PHUSICOS

According to nature

Deliverable D6.1/D6.2

Training program

Work Package 6 – Learning arena innovation to encourage knowledge exchange

Deliverable Work Package Leader:
Innlandet County

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Project information

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Summary

Communication and education are considered fundamental for the implementation of Nature Based Solutions (NBS) (EU, 2015). Furthermore, the EU's Green Infrastructure Strategy (EC, 2013b) identified capacity building, training, and education as a priority task to support the implementation of NBS, with both decision-makers as well as the public being identified as two key groups (EU, 2016). In addition to a lack of understanding among stakeholders on the functioning of natural ecosystems, studies indicate that improved capacity building of decision-makers and better institutional cooperation are key success components.

As an innovative approach to education and training, WP6 developed a virtual reality (VR) educational game to facilitate communication and learning about the NBS implementations at the PHUSICOS demonstration sites. This VR experience is developed specifically for decision makers at the local (community level) and as a general learning tool for the public.

The user experience includes visits to four of the demonstration sites, where each site presents a suitable NBS implementation:

- Jorekstad (Norway) – receded barriers for flood control
- Saint Elena (Spain) – terracing to control rockfalls
- Capet Forest (France) – reforestation for avalanche hazard mitigation
- Serchio River Valley (Italy) – vegetative barrier strips for erosion and contamination control

Lessons learned in the development process center around the complexity of developing learning products, not only in terms of technology (VR implementation) but also the importance of defining the target audience and structuring the pedagogical content to appropriately communicate the key learning points of the experience.

The VR game is published on the Oculus Labs app store as a free (open access) VR game downloadable by any interested user. The source code is provided as open source via a GITHUB repository, allowing additional modules (case sites) to be added by interested parties or future research projects.

This document describes the VR game and the development process necessary to create it. These two elements (document, and downloadable VR game) comprise deliverables 6.1 and 6.2 of WP6.

Contents

1 Introduction

Nature-based solutions (NBS) are actions and measures that are inspired by, supported by, or copied from nature. There are solutions that use or restore existing habitat types and ecosystems, are based on the use of nature, or can be categorized as blue-green infrastructure (nature-mimicking solutions). In climate adaptation work, NBS can be robust and cost-effective alternatives to traditional solutions and contribute to society dealing with natural hazards in a sustainable way. Traditional solutions are designed primarily to increase security. NBS often have social, economic, and ecological functions in addition to the safety aspect.

In Norway, the 2018 government issued guidelines for climate and energy planning state that NBS shall be part of the decision basis in planning procedures where climate adaptation measures are being considered. Essentially the guidelines require that justification must be given if the NBS option is not chosen.

Implementing these guidelines requires a level of knowledge about NBS among decision-makers. However, surveys done as part of PHUSICOS (in WP3) clearly showed that local politicians, decision makers and other stakeholders in the Living Lab process did not have the necessary knowledge level needed to be able to make such decisions.

1.1 Purpose

The inland county municipality has the responsibility under Work Package 6 of the PHUSICOS project to develop training materials on the use of NBS for climate adaptation. The target group for these materials were decision makers (politicians), public administration employees and to a certain degree the general public.

The idea of the Learning Arena of WP6 is to facilitate better understanding of NBSs and closer collaboration between stakeholders by harnassing the power of innovative learning techniques, methods and materials. UThis WP6 is complementary to the innovation arenas of the other work packages (WP3 Service innovation, WP4 Technology innovation, WP5 Governance innovation and WP7 Product innovation). Ultimately, this work should contribute to improving decision making processes.

Innovations in learning contribute to capacity building and support knowledge transfer to help participants that lack know-how with regard to: i) challenges faced in our NBS demonstrator sites, ii) understanding the functions of various types of NBS, iii) experiencing viable land management options provided at the demonstrator sites, and iv) seeing practical implementations at actual case study sites. Another aspect became apparent during the co-creation activities: the pre-existing level of knowledge regarding nature based solutions was quite variable across the range of stakeholders and case sites. It became obvious that there was a need for specific learning tools to lift the general level of knowledge and interests in these solutions.

Quite early in the PHUSICOS project the opportunity for innovation became evident, and the decision was made to modify the original objectives (traditional training materials) to a more innovative solution made capable by advances in available technolology and supporting software. The new approach harnesses new and developing visualisation technologies within the field of Virtual Reality for facilitating communication, dissemination and learning in the PHUSICOS project.

1.2 Overall goals

When the original PHUSICOS proposal was prepared the stated goals for WP6 were to develop relatively traditional training materials for technical development, in the form a webinar, video, or online training materials. However, as the project progressed it became apparent that we need tools to further develop the understanding of NBS among local authorities and decision-makers. Although the nature of the goal has changed (from using traditional means and methods, to applying new technology and experiences), the original goal of developing learning materials and innovating the learning arena is still central to WP6.

The potential target groups for these materials are politicians, decision-makers, and public administration. The objective of the training program is to increase knowledge about NBS, and thus improve the decision basis when choosing measures.

1.3 Project expectations

The PHUSICOS proposal expresses specific expectations for WP 6. In the project proposal, Task 6.1 (T6.1) will develop a training program together with stakeholders as established in the Living Labs (WP3). For this purpose, a review of project design practices, implementation laws, and feasibility studies will be conducted to provide an overview over implementation procedures, biding laws and responsibility among different authorities. It is expected that the risk modelling (WP4), the NBS overview database (WP7) and the governance models for designing, financing, and implementing NBS (WP5) will provide valuable input to the review. Once the review is completed, 5 to 6 best practices will be identified and discussed with the stakeholders at the demonstrator sites to further co-develop a training program that is specialized for the local authorities and decision-makers on how to relate costs of NBS compared to traditional grey solutions (e.g., for procurement contracts) and risk assessment modelling.

2 Implementation strategy

2.1 Concept: Virtual Reality

The NBS implementations planned for the PHUSICOS demonstration sites are large scale activities in the natural environment. These implementations are difficult enough to envision for professionals familiar with them, such as landscape architects and infrastructure engineers, but for ordinary persons unfamiliar with them it may be almost impossible to really understand the design and function of these. There are adages and proverbs in English offering some wisdom: 'Seeing is believing', 'a picture paints a thousand words', and 'show me don't tell me'.

Virtual Reality (VR) is the concept of a computer-generated environment where the user feels as if they are immersed in (and interacting with) that environment. The VR environment is presented in scenes containing objects that appear real and where the user is provided with the ability to move about in the environment and interact with the objects. Everything the user sees is artificially constructed through 3D objects, and the experience is enhanced using ambient sounds and often an active soundtrack.

However, there is also a combination of both realities called mixed or augmented reality. This hybrid technology makes it possible, for example, to see virtual objects in the real world and build an experience in which the physical and the digital are practically indistinguishable.

2.2 Implementation model: Co-creation

The PHUSICOS VR concept was developed using a co-creation process within a multi-disciplinary team representing 'stakeholders' with various interests:

- Innlandet County, as project owner and overall project manager. Innlandet County's stakeholder interest is to develop a practical learning tool that meets their needs for educating local landowners, local politicians, and common persons. Innlandet County also brought in GIS technical experience and access to data sources relevant for the Jorekstad case site.
- NGI, as project technical anchor for NBS/climate related geohazards. NGI's stakeholder interest is an accurate representation of the demonstration sites and associated geohazards, and a correct technical representation of the implemented NBS measures.
- Vea vocational school is a stakeholder focused on the pedagogical content of the VR experience, ecology, and the accurate representation of flora and fauna utilized in the various VR landscape scenes.
- Sopra Steria, as programming lead for the VR experience. Sopra Steria's stakeholder interest is in building competency in open VR development - the development of applications that can be made available for open access development. This focus is to help ensure the legacy of the developed application.

- Case site representatives, as technical control of the 'story' of the demonstrator sites. Their stakeholder interests are to ensure that the representation of the demonstrator sites and the implementation of NBS at these locations is realistically represented.
- Selected political representatives from Innlandet, performing individual user assessment of the prototypes of the VR application. Their stakeholder interests are to ensure that the VR experience presents factual content and communicates the challenges and solutions offered by the intended NBS at an appropriate level for these recipient groups.

The development team worked together during an intensive development period of several months, meeting weekly to discuss mutual progress and to address the development plans from each of their stakeholder interest positions. The team had a high level of interaction, meeting (digitally) several times per week and actively participating in tasks and information exchange. All team members contributed actively to the development works.

2.3 Technology and development platform

Virtual reality applications are based on the idea of complete immersion experiences, e.g., the user of the application is given the visual and audio impression of being present in a virtual environment. This is achieved using VR headsets, where images supplied individually to each eye simulates normal vision and creates a 3D world for the user. Most often these headsets include also integrated audio, and the user is provided hand controllers allowing tactile interaction within the virtual world.

Headsets can be categorized in two major groups: Tethered and untethered.

- Tethered headsets are connected to a powerful graphics PC by cable. These are essentially just sophisticated monitors, where the simulation application runs on the powerful computer allowing highly sophisticated virtual worlds to be modelled and rendered for visual presentation to the user. The practical limitations are defined by the quality of the PC.
- Untethered headsets are self-contained, meaning the application is loaded and runs on the headset. The advantage is mobility, e.g., the headset can easily be used at any location without complicated set-up. The disadvantage is that the modelled virtual world is more simplistic. In terms of computational power, an untethered headset is roughly equivalent to an average smart phone.

As the PHUSICOS VR application is intended to be used by a variety of stakeholders, nominally at their offices, homes or at public locations, it was decided that an untethered headset is most appropriate as the target hardware platform. The flexibility and mobility offered by this type of device outweighs the benefit of more advanced graphics. Several commercially available products were considered, and finally the Oculus Quest headset (Figure 1) was chosen as the target platform.

Figure 1. Oculus Quest VR headset. Photo credit: Meta (Composite image made from individual images presented on the manufacturer's marketing website, https://store.facebook.com/no/nb/quest/)

The development process, e.g. programming of the virtual realty experience, requires a development environment providing the necessary tools and assets to create three-dimensional (3D) games, interactive simulations and other experiences.There are several prominent commercial services available, including Unity, Unreal, Maya, 3ds Max Design, ApertusVR and others. The Unity Hub platform (Figure 2) was chosen for this development, based on the existing expertise of the software development company engaged to program the application. In this figure, we see a rendition of the Besseggen mountain ridge in Norway, which is the scenery/terrain used in the opening session of the PHUSICOS VR game.

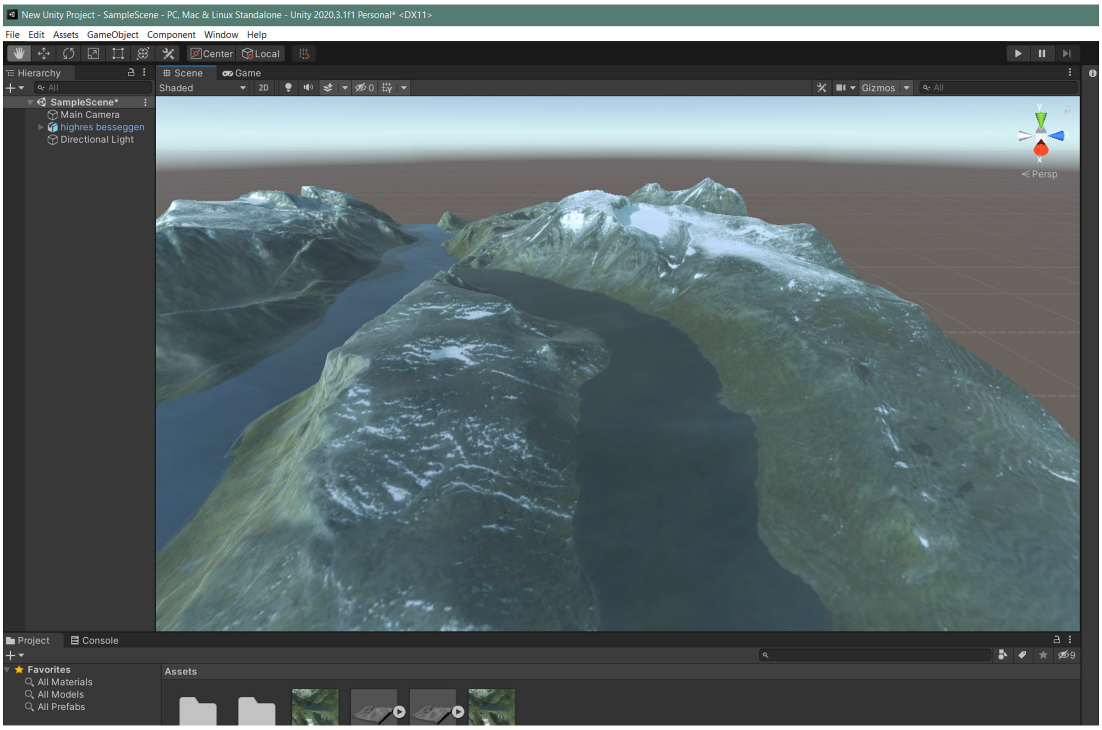


Figure 2. Screenshot – Unity Hub game development engine

A 3D application consists of 'assets', e.g., digital components placed into a terrain model and assigned attributes and actions. Assets are essentially the objects in the virtual reality, for example, plants and trees, buildings, vehicles, signage etc. Attributes (properties) assigned to the assets including a wide range of things such as size, color, surface texture, lighting and shading, motion characteristics, 2D/3D physics response, visual effects and rendering effects, and so on. Actions may include triggering of actions, playing of audio, movement throughout the game storyline, or other interactive responses between the user and the environment.

Assets included in the PHUSICOS VR application have been acquired (licensed or purchased) from asset libraries providing digital objects, for example the trees and plants used throughout the application. While there is a virtually unlimited range of potential assets with all levels of complexity and realism, a necessary consideration for the PHUSICOS VR development was the computational 'weight' of the assets deployed in each scene. More complex (realistic) assets are computationally 'heavier' than less realistic assets, and fewer assets are 'lighter' than many assets present in a scene. The level of realism and detail that could be achieved in a scene had to be balanced against the computational capacity required to display it– if the scene is too complex, it will render poorly causing hacking and stops in the video; whereas if it is too simple then the visual impact of the 3D experience would be diminished.

Managing graphical complexity for different devices can be explained through the example of a forest. In the development of a 3D forest experience, the graphical designer may disperse many 3D trees over a large area. While this gives an excellent experience for a tethered device (with exceptional capacity for graphic rendering), it would overwhelm an untethered device causing the video image to stop or stutter. The graphic designer can work around this for an untethered device by creating a 2D backdrop image of a forest, add a few 3D trees in the foreground, and limit the area of movement accessible to the player in the game. They can interact in 3D with some trees but are prevented from moving too close to the 2D background image maintaining the illusion of being in a forest.

The graphic designer may also optimize other parameters, for example the level of detail in textures used on surfaces, the complexity of lighting/shadows, the number of objects etc. as necessary to keep the level of graphical rendering to within the capacity of the untethered device. Development platforms like Unity provide graphic calculation intensity measurements to allow the designer/developer to adjust scene complexity as needed to stay within optimum capacity of the target device.

2.4 Modularity

A specific requirement in the development of the VR experience was to prepare the VR game for later expansion, e.g., adding additional locations representing other forms of NBS implementations. The VR implementation was specifically designed with the concept of modular software architecture so that other case sites can easily be added, and that multi-language support can be added easily.

2.5 GDPR / data management

The PHUSICOS VR application does not collect personal information and does not store any data about the use session. The individual user can choose to take 'screen shots' of their experience, and these are stored on the VR headset. The only detail captured is the visual image viewed by the user in the headset. (Images from the PHUSICOS VR game presented in this document are examples of screen shots from the application).

3 Development process

3.1 Storyline development

Creating a story requires several essential ingredients: who will experience the story (the audience), what is the message to be conveyed (the lessons learned), and how does the story progress to bring this message to the audience (the narrative, or 'journey'). In our case, the narrative and lessons learned are intertwined as each major step in the journey is expressed as a scene, where the narrative describes the situation in the scene and presents problems and solutions (lessons learned) for the scene. In the development of the story these were identified as 'thematic focus' areas.

3.1.1 The Audience (Personas)

The first stage of the storyline development was to establish 'personas', e.g., idealized possible users of the VR product. A specific 'persona' describes and imaginary person, for example:

> *'Jennifer', a 34-year-old grade schoolteacher, is genuinely interested in topics related to sustainability and nature but struggles to make major changes in her life due to a tight personal economy after her recent divorce. She lives in a townhouse on the edge of a larger metropolitan area and often goes hiking in the weekends. She is interested in technology, and not afraid to try out new things.*

The purpose of creating a portfolio of 'personas' is to help in developing the narrative of the VR experience, e.g., what are the core values of the VR experience, what is the message we are trying to communicate, and how the target 'personas' will understand and react to our narrative. Broadly these personas can be grouped into

A) Which sector they represent (State, Regional or Community authorities, Private interests, Nongovernmental organizations, and R&D institutions.
B) Their natural roles in their organization (Politician, leader/decision maker, administration, researcher, interested party)

In this initial process the project team created several personas, representing various types of persons within the most relevant stakeholder groups (politicians, farmers, school children, administrators, and others). Finally, the project team selected two personas: one representing a typical politician in rural districts, and one representing an average and ordinary citizen. Selecting the target personas provided a clear target audience to develop the core message, e.g., what facets of the nature-based solution discussions should be prioritized.

3.1.2 Thematic focus

Each of the case site modules are developed around a common storytelling structure using scenes, where each scene presents some aspects of the following:

1. Present problem and explain needs,
2. Demonstrate solution
3. Discuss benefits and co-benefits

The pedagogical content in the story was carefully considered during preparation of the manuscript. The specific goal of the pedagogical review was to ensure that information is presented at a level of detail to convey the core message, but not overly complicated such that the target audience would experience any difficulty in following the narrative Figure 3).

The project team combined the above elements and developed a script for each of the case sites. The script for each site specified scene details (contents, look directions, key visual elements, audio clues), a spoken manuscript, and timing points between the voice over and visual changes in the scenes. As the scripts were developed, these were shared with representatives for the case sites to ensure reasonable accuracy and representativeness of the core message to be communicated. The feedback was incorporated into the scripts (a co-creation process).

Goals	Learning conditions	Learning process	Content	Settings
Main goals - knowledge exchange - training - convincing storytelling **NBS** - experience NBS - see the benefits - recognition of NBS - make NBS concrete - see different possibilities - see tailored solutions - documentation (Screen dump? Video?) - enable cooperation Etterlatt inntrykk…	**Target groups** - specific needs - specific goals - specific interests **Level** - competence level - knowledge of NBS - use of professional terms - need of explanations	**Introduction** – start **Ending** - ? - tell a story from A-B - go and explore, solo Movement in the scene: - free path? - set path? - guided path? - see the building process? - see the results only? **Activities:** - Tasks when and how - quiz? When and how - motivating - activating - concrete - visual - cooperate, share… - evaluate/assess	**Visual elements** - landscape - fauna - flora - NBS - people - machines… - roads.. - GPS-coordinates - Google Earth… **Text** - voiceover - written **Engaging content** - tasks? - statistics? - numbers? - features (flood, crisis..) - before and after….	**Limitations** - time - size - number of elements - naturalistic elements possible? (movement, details, growth…) **Sites** - how much of the site should be included? - how much details? - three NBS in the same module - Module 1a, b, c?

Figure 3. Structuring the narrative

3.2 Developing the script

The process described in the previous section was the starting point for preparing a production script. This script defines the narrative and includes a description of scene-setting and visual clues. The production script is used as the basis for forming the final visual experience in the VR game and is the working document for the voice artist and sound engineer in creating the voice-over and audio tracks (Figure 4).

Production Script Final v.0.1 – 12.04.2021

Modul 1 – Jorekstad

Scene: Gudbrandsdalen - Jorekstad

Theme: Floods

Synopsis:

The river Gausa, a tributary to the river Gudbrandsdalslågen, experiences regular flooding and occasionally extreme flooding events, such as in 1995, 2011 and 2013.

The frequency and severity of extreme events are expected to increase over the coming decades. The lower parts of Gausa, where the river meets Gudbrandsdalslågen at Jorekstad, are particularly vulnerable due to agricultural land, homes, and infrastructure such as the local football stadium and sports facilities.

A receded flood barrier allows the river to flood the floodplain riparian forest and the nearest farmland during extreme events, but l significantly reduce the risk of flooding for areas outside of the barrier. It will also reduce erosion along the riverbanks and sediment deposition in the confluence zone with Gudbrandsdalslågen.

Miroboard for the module:

https://miro.com/app/board/o9J_lYkxdLI=/?moveToWidget=3074457353449487758&cot=14

Sequence 1: Fictional hiltopview
Sequence 2: The River
Sequence 3: The Riperian Forest
Sequence 4: Jorekstad
Sequence 5: Sediment build-up
Sequence 6: By the barrier
Sequence 7: On the barrier
Sequence 8: The Recreation area

Page Break

SCENE 1	**FICTIONAL HILTOPVIEW JOREKSTAD – Introduction**	
	Audio track	*Visual track*
1.1	We are now in the Lillehammer region of Norway. Walk to the viewpoint in front of you to have a better look.	*The user* ***spawns*** *on a hilltop near a* ***viewpoint on a hill****. There is a hiking* ***signpost*** *in front of us showing the areas we can visit in this module.* *(The user must move towards the viewpoint to proceed.)* *The user navigates to the viewpoint on top of the hill.*

Figure 4. Example of a production script

3.3 Scene developments and visual elements

A specific process for selecting and implementing the visual elements was required due to the inherent limitations of the VR hardware. A careful balance was required between visual complexity and believability: Complex 3D elements in the scene improves realism, but also creates higher computational demand which can lead to lagging or pauses in the VR visualization. For this implementation the project team made the decision for a semi-realistic, semi-cartoon like representation. The terrain for each location is based on real topographical models for the locations. 3D visual elements are appropriately selected for the flora of the demonstrator site, and these were gradually added to the scenes by the developers until the overall performance of the VR hardware fell below a performance threshold.

Each site was based on a realistic terrain model (obtained from publicly accessible digital terrain model data) which was simplified and idealized for implementation in the VR world (Figure 5).

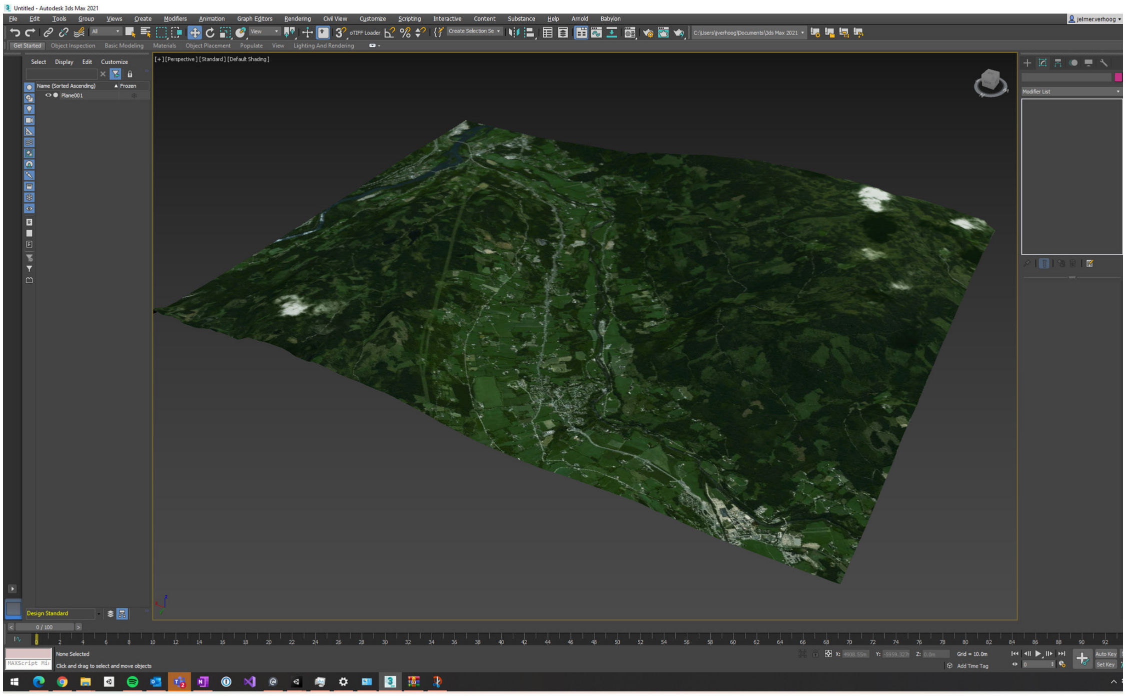


Figure 5. Graphic artist developing terrain models and scenery

3.4 Soundtrack

A professional voice actor was hired to perform the spoken soundtrack (script), and this was recorded in a recording studio. The recordings were edited into sound packages, representing parts or stages of the overall script tying into the timing points and user-initiated actions in the VR scene. The purpose of this was to create a responsive audio track, allowing the playback of context-specific text and information as needed within the VR experience.

An additional soundtrack consisting of ambient sounds (insects buzzing, water running etc.) was also recorded and added into the audio cues for the game.

4 Game elements

The overall VR game currently consists of 6 visual elements:

- A training ground (to learn how to use the VR system
- A landing site / access portal (with guide signs to select the demonstrator case site to visit)
- Four individual case sites representing different types of NBS implementations from the PHUSICOS project.
  Future expansions to the VR game can be made by adding additional case site modules and updating the landing site/access portal with new guide signs

4.1 Training grounds

The training grounds (Figure 6) are presented as the first location for the game user. This is a camping site next to a small lake. The voice over at this location provides instructions on operating the basic mechanics of the VR game, e.g., how to move about within the scenes and how to advance to the next locations. As the user masters the controls, they move up the mountainside to reach the landing site/access portal. An experienced user can skip the training grounds and move directly to the landing site.

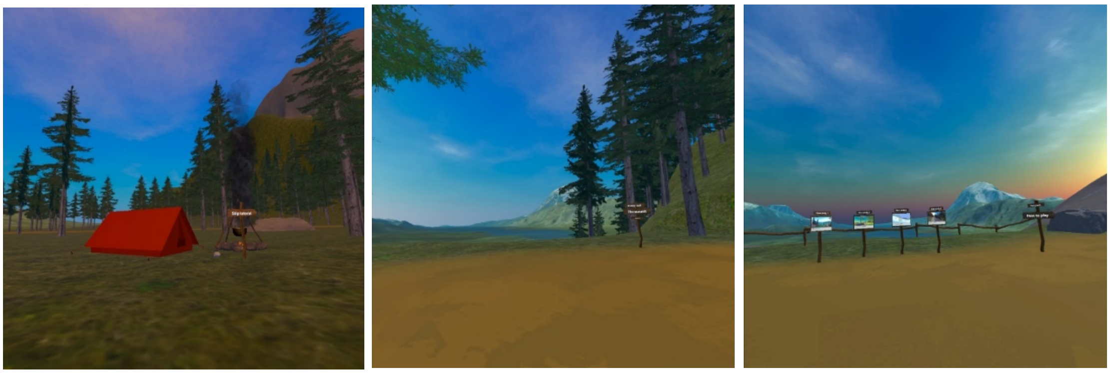


Figure 6. Training grounds

4.2 Landing site / access portal

This location is the starting point to access each of the NBS training modules. The game player can reach this location either by completing the tutorial (training grounds) or by selecting 'skip tutorial' when the game is started.

The landing site (Figure 7) uses the regional topography of a famous Norwegian mountain pass, 'Besseggen' for a dramatic visual impact. Each of the NBS case sites implemented in the game are represented by a guide sign, which the user can select to enter the training module. These can be visited in any order, as each module is a complete and independent presentation of the NBS case. Upon completion of the module, or at any time the user selects the 'Home' button, the user is returned this location to enable access to other modules.

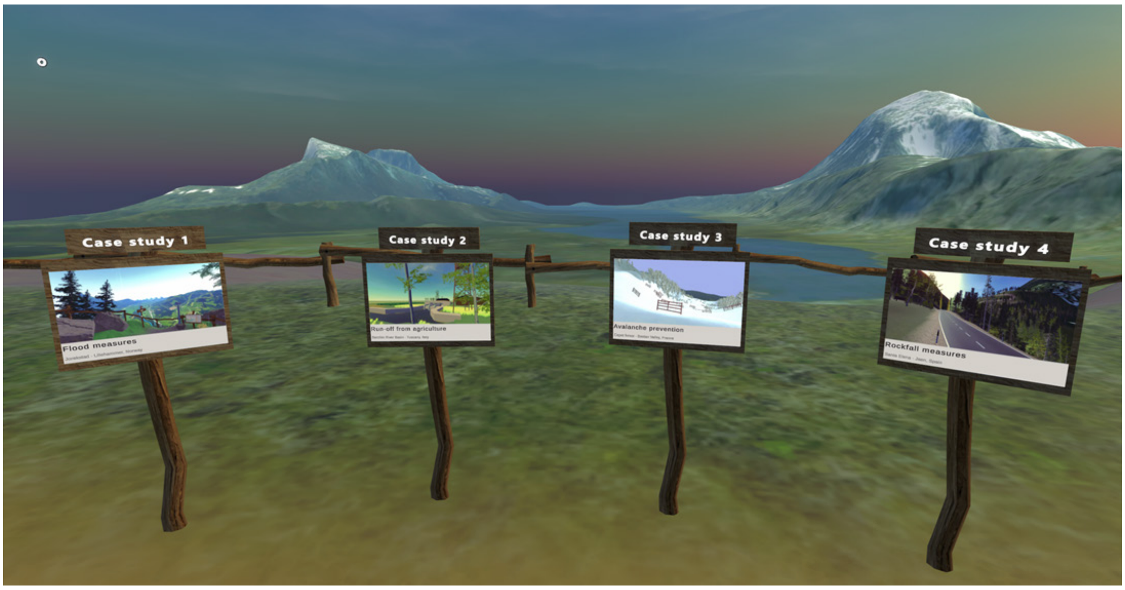


Figure 7. Landing site/Access portal

4.3 Case: Jorekstad - receded barrier

The demonstration site at Jorekstad in the Lillehammer region of Innlandet County focuses on the problems of river flooding and the ecological and physical impacts of this. The challenges are complex, balancing the ecological needs of a riparian forest, the economic needs of farmers and contractors, the impacts of pollution and wastes in the larger context of downstream waters, and the interests of the general population for recreation and land use of the impacted area.

The experience is pedagogically presented in a series of scenes:

1) Description of the situation. The user arrives at a viewpoint over the region and is provided a narrative describing the flooding challenges and the impact of climate change on these. An overall understanding is established before the user moves on to study detailed aspects of the challenge. The visible terrain is representative of Jorekstad; however, the viewpoint is fictive. (Figure 8)
2) At the next scene the user is teleported to the banks of the river, where the flood dynamics are described in more detail. The user moves to the other side of the river into the riparian forest, and the narrative explains the importance of the

eco diversity and the necessity for occasional flooding to maintain the forest. (Figure 9).

3) The next scene is located on the sports fields and farmland, where the flooding illustrates the impacts on the farmland and the public facilities, and how the flooding contributes to waste transport into the rivers. The user moves on to a location by the river where the economic aspects of gravel outtake and the environmental impacts of this is explained. (Figure 10).
4) The final scenes illustrate how the implementation of a receded barrier provides the ability to protect the economic interests of the farmers and the local community's sports facilities, while maintaining the health of the riparian forest and preventing the spread of pollution into the rivers and waterways. The barrier becomes a public use space, creating co-benefits for the local community. (Figure 11)

Figure 8. Jorekstad case site, overlook viewpoint

Figure 9. In the riparian forest by the river

Figure 10. Flooding of the sports facilities and local farmland, and gravel outtake activities

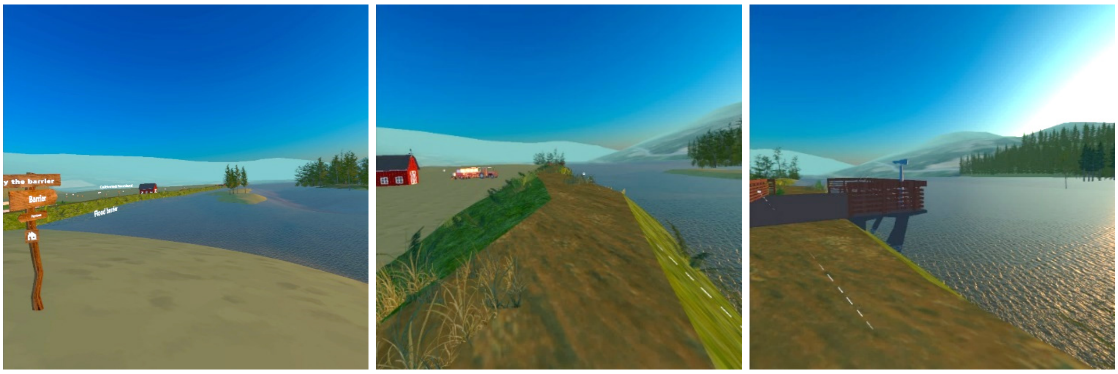


Figure 11. The receded barrier protects the farmlands and creates a public use space

4.4 Saint Elena – Rockfalls

The demonstration site focuses on the problems of rockfalls from a roadway cut through a morainic ridge along a busy road connecting tourist areas in the Pyrenees with France and Spain. Increasing rainfall from climate change is causing more frequent rockfall events. The site is at Saint Elena along the A-136 roadway (Figure 12).

Figure 12. Hillside at Saint Elena (left image unknown, right image Google Earth)

The VR experience explores the implementation of terracing the steep hillside, and the planting of native species to help stabilize the soil and to create a natural use space. The experience is pedagogically presented in several phases:

1) Description of the situation. When the user arrives, they are immediately confronted with a rockfall that hits the road and strikes a car. The narrative presents the problems with rockfalls along this busy stretch of road, and the danger this is for motorists. (Figure 13).
2) Terracing and planting as the primary mitigation measure. The next scene is on the terraced hillside, where the NBS has been implemented to stabilize the slope. The narrative describes the implementation of the terracing and its history as a mitigation measure in this region (Figure 14).
3) Overview and benefits. The final scene provides a distant overview of the terraced hillside, indicating how it blends in with the natural terrain and how this NBS contributes to both safety and biodiversity (Figure 14).

Figure 13. Situation description for Santa Elena, showing the effects of the unstable slope.

Figure 14. Visiting the terraces, and a final view from the other side of the valley

4.5 Serchio River valley – barrier strips

The demonstration site focuses on the problems of flooding and surface water run-off in areas with heavy agriculture. The site is in the Serchio River valley, just beside Lake Massaciuccoli in the Province of Lucca, Tuscany, Italy. The lake suffers from eutrophication due to nutrients and soil washing into the lake. A few real-world images from the site are shown in Figure 15.

Figure 15. Real world images from the Serchio river valley

The VR experience explores the implementation of vegetated barrier strips around the irrigation and drainage canals crisscrossing the (previously) marshy areas of the river valley. The experience is pedagogically presented in four phases:

1) Description of the situation. Upon 'arriving' at the site, the user is presented with a short history of the area, and an explanation of how the man-made drainage canals and pumping systems are used to dewater the marshy land making it accessible for farming (Figure 16).
2) Buffer strips as a primary measure. The next scene of the experience presents the idea of vegetated buffer strips, providing erosion control and helping to stop the flow of nutrients (fertilizer and organic wastes) into the canal system (Figure 17).
3) Settling bonds to improve efficacy. The third scene presents the retention / settling pond, a technique used to further reduce sediment transport (Figure 17).
4) Summary and impact. Finally, the fourth scene describes how the implemented NBS improves water quality, reducing the nutrients and sediments pumped into Lake Massaciuccoli and helping the lake to recover from eutrophication. (Figure 18).

Figure 16. Serchio river basin. First learning stage: history and situation description

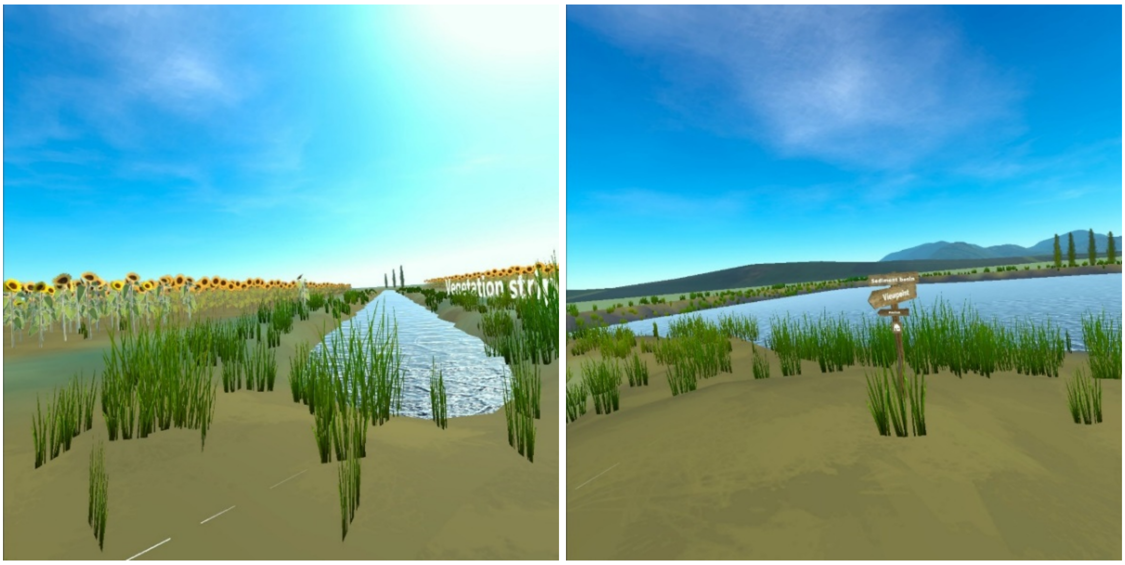


Figure 17. Use of buffer strips and a retention/settling pond

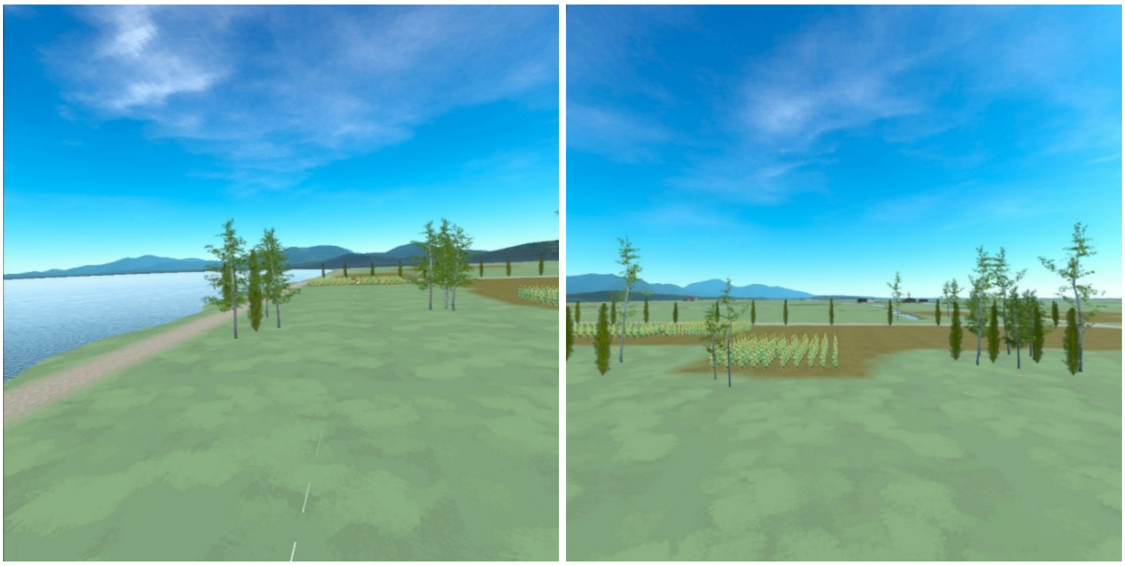


Figure 18 View over the agricultural land and the coast of Lake Massaciuccoli

4.6 Capet Forest – avalanche

The challenge at the Capet Forest is avalanches, which periodically are so large that they overcome the existing avalanche protection systems (avalanche fences) and reach down into the town below the slope. The site is in the Bastan valley of the French Pyrenees.

The VR experience explores reforestation as a mitigation measure to manage the avalanches. The experience is pedagogically presented in three phases: Situation and problem description; the implemented solution, and the summary and impacts of this mitigation measure.

1) Description of the situation. Upon 'arriving' at the site, the user is presented with a demonstration of the danger avalanches present at this location. The narrative explains how the traditional snow fences fall short under heavy snow conditions (Figure 19).
2) Implemented solution. Reforestation. Trees are planted, and small tripods are made from natural local materials to protect the trees until they grow large (Figure 20).
3) Summary and impact. The narrative describes the NBS as implemented, and highlights the co-benefits provided.

Figure 19 Avalanche in the mountains of the Capet Forest. Traditional snow fences are used to stop the snow but are not always effective

Figure 20 Planting trees (afforestation) is an effective mitigation measure. The juvenile trees eventually grow strong.

The proposed mitigation solutions are being installed at this location, as illustrated by a site photo from the Capet forest showing the protective structures installed for the juvenile trees (Figure 21).

Figure 21. Real world mitigation measure at Capet forest

5 Lessons learned

5.1 Advantages of VR

Implementing a virtual reality (VR) experience as an alternative to a webinar is a significant paradigm shift, which of course begs the question: *Why is VR better than a webinar or video?*

There are several fundamental aspects to consider:

- Broader reach. VR is exciting and new, giving it the advantage of immediate appeal to a large audience. It is easily arguably more playful and exciting than a traditional webinar.
- Longer shelf life. The design of the VR implementation is modular, allowing additional content to be easily added. Further, it can be adapted to other countries / languages by switching out the soundtrack and via a modular language solution for signpost and visual clues.
- Higher pedagogical impact. VR engages the user and enhances understanding of complex topics. We believe the long term learning effects of this approach are significantly better than a webinar or video.

- With access to a broad potential audience, the pedegogical content needed to be appropriate for the primary target groups (personas), but at a level and complexity that is still accessible and interesting for other potential users.

The implementation as a VR game included the expectation that the resulting product should be accessible for everyone. This was ensured by developing two versions:

- Full 3D immersive experience, using *an Oculus Quest VR headset*
- 3D browser based experience, using a common PC and an internet browser (like safari, google chrome, microsoft edge)

5.2 Design and implementation

Conventional development processes in work groups or teams generally require a lot of interaction. However, due to the restrictions present due to COVID we were forced to implement this as a completely digital development project. The development team has never met or worked together in person, and in fact most of the team members have never actually met many of the other participants. The coordination of the team and the creative processes needed to produce the game were facilitated by digital collaboration tools, including a Microsoft Teams based environment and the Miroboard digital workspace.

The dynamic of the development team was essentially a high intensity sprint, where our team organization, planning and execution were organized as well defined (and delimited) activities completed as weekly 'sprints' using the sprint philosophy for software development. One person had the role as project manager, with the exclusive responsibility to develop clear sub-goals and milestones, and to coordinate the flow of information and inputs to ensure that the team could operate efficiently and unhindered. Tracking was done using an interactive system of tasks and responsibilities (Figure 22).

In this kind of development environment and pace it is not surprising that mistakes, misunderstandings, and small conflicts arose during the project. The project was operated at a day-by-day level of planning and deliverables (Figure 23). With this level of detail there was bound to be friction. These friction spots were managed by following a project philosophy of clear expectations and communications, and quickly moving to address and resolve any issues or problems arising. The team held frequent short meetings ('stand up' meetings) where each team member was given 1-2 minutes to present status, plans for the coming period (2-3 days), any obstacles present or missing information, and their understanding of necessary interfaces with other team members. This approach proved highly effective.

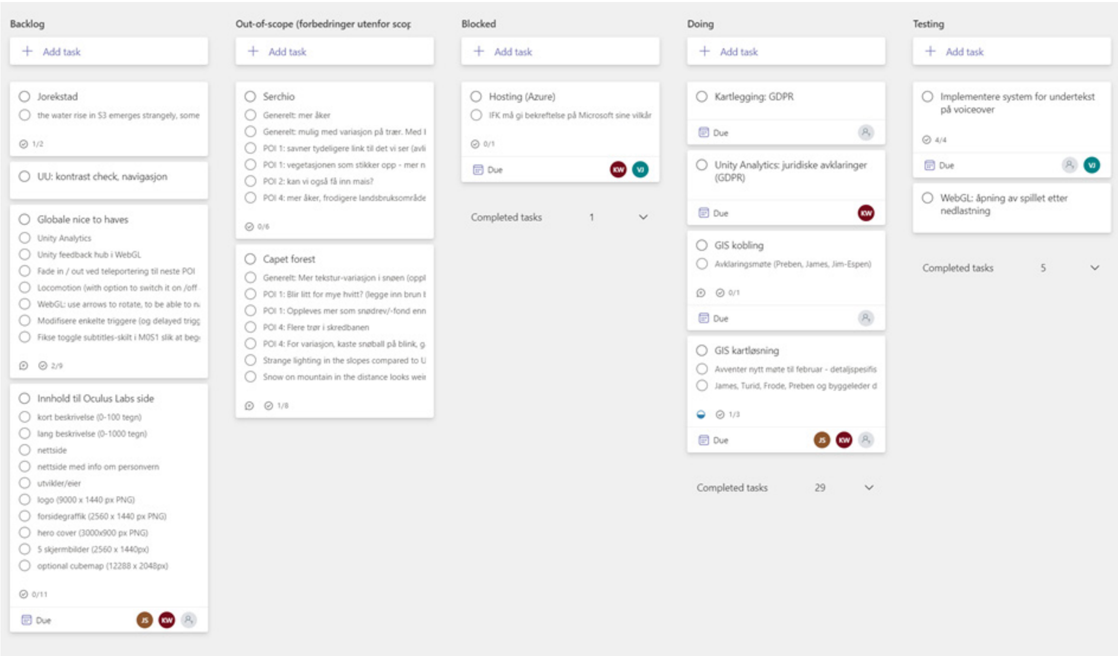
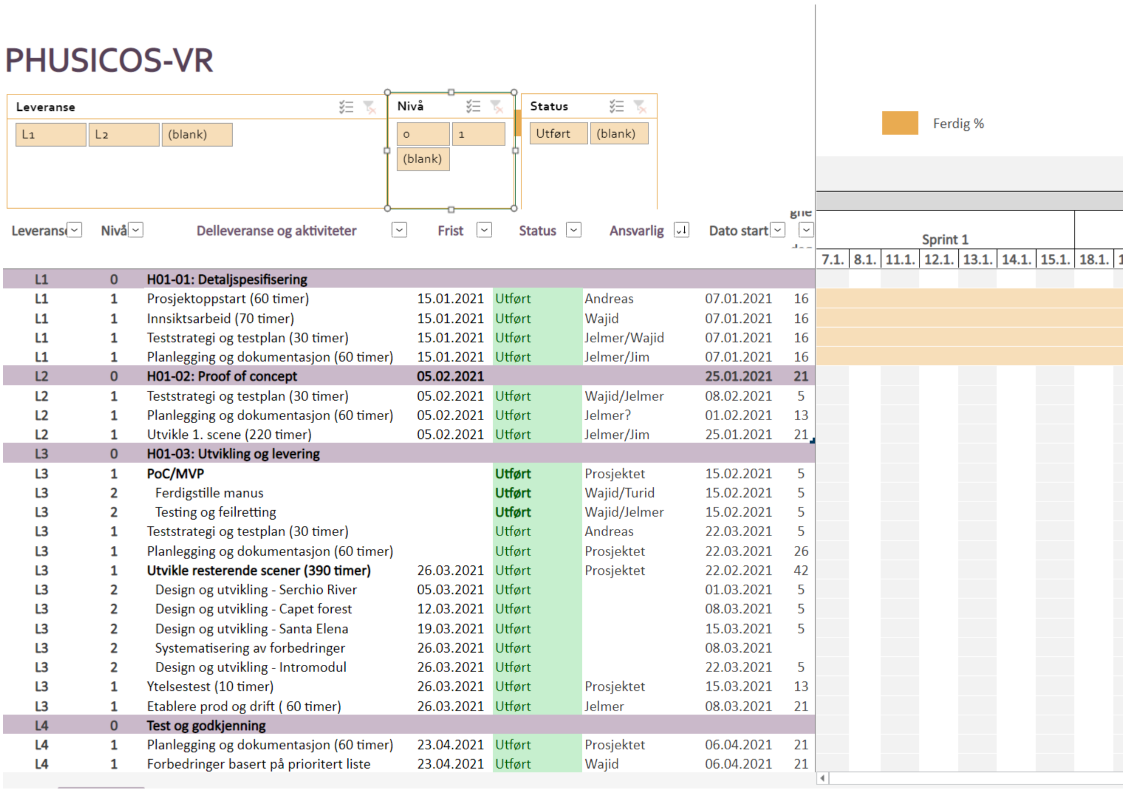


Figure 22. Project planning tool to manage tasks and project deliverables



PHUSICOS-VR

Leveranse	Nivå	Delleveranse og aktiviteter	Frist	Status	Ansvarlig	Dato start	
L1	0	**H01-01: Detaljspesifisering**					
L1	1	Prosjektoppstart (60 timer)	15.01.2021	Utført	Andreas	07.01.2021	16
L1	1	Innsiktsarbeid (70 timer)	15.01.2021	Utført	Wajid	07.01.2021	16
L1	1	Teststrategi og testplan (30 timer)	15.01.2021	Utført	Jelmer/Wajid	07.01.2021	16
L1	1	Planlegging og dokumentasjon (60 timer)	15.01.2021	Utført	Jelmer/Jim	07.01.2021	16
L2	0	**H01-02: Proof of concept**	**05.02.2021**			**25.01.2021**	**21**
L2	1	Teststrategi og testplan (30 timer)	05.02.2021	Utført	Wajid/Jelmer	08.02.2021	5
L2	1	Planlegging og dokumentasjon (60 timer)	05.02.2021	Utført	Jelmer?	01.02.2021	13
L2	1	Utvikle 1. scene (220 timer)	05.02.2021	Utført	Jelmer/Jim	25.01.2021	21
L3	0	**H01-03: Utvikling og levering**					
L3	1	**PoC/MVP**		**Utført**	Prosjektet	15.02.2021	5
L3	2	Ferdigstille manus		**Utført**	Wajid/Turid	15.02.2021	5
L3	2	Testing og feilretting		**Utført**	Wajid/Jelmer	15.02.2021	5
L3	1	Teststrategi og testplan (30 timer)		Utført	Andreas	22.03.2021	5
L3	1	Planlegging og dokumentasjon (60 timer)		Utført	Prosjektet	22.03.2021	26
L3	1	**Utvikle resterende scener (390 timer)**	26.03.2021	Utført	Prosjektet	22.02.2021	42
L3	2	Design og utvikling - Serchio River	05.03.2021	Utført		01.03.2021	5
L3	2	Design og utvikling - Capet forest	12.03.2021	Utført		08.03.2021	5
L3	2	Design og utvikling - Santa Elena	19.03.2021	Utført		15.03.2021	5
L3	2	Systematisering av forbedringer	26.03.2021	Utført		08.03.2021	
L3	2	Design og utvikling - Intromodul	26.03.2021	Utført		22.03.2021	5
L3	1	Ytelsestest (10 timer)	26.03.2021	Utført	Prosjektet	15.03.2021	13
L3	1	Etablere prod og drift (60 timer)	26.03.2021	Utført	Jelmer	08.03.2021	21
L4	0	**Test og godkjenning**					
L4	1	Planlegging og dokumentasjon (60 timer)	23.04.2021	Utført	Prosjektet	06.04.2021	21
L4	1	Forbedringer basert på prioritert liste	23.04.2021	Utført	Wajid	06.04.2021	21

Figure 23. Detailed planning document at day/week level of detail

5.3 Mapping the target audience

One of the necessary activities in developing the narrative was to attempt to map the level of knowledge and understanding present in the target audience(s). As part of this process, Innlandet County conducted a survey among its administrative personnel as well as elected representatives. This survey had several central themes:

Laws, regulations, and recommended practice

- Are you familiar with the recommended practices and laws in place regarding the use of nature-based solutions? (yes/no/do not know)
- Do you know if there are guidelines or recommended practices for the use of nature-based solutions (yes/no/do not know)?

Knowledge gaps

- What do you need to know about nature-based solutions to evaluate these as part of the process of choosing mitigation measures?
    - Basic knowledge of what these are and how they can be used
    - Advantages and disadvantages
    - Costs and risks
    - Examples
    - Anything else:
- At what level should training be held? (Basic / comprehensive / advanced)
- How much time would you use for learning (<15 min, 15-30 min, >30 min)

Co-benefits / Added value

- Nature based solutions can give co-benefits within social, ecological, and economic factors. Examples are increased biodiversity, access for recreation and local value creation. Would this affect your choices? (Yes/no/do not know)

Costs and risks

- What is your understanding of costs associated with establishing nature-based solutions? (more / less / same costs as traditional solutions)?
- What is your understanding regarding maintenance costs for nature-based solutions? (more / less/ same) same costs as traditional solutions?
- What is your perception of risk in using nature-based solutions (assuming the measure is correctly designed) (more / less / same / do not know) potential damage compared to traditional solutions?

5.4 Long term legacy

The PHUSICOS VR game is developed on the principles of open access, and the source code is made freely accessible for further develelopment including the implementation of other case sites. The game itself is made available as a free download from Oculus Labs, allowing anyone with an interest to download the game to their VR headsets.

An important aspect for securing the legacy of this game is adequate 'marketing', e.g. making stakeholders aware of this tool. Publishing via Oppla (http://www.oppla.eu) which focuses on sharing knowledge between for practitioners, policy makers and scientists; and ii) PreventionWeb (http://www.preventionweb.net) which hosts information exchange tools to facilitate collaboration.

6 Acknowledgements

The PHUSICOS VR game was developed within the context of the PHUSICOS project, but additional funding was necessary to realize the development of the game. This additional funding provided by Climate and environment ministry of the Norwegian Government.

The project participants (Innlandet County, NGI, VEA vocational school, and Sopra Steria) have also commited their own internal resources and funding to allow the game to be developed.

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