.

The evaluation approach

The formative evaluation approach adopted was founded on a close working relationship between the project leaders and the external evaluator in order to monitor and advise on the evaluation framework and dissemination opportunities, as well as the

resourcing and investigation strategies adopted by the project. This approach enabled the identification of noteworthy practices and areas for improvement across the life of the project and, most importantly, enabled the project team to respond to the areas identified.

These criteria informed the development of the key evaluation questions:

1. Were project goals, objectives and intended outcomes achieved?
2. How relevant and appropriate were the chosen project plans, activities and strategies for achieving the project aims?
3. How effective are the chosen dissemination strategies?

The evaluation activities began in April 2013 and concluded in September 2015.

About this report

This summative report offers an overview of the external evaluation approach and method, an overview of the data collection strategies and a synthesis of findings against each of the above questions, before offering conclusions. The report concludes with an invited response from the project leader to the evaluation findings prior to submission to the funding body.

EVALUATION REPORT: EVALUATION PROCESS

The following data collection strategies were used to collect and analyse the required data against the relevant evaluation questions:

1. *Were project goals, objectives and intended outcomes achieved?*
 - a. Review of project deliverables. Early stage meetings with the team helped to form, critique, review and re-think the foundational concepts of immersion, authenticity, and behavioral analysis of user actions and products within the nDIVE environment.
 - b. Informal interviews with selected project team members. Meetings held throughout the formative stages of the work refined ideas, subjected them to outside scrutiny and developed a critical stance of the team on its proposed work. These communications were maintained during the life of the project via opportunities such as conference papers, sharing of presentations, and co-presenting at business and community workshops.
2. *How relevant and appropriate were the chosen project plans, activities and strategies for achieving the project aims?*
 - a. Monitoring project progress through regular evaluation meetings with project leader and project officer. Meetings with Torsten, Lincoln and Hannah were frequent at first and became less frequent over time as the project progressed. Progress of the work was shared at regular intervals and included discussions with closely related graduate students working in related areas.
 - b. Observation of project team meetings. The evaluator sat in on team meetings and participated in the review and discussion.
 - c. Reports, papers and dissemination products were examined.
 - d. Due to constraints of time allowed for the evaluation, there has not been a deep independent analysis of evaluation data collected across the life of

the project, but the processes, data collection methods, and general results have been reviewed to the satisfaction of the evaluator.

3. *How effective are the chosen dissemination strategies?*

- a. Monitoring of potential influence. The project leaders have completed an edited book and several conference and business workshop presentations, and been invited to join in entrepreneurial applications of their work. So the impact of the work has been evident and seems to be growing. The collaborative research partnership seems well poised to do further work building upon this initial effort.
- b. Review of project reach. The project has had international outreach via the professional connections of the project leaders to a global network in the Association for the Advancement of Computing in Education and has thus reached over 40 countries. Publications now sit in the EdITLib, which has 213,000 authors and 108,000 papers.

Achievement of project goals, and intended outcomes

1. Review of project deliverables

Project deliverables were reviewed across the life of the project, with input provided as part of the development process.

The evaluator is not a content expert in logistics and is thus not in a position to evaluate the accuracy or relevance of the resources developed. Instead the deliverables have been evaluated according to the following criteria: (a) accessibility by potential end users; (b) quality of evidence base used towards development; and (c) alignment with project aims and goals. Drawing on these criteria, the external evaluator acted as a critical friend, providing formative input across the development processes. Using these criteria, the project has been successful in reaching its aims, creating quality products for a world audience, and achieving global reach.

2. Review of Project team

The project team is a promising group of researchers who are well poised to continue to build upon their work. They have built a level of trust, friendly competition, and serious effort which appears to be a solid foundation for continued success as an international research group.

3. Review of stakeholders

As a stakeholder, the evaluator had first-hand experience in learning from the project team, participating in some of the experimental pilots and trials, and seeing the innovative impacts of the team on other stakeholders at meetings, conferences and corporate trainings. A palpable level of excitement about nDIVE-empowered training has been evident at all sessions involving stakeholders.

Relevance of project plans, activities, strategies

- Monitoring project progress through regular evaluation meetings with project leader and project officer

Since August 2013, Dr. Reiners (project co-leader), the project officer and the external evaluator have conducted regular “check-in” meetings to monitor project progression. These were conducted, in the main, as teleconference, phone and face-to-face meetings. The evaluator acted as a sounding board and a ‘critical friend’ in these interviews. The evaluator followed up on any issues raised in prior meetings, to ensure that these were being addressed by the project team.

- Observation of project team and reports

In addition to focused evaluation meetings, the external evaluator participated as an observer in face-to-face project team meetings involving team members living in Perth and with other team members when they visited Perth. Progress reports submitted to the OLT since July 2011 were reviewed prior to submission and feedback given. Project plans were discussed during the evaluation meetings and project timelines reviewed.

- Review of data collected by project team

The external evaluator reviewed the dissemination and data collection and provided feedback for refinement of the instrument. Advice was offered regarding observation strategies and tools for gathering observational data. Feedback on the materials developed for this purpose was also provided.

Effectiveness of dissemination strategies

1. Monitoring of potential influence

Data were gathered regarding potential influence of the project on the uptake of project deliverables beyond the project team, and evaluation of media reports. This strategy included noting details regarding potential adopters and industry stakeholders that observed the participants using the environment and individuals and groups who indicated their interest in following the project. The project team was asked to present to industry meetings and to be part of prospective-taking by industry consulting groups in Western Australia.

2. Review of project reach

The project team has been active in dissemination activities over a range of forums and with global reach amongst both academia and industry. Monitoring these activities and recording the details in a developing spreadsheet enabled the project team to establish whether there was a potential to spread project outcomes beyond the life of the project. These records also noted the potential number of people that heard about the project and were exposed to the concepts. Workshops and presentations have been held around Australia, New Zealand, Germany, Norway, Austria, and Finland.

EVALUATION REPORT: FINDINGS

Achievement of aims and outcomes

Soon after the project nDiVE started, the project team focused on an external dissemination by publication in academic and non-academic outlets and used the local institution to present at key-events to initiate a word-by-mouth propaganda; leading to invites in Curtin events and early industry connects. This allowed the proceeding of short and long term goals:

The following goals were classified as medium to longer term aims:

- provide a national, comprehensive, immersive, 3D virtual environment with spaces and
- resources designed to facilitate authentic teaching practice and formative assessment activities
- Demonstrate current/future student the field of Logistics/SCM
- Extend the framework nDiVE to other disciplines
- Exemplify the theory in short modules to demonstrate the impact of “wrong” decisions and not considering the environment as such

There is evidence from across the life of the project that aims were achieved.

- Several interactive 3D scenarios were developed to enable students to experience and manage emerging situations in real-world working environments with no risk to themselves.
- These scenarios provide opportunities for skills development and authentic learning. The logistics scenarios have been tested with a wide-range of people of different ages and professional backgrounds. Data have been collected about the possible impact of the experience on learning through surveys, data about movements and actions in the scenarios, and observations and feedback from users.
- The materials developed emphasized incorporation into supply chain curriculum to support self-led and expert-directed learning.
- The software driven nature and low-resource requirements means that students and learners can download and run these environments off-line. (e.g., there is a potential for a non-immersive use of the environment on a tablet, enabling miners to engage in additional safety training and awareness building of hazards while on a flight to remote mine sites around Australia.)
- In addition, the development of automated bots designed to interact with learners within the environment will improve the ability to use nDiVE for self-directed learning. However, the project discovered multiple concerns about bots; among others 1) the difficulty to program them without the right knowledge, 2) low-level AI results in unexpected behavior and by that to outcomes that may contradict the intended learning goals, 3) alternative development of a gamified nudge to direct the learner indirectly.
- An outcome of the project has been to develop a stable immersive, 3D virtual environment with scenarios and resources designed to facilitate authentic learning and provision of valuable formative feedback to users. These resources are available for other teaching staff or managers with responsibility for developing skillsets for working in these real-life environments.

The resources developed for teaching and assessment can be rapidly and easily adopted by many other educators or business professionals for training courses. However, the virtual/immersive environment resources are not as re-usable or as adaptable as the team initially hoped....

There has been a strong consensus amongst the stakeholders and potential users of the project outcomes that the expertise and effort required to create and modify the environment is a hindrance to adoption. While the project team have attempted to overcome this problem, their attempts were aborted due to resourcing constraints and because it overstepped project scope. However, the assessment tasks and scenario

development guideline resources based on the nDiVE project are potentially extremely useful for other academics and industry stakeholders attempting to use nDiVE or develop their own similar platforms. These materials have not been extensively tested over different institutional and industry contexts and this is an appropriate area for further projects following nDiVE.

One of the infrastructural issues that emerged during analysis of participant data is the wariness of the sense of immersion as a negative – while they are still physically in another environment. Being ‘divorced’ from your body and unaware of what is going on around you can result in a sense of fear or anxiety in some users. This may dictate the use of many small private rooms/booths for use of this type of technology, which may limit the utility in resource-constrained universities.

Furthermore, the technical expertise with the range of consumer technologies that have been brought together strongly indicates that adopters have sufficient organizational support (e.g., skilled ICT support staff) as this is not a ‘plug and play’ environment.

Given the timeframe and geography, the strong start with F2F meetings was valuable. The lengthy time for development – and changes in technology part-way through the project – have pushed out the attainment of long-term goals ... hence, reaching some of the long-term goals will take longer and was not achieved in the current project.

nDiVE was essentially a “proof of concept”. It has identified what is necessary to make this type of environment work and how to use it in the classroom.

In this respect it has been successful. Deliverables and teaching support materials can be easily used to inform practice at other institutes and by other teachers, or within industrial organisations.

However, further evaluation on the efficacy of the solution needs to take place. The project team also identified that this type of approach may not be valuable over as broad a range of classroom environments as they first envisaged – rather, it is best adapted for use as a ‘capstone’ type experience.

Another challenge is that it is unclear whether this nDiVE environment and approach provides greater opportunity or benefit than other, competing, pedagogical approaches. There is no evidence of improved retention of skills or knowledge developed using nDiVE. At this stage of development, the outcomes are appropriate to indicate that these materials and approaches can achieve their promised potential in ‘laboratory conditions’, but not proved with extensive large-scale field-tests.... The difficulties of receiving accurate and relevant results are

- the novelty technology impacts positively on the engagement and classic experiments are not able to identify the true attribute that cause the positive experience results; that is, with the limited scenarios. The team (i.e. the PhD student, is conducting a phenomenology study with industry partners to identify the true value and relevance of virtual training; in progress and could not be achieved within the given project duration.
- Large scale experiments (>300) resulted in a strong positive feedback. The analysis showed a strong influence of the technology and the first viewer experience of the scenario (comparable to game playing). A long term study over multiple semesters would require the intensive use of the framework and its technology to create a

mode where the technology and environment becomes a tool like blackboard or mail. Experiments can then compare the inclusion vs exclusion of the technology.

Recommendation:

- Additional project undertaken to broaden group, more field testing, longitudinal study on the impact of nDiVE
- environments on student learning; and (b) more extensive field-testing (c) more extensive, long-term, longitudinal studies on skills/knowledge retention.

Project process

The project team has worked together effectively despite the geographic spread and change institutional affiliations (and countries) during the project.

Project members kept in touch via email, skype/hangout meetings, and F2F meetings while in Perth. All cited the strong role of Dr Reiners as project leader in keeping project activities on track and adhering to timeline and budget.

The project team shared many emails around publication deadlines and resolving technical challenges, working in waves of activities. This was followed up by bimonthly updates from the team leader and additional skype/hangout calls as required to tap the expertise of the various team members. The periodic F2F meetings were beneficial, particularly early in the project, and enabled the team to solve some challenging issues effectively and quickly.

The team capitalized on travel for conferences and their shared interest to attend the same circuit of conferences that they co-presented at and had additional meetings before/after conference. The resilience of the team leaders enabled them to keep the project on-track despite changes in academic workloads, working conditions, and personal challenges experienced by the project, which otherwise would have slowed the progress.

The team could have improved their process with a more rigorous reporting process back to the team and monthly or bi-monthly newsletters/updates being sent around on a regular basis. During the biggest period of disruption due to changes in the working environment at Curtin, while the project continued, there was a notable drop in the clarity and frequency of communication from the project leaders and project Coordinator/manager.

Dissemination strategies

A strength of this project has been the clear identification of both academic and industry groups that would be potential adopters of the project outcomes. This enabled a close and meaningful engagement with the various adopters throughout the project, to gauge their opinion and perspectives on the technology and pedagogical tools.

The dominant dissemination methodology was awareness raising through academic publications, journal articles, conference presentations, coupled with strong promotion of the project by Curtin University and coverage in the media (e.g., newspaper and radio). These linkages developed from these activities will encourage further development and interest in the project. For details on development and outcomes see the reference list of the project.

The awareness raising strategies have been wide-reaching and resulted in an impressive list of publications based on various elements of the project. These results indicate the extensive thought and trial-and-error development for this proof-of-concept project but

also indicates that further implementation may be required over a more extended period of time.

The personnel movements around universities and countries over the duration of the project had a significant impact on the project and the ability to engage with more students in real-classroom use of the scenarios.

EVALUATION REPORT: CONCLUSION

In summary, this project has successfully developed the deliverables under the constraints of a changing environment, context, and consideration of feedback during the experiments.

21 Signature DVC Curtin University

Certification by Deputy Vice-Chancellor (or equivalent)

I certify that all parts of the final report for this OLT grant/fellowship (remove as appropriate) provide an accurate representation of the implementation, impact and findings of the project, and that the report is of publishable quality.

Name: Date: 29/10/15.

Professor Jill Downie
Deputy Vice-Chancellor, Education