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Virtual fieldwork on a ship's bridge: virtual reality-reconstructed operation scenarios as contextual substitutes for fieldwork in design education

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Abstract

Designing for professional, high-risk user contexts often implies limited accessibility for interaction designers to conduct field research and field testing, and the measures taken by most universities in Norway in 2020 to prevent COVID-19 spread have further contributed to the problem of achieving the contextual insight needed throughout the design process by severely restricting travel for research purposes. In this paper, we describe the use of virtual reality-reconstructed operation scenarios (VRROS) for Arctic-going vessels implemented in support of and as a substitute for the contextual aspects of fieldwork in the education of master's students studying interaction design. The virtual reality rig contains three scenarios contextualizing ships' bridges and their surroundings originally developed for research on designing navigation and operation applications using augmented reality technology. We evaluate whether aspects of the VRROS can substitute for real fieldwork by evaluating students' use of the VRROS using a student questionnaire. Finally, we discuss the value and potential of using VRROS as a supplement and support when studying how to design for hard-to-reach contexts in the future.

Keywords Virtual reality-reconstructed operation scenarios · VR simulator · Contextual support · Interaction design education · Fieldwork · Augmented reality

1 Introduction

Design-driven fieldwork is an important component in user-centered design processes for complex professional domains, such as the maritime (Lurås and Nordby 2014). Gaining knowledge of and working on a given problem within its context is key for professionals alongside students to acquire the ability to reflect *in* action and *on* action (Schön 1984). Testing and prototyping in context are important in the educational modules offered by the Ocean Industries Concept Lab (OICL) and in our research practice. As researchers and teachers in the Master of Design program at the Oslo School of Architecture and Design, we aim to facilitate different forms of fieldwork in all courses. However, the many measures taken to fight COVID-19 spread restricted all forms of fieldwork in 2020.

To overcome the challenges represented by the fieldwork restrictions, we leverage what we define as virtual reality-reconstructed operation scenarios (VRROS) of Arctic-going vessels running in our virtual reality (VR) lab as a contextual substitute. The VRROSs were developed in our previous EU project, SEDNA—Safe Maritime Operation Under Extreme Conditions: The Arctic Case (referred to as SEDNA), which centered on various aspects of safe and efficient maritime operations in the Arctic. We further framed the assignments to match the three VRROSs of Arctic-going vessels playing out realistic events and operations in detail scenarios. Hence, the students could benefit from the potential to gain a situational understanding and a tangible sense of scale, space, and time in the ship's bridge environment that the VRROS offered.

The students' group work in the VRROS resulted in two generally important learning outcomes for them. First, the students were achieving a common tangible understanding and experience of the context they were working with by familiarizing themselves with physical, spatial, and temporal

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aspects in the scenarios. Second, they explored efficient ways to prototype and evaluate design concepts. In addition, regarding the strict COVID-19 measures, the students' work in the VR lab counteracted the isolation they experienced because of learning remotely and brought them into a physically and virtually shared working situation in which they could discuss and try out meaningful and logical interaction design concepts. Therefore, we argue that VRROS potential for doing design-driven virtual fieldwork for both students and practitioners should be further examined. Our research question (RQ) is: *How can aspects of design-driven fieldwork be substituted with the VRROS used in a VR simulator?* We answer this question by first presenting and evaluating the use of three VRROSs of Arctic-going vessels played out in detail and simulated in VR as a substitute for real student fieldwork during a six-week module. Second, we evaluate a questionnaire asking seven open-ended questions to determine how the students reflected upon their learning outcomes and VRROS usage. Finally, we discuss the potential of using VRROS in education and practice.

This study centers on OICL research from the following research projects: 1) the EU-funded project SEDNA, which has focused on developing an innovative and risk-based approach to safe Arctic navigation, ship design and operations (SEDNA-project.eu 2017; Nordby et al. 2020), 2) the Open VR project, targeting the next generation of virtual reality for human-centered ship design, and 3) the OpenBridge project, where an open-source platform for development of software for safe and efficient workplaces is under development (Nordby et al. 2018).

2 Background

2.1 Design-driven field research

Safety–critical workplace design is a demanding field for both students and professional designers. In our research on the maritime domain, we uncovered several reasons for this. First, most safety–critical workplaces restrict third-party access, which makes the context and the users difficult to reach (Lurås and Mainsah 2013). Second, for most designers, the working context of a vessel—spanning offshore vessels to icebreaker vessels and coastguard vessels to fishing trawlers—is highly unfamiliar (Lurås 2016). Changing weather conditions and complex operations, constitutes an unpredictable and challenging workplace for the field researchers as well as the crew (Nordby and Lurås 2015). However, understanding the users of a safety–critical workplace requires insight into good seamanship and the high levels of complexity in their use of advanced technology to perform tasks (Lurås and Mainsah 2013). The ability to systematize premises and user requirements for the complicated bridge systems used during complex operations and under demanding conditions depends on high maritime domain awareness (Lurås and Nordby 2015). Therefore, to design safe and efficient solutions that support navigators' situational awareness in safety–critical workplaces, such as on ships' bridges, a designer needs to fully understand—and preferably personally experience—the implications that contextual factors have for the user's situation (Frydenberg et al. 2018).

Previous research projects in the OICL have proposed an approach for acquiring experience and knowledge specifically for designers working within the maritime field called *design-driven field research* (Fig. 1). The approach contains three main aspects of field research: 1) *design reflection*, which implies the reflection and mental process of developing design ideas while in the field; 2) *experiencing life at sea*, which implies gaining familiarization with and insight into the context, the situations, and the people; and 3) *data mapping*, which implies the collection of raw data.

2.2 Related work

The practical approach of applying, developing, and evaluating concepts and processes as a continuous learning process for a specific context is important in some other fields. The term *virtual fieldwork* has multiple interpretations; it can be used as a term for conducting web-based research techniques, such as netnography (Mkono 2012) or for understanding qualitative research (Mejias 2017). However, the perspective of the internet as a virtual site differs in meaning from the physical context like we refer to. Systems for conducting virtual fieldwork of physical sites have been established as exploratory learning environments for practicing excavation in archaeology (Getchell et al. 2010) and for digital landscape architecture (Rekittke et al. 2021). Domains such as geology and geography have implemented several forms of virtual fieldwork, such as for professional development programs for teachers to familiarize with and investigate field sites in geoscience teacher education (Granshaw and Duggan-Haas 2012), as smartphone-driven virtual reality applications for use by geography students jointly

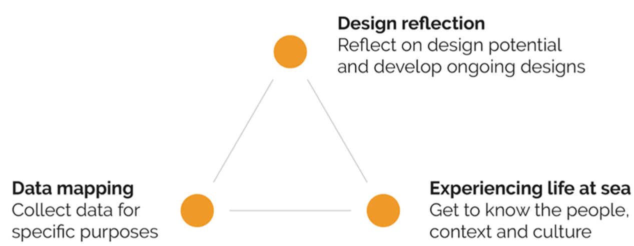

Fig. 1 Model for design-driven field research representing a triangulation between the aspects of design reflection, experiencing life at sea, and data mapping (Lurås and Nordby 2014)

with physical fieldwork (Minocha et al. 2018), and as virtual field experiences of relevant locations based on drone images for students in introductory geology courses (Dolphin et al. 2019). Within engineering, virtual fieldwork has been implemented for virtual access in remote situations, such as virtual field trips for students to achieve insight for designing industrial scale plants (Seifan et al. 2019), virtual laboratories supporting traditional hydraulic engineering learning (Mirauda et al. 2019), and immersive virtual fieldwork in the petroleum industry (Gonzaga et al. 2018).

Virtual field studies on public displays have been used for evaluating public displays and found to be a powerful research tool (Mäkelä et al. 2020). However, implementing virtual fieldwork in developing AR applications using virtual reality worlds is rare and has been suggested to be particularly suitable for indoor environments without other people (Gushima and Nakajima 2021). Besides Gushima and Nakajima's recent conference paper describing this approach, we believe that only a few examples explore virtual fieldwork for designing AR.

3 Method

This study is based on a case study of a design education module that was implemented with an ad hoc approach to accommodating the drastically changed premise of teaching due to COVID-19 restrictions. The case study was based on two methods: student project documentation and a questionnaire. The first dataset was the students' project documentation from their projects containing images, videos, keynote presentations, and written documentation. The second data set was based on the questionnaire comprising seven unstructured questions reflecting upon the students' learning outcomes and VRROS usage.

3.1 The teaching module

Cross-Situational Design Patterns is the name of a six-week module held by the OICL at the Oslo School of Architecture and Design. A total of 15 (five male) students participated in the module. The participants had somewhat different educational backgrounds before entering the course, spanning industrial and interaction design to visual communication and fashion design; thus, they possessed different background knowledge, skills, and assumptions regarding how they approached virtual fieldwork.

In this module, the students had three shorter projects with the aim of exploring multimodal design patterns for AR to be used by navigators on an Arctic ship's bridge. By design patterns, we refer to solutions to interaction design problems in a specific context (Tidwell et al. 2020). The *solutions* should be developed as design concepts for an interface between the navigator and ship bridge systems. The students should use the specific *problems* from the assignment descriptions (listed below) to decide on a narrow and specific problem area, such as making an AR widget design for the representation of other vessels in the oceanscape (Scenario 1). The students defined whether the design concept was intended to work as a replacement or as an add-on to the existing ship bridge systems. For the three projects, different written scenarios alongside VRROS were given to the students to represent the *context*. In the following, we list a summary of the scenario with the belonging assignment:

1. **Scenario 1—The Grounding of Vega Sagittarius:** In this scenario, a container vessel departing from the port of Nuuk, Greenland, runs aground on a submerged rock after its sudden change of course to avoid drift ice.

   Assignment: *How can a user interact with a point of interest (POI) in the oceanscape? The type of POI (for example, another vessel) should be decided by the student.*

2. **Scenario 2—The sinking of the MV Explorer:** In this scenario, an expedition vessel entering an ice field in Antarctica collides with an underwater iceberg and sinks.

   Assignment*: How can interactions for regions of interest (ROIs) be designed? The ROIs should represent different types of ice conditions.*

3. **Scenario 3—Convoy:** In this scenario, an icebreaker vessel rescues two cargo ships stuck in the ice by breaking them free and leading them into a convoy until they reach secure waters.

Assignment: *How can the user assess risk proximity during navigation and operation regarding fixed or moving objects in the immediate vicinity? Assessment of risk proximity could be either in the planning phase, during the breaking free phase or during the convoy.*

The intended purpose of the solutions should be to improve the safety and efficiency of the navigator's interaction with the ship bridge systems. To learn more about the premises for this, the students had several lectures with field experts and relevant literature supporting their background knowledge. The premise for their design solutions was to use Microsoft HoloLens as a mediating technology to design for (Microsoft HoloLens 2021). The students were encouraged to use the VRROS to familiarize themselves with the current scenario and work with a prototyping method with which they thought they could best convey the user experience to the rest of the class to understand and evaluate the usefulness of the design solution concept.

3.2 Virtual reality-reconstructed operation scenarios

The VRROSs were developed in a recent research project exploring the use of AR technology in Arctic navigation (SEDNA), where the purpose of the scenarios was to produce a realistic 3D modeled context wherein we could design and test new AR concepts (Frydenberg et al. 2021). We recreated three different scenarios containing icebreaker operations using a VR-enabled simulator. The scenarios were partly developed based on facts and data from some selected real shipping accidents and operations, such as the sinking of MV Explorer in the Antarctic Ocean in 2007 and convoy operations in the Bay of Bothnia. The detailed scenario descriptions were constructed by a multidisciplinary research team—spanning navigators to human factors engineers to interaction designers—to quality-check different aspects, such as realism in some events during the operations and applicability for exploring improvements.

The VRROSs were realized as dynamic 3D model scenes using the Unity game engine (Unity 2020) with an attached HTC Cosmos VR headset. The VR system was powered by a personal computer with an NVIDIA 3090 game card (NVIDIA 2021). The simulation was run on a steady 90 fps, and we did not receive any reports of nausea from the users. We removed buoyance on the ship to reduce the chances of the user getting wave-induced motion sickness during the scenario.

The three different VRROSs have slightly different contents according to which scenario they represent. They all comprise a main vessel where the VRROS user is situated (see Fig. 2), alongside other vessels and environmental volumes and surfaces, such as icebergs, rocks, and ice floes in the oceanscape. The VRROS allows the user to move freely around the entire virtual ship's bridge by teleporting or moving physically in the tracking space. The VRROS plays through the prescripted timeline of the scenario, comprising some events. The main vessel has a determined route and actions with which the VRROS user cannot interfere with. However, by altering the user interface (UI) on the bridge and experimenting with new AR UIs, the VRROS offers possibilities for experiencing the UIs in realistic contexts in ways that were not possible in a training simulator. Altering the UIs directly in the VRROs requires some knowledge of using the Unity game engine. Therefore, we asked the students to make recordings from the scenarios and use Adobe After Effects software to add visual layers on top of the recording to simplify the prototyping process of the new AR UIs they created (Adobe 2021). Hence, they could also add recordings of a user interacting with the graphics to convey the overall concept to the class.

Although the ship bridge is unpopulated, this setup enabled the students to familiarize themselves with the ship bridge's physical, spatial, and temporal properties during the scenario timelines. Adding to the possibility of moving around on the bridge, the students could manipulate visual conditions such as the amount of daylight (bright, day, dusk, and night), waves and weather conditions in addition to time. Potential motion related to changing conditions is removed due to high risk of motion sickness for the wearer of the VR equipment. The students could do a simple manipulation of the scenario, such as jumping through time and triggering AR functions from a control screen, while a user was immersed in the VR scene. They could test their UI concept in different conditions by asking themselves questions: "What if the situation was characterized by heavy motions from waves, will this design concept work then? If not, how can we better adapt it to be used during wavy conditions?" or "What if the situation was characterized as night with no natural light and the need for maintaining a good night vision is important for the user, will this design concept work then? If not, how can we better adapt it to be used during night conditions?" This form of cross-situational testing of design concepts induced the exploration of the many variations and adaptions needed in the work of designing AR UIs for ship bridges. Followingly, this manipulation of conditions back and forth increased the students' awareness of the need for situational adaptation.

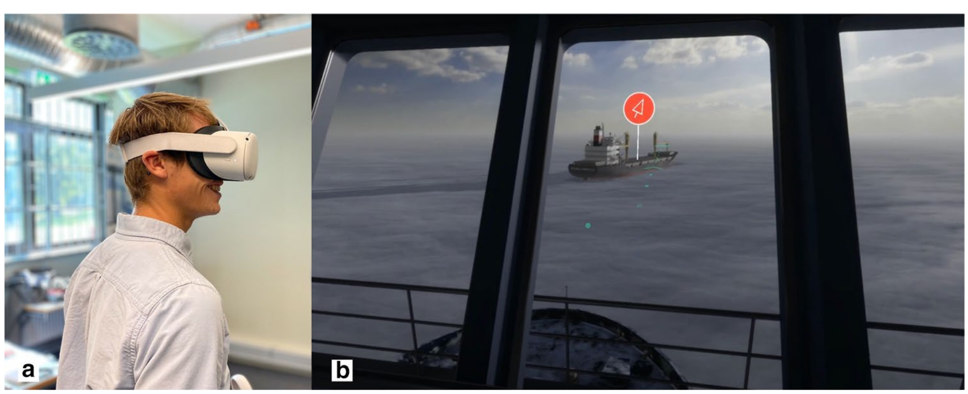

Fig. 2 The virtual reality-reconstructed operation scenarios (VRROS) setup. **a** shows a student using the headset to access the VRROS. The rest of the participants can see what the user sees in the VR headset on a big screen. To the right: a screenshot from the what the user experiences in 3D modeled world representing the VRROS

3.3 The students' use of VRROS

The students started with a self-organized familiarization period with the VRROS. This period was guided by four of the students who had received special supervision in learning the features and possibilities for manipulation of the VRROS in advance. In addition, a student assistant from the OICL lab and one of the teachers offered supervision upon demand.

Two of the students did not test the VRROS, while the thirteen other students used the VRROS in varying degrees during the three projects. The students' use of the VRROS was documented using their own images, videos, and presentations from 15 different projects. In addition, each student produced an individual final report that documented the projects they had participated in alongside their reflections. From this sample, we selected examples that demonstrate the various findings presented in the result section. We analyzed these data based on a model of design-driven field research to isolate the different aspects and further used the RQ to filter out the aspects of design-driven fieldwork for which the VRROSs have functioned as a substitute.

3.4 The questionnaire

The questionnaire's open-ended questions were part of a final exam where the students documented, reflected upon and discussed the learning outcomes associated with the module. Table 1 shows the part of the exam from which the answers represent the second sample for this article (Table 2).

We analyzed the questionnaires using coding (Robins et al. 2009). To categorize the responses, we flagged each response with a color code representing a thematic category,

Table 1 The student questionnaire comprising seven open-ended questions

Write an overall reflection on what you have learned in this module. Some questions you should include in your reflection:	
1	Did you accomplish what you expected (how/why not)?
2	How did you approach working with a complex user context?
3	How did you use VRROS to understand the complex user context?
4	How valuable and how useful was access to the context through the VRROS?
5	How did you approach working in a new technology (if you worked with AR/VR)?
6	How did you relate to working within the time constraints imposed on developing each project?
7	How did the COVID-19 measures affect your work?

Table 2 The table lists the learning concepts (Anderson et al. 2001) in the left column. The middle and the right columns reveal different aspect within each of the learning concepts that can be facilitated through either design-driven virtual fieldwork or design-driven field research (Lurås and Nordby 2014). The table displays the different qualities in each method

Learning concepts	Design-driven virtual fieldwork	Design-driven field research
Creating	Rapidly explore concepts and prototypes in virtual context	Explore concepts in real world situations
	Develop high-fidelity design	Develop low-fidelity design sketches
	Create complex design patterns	Co-create with users
Evaluating	Undisturbed decision making	Reflecting on designs
	Checking standards	Implement and collect data from real user tests (lower frequency)
	Implement simulated user tests (higher frequency)	
Analyzing	Easy access and full control over the situation to organize, differentiate, restructure, and relate elements	Ad-hoc analysis while collecting data
		Full analysis done after the field study
Applying	Low threshold for testing	Higher threshold for testing due to situational constraints and lack of equipment
	A/B testing	
Understanding	Familiarizing with the physical (partly), spatial, and temporal aspects of the context	Ethnography, user insight
		Familiarizing with the physical (partly), spatial, temporal, social, and emotional aspects of the context
		Embody experiences
		Combinations of sensory input
Remembering	Conveying realistic design concepts by simulation on demand or by generating high-fidelity videos	Raw data (Video recordings, sound recordings, images)

such as representing an experience like “I found it challenging,” “I adapted,” or “I learned,” or as answers within spans from “not at all,” “to some extent,” and “to a wide extent”. The list of codes was developed while reading the responses, thereby allowing us to customize the codes according to the responses and adjust them accordingly.

3.5 Limitations and strengths of the methods

Neither method provided reliable or replicable data. Our roles and biases as teachers most likely affected our interpretation of the results, as we knew far more about what each student had achieved and about their experiences than what they expressed through their answers in the questionnaire and in their project documentation. Further, the students were instructed to answer each question in one or two sections of continuous reflection. However, some responses were deficient, mixed together with another question or did not answer explicitly the question. This limits the full basis of the response.

The strengths of the methods were their low cost and effort. Further, they yielded a fair amount of data that, rather than playing a validating role toward answering the RQ, functioned as descriptive to develop a new approach to teaching. The totality of these descriptive data forms an interesting and—in our situation of strict and ongoing COVID-19 measures—relevant reflection on how education can adjust to the new travel restrictions and on whether such solutions can even contribute to giving immersive fieldwork methods an extended value.

4 Results

In the following, we present a summary of the data we collected based on the students’ use of the VRROS and the questionnaire.

4.1 The students’ use of virtual reality-reconstructed operation scenarios

Many of the student groups leveraged the VRROS. They did this in often unexpected and innovative ways. In this section, we will present examples of how the students integrated the scenarios into their creative processes.

4.1.1 Familiarizing themselves with the use context and the technology

The students used VRROS to familiarize themselves with the physical, spatial, and temporal aspects of having the ship’s bridge as a working context. None of the students had been on a real ship’s bridge before. Their search for insight into the user’s surroundings by inspecting potential areas, surfaces, and perspectives suitable for design ideas seemed to fuel their concept development, both for quality and quantity. In addition, few of the students had previous experience with using or designing for AR. Therefore, their synchronized familiarization with both the virtual use context they were going to design for (the VRROS) and the technology they wanted to design with (Microsoft HoloLens) appeared to have a constructive effect. Figure 3 shows a group of students switching between the two modes of familiarizing themselves with the user context employing the VR simulator to access the VRROS and in addition exploring the nature of AR interaction by testing the Microsoft HoloLens (Zeller et al. 2019).

4.1.2 Using video recordings from VRROS as raw material in design visualizations

Having familiarized themselves with the use context, the students made scenario recordings by selecting the viewer’s placement and perspective on the bridge, contextual conditions, and time slots in the scenarios that they found relevant for applying their design ideas.

To illustrate this, we will describe an example from the third project working with risk proximity in scenario 3. The group explored how AR interfaces for placing vessels in a convoy could be designed (Fig. 4). In the project presentation, the group demonstrated their exploration by showing a selection of videos made by combining recordings from the VVROS, graphics, and recordings of a user interacting with the graphics, all put together and animated in After Effects. Their concept conveys a UI setup in which the icebreaker navigator can adjust and monitor the distance between the vessels. They exemplify how the UIs can co-exist in the oceanscape and on floating panels with more detailed information inside the ship bridge, such as a screen replacement.

4.1.3 Exploring interaction gestures using VRROS as an underlay

The project assignments emphasized the exploration of interaction mechanisms in sequences. Many student groups used the VRROS as an underlay to contextualize the whole sequence they were working with and thereby managed to convey highly realistic user experiences well suited for plenum discussions (Fig. 5).

To illustrate this, we will describe an example from the second project focusing on ROIs in scenario 2. The group explored how AR interfaces display how ice maps could be designed and various ways the user could interact with the maps to place them correctly, zoom in and out, hide, show and highlight ROIs (Fig. 5). In the project presentation, the group showed how they had conducted their exploration of

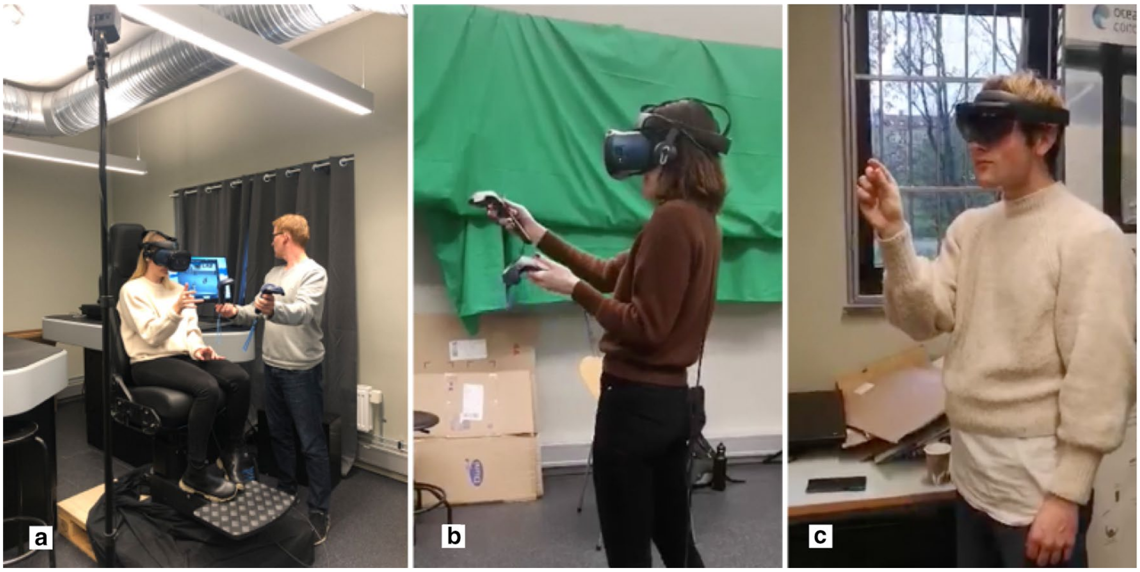

Fig. 3 Students familiarizing themselves with the use context and testing AR and VR equipment. In **a**, a student sits in the VR simulator with a VR headset on. The simulator was built with an original ship's bridge chair and console tables for flexible setups to test equipment. **b** shows a student testing the VR headset with handle tools that allow the user to interact with the scene by teleporting from one place to another, or pointing or selecting, for example. **c** shows a student exploring the use and interaction possibilities of the AR headset Microsoft HoloLens 1 (Zeller et al. 2019) by testing gestures

Fig. 4 Screenshots from a video in a student presentation. **a** demonstrates a concept for how navigators can set and monitor the opacity of risk zones in AR using gestures. **b** illustrates the perspective of the navigator, who can monitor the dynamic risk zones in AR projected onto the convoy behind the ship alongside an information panel in the top right corner of this view

finding useful interaction possibilities using the green screen to record various gestures and further combining these with recordings from the VRROS and graphics. Their final concept communicates a navigator applying the graphical ice map to match the outside surroundings, adjusting and rotating the map, and picking up map elements from a screen to further process in AR.

4.1.4 Testing multimodal and distributed interactions with video prototypes

In the project assignments, we encouraged the students to test various interaction modalities on the same problem to understand how interactions need to be designed and distributed across all interfaces to be adaptable to the user situation.

To illustrate this, we will describe an example from the third project focusing on risk proximity in scenario 3 (Fig. 6). The group used the VRROS to video prototype a detailed interaction concept in a selected sequence of the VRROS where the icebreaker vessel is approaching another vessel stuck in ice to rescue it. The group explored several different input and output modalities, such as voice control, gestures, gaze, and command, and finally, by connecting a portable controller for the same interaction functions. Using recordings from the VRROS as an underlay on which to design, the students managed to convey user experiences with a quality and realism that made it possible to evaluate

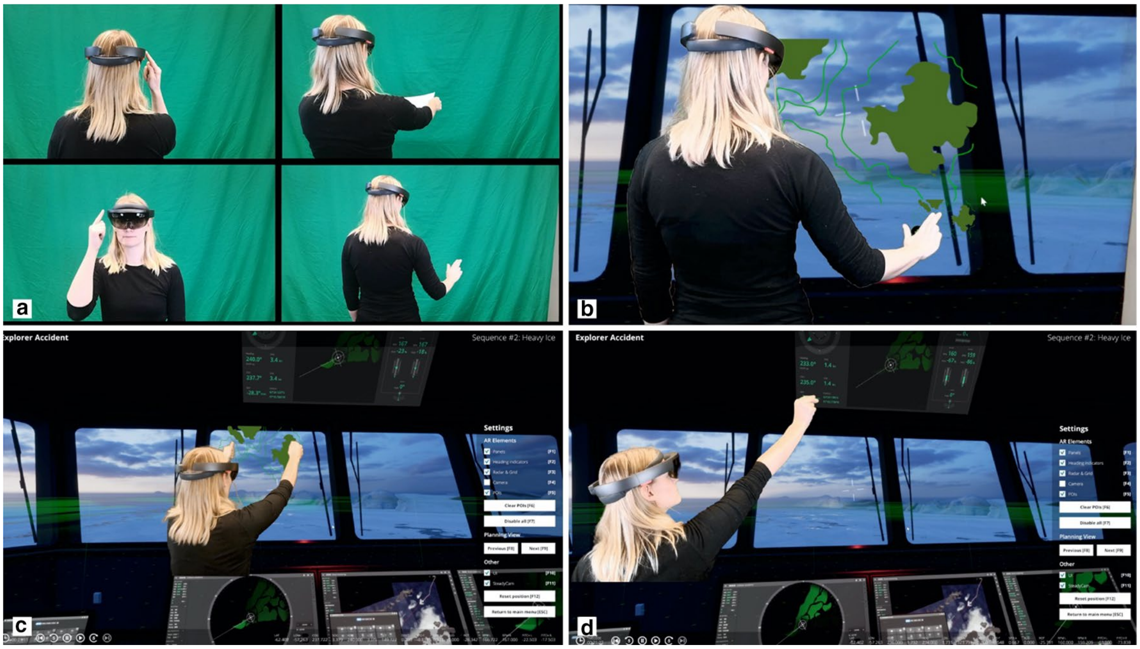

Fig. 5 A student group's testing of different forms of gestures for interacting with an AR map. **a** shows the use of greenscreen when filming gestures performed by one of the students. The greenscreen makes it easier to further process the recorded material. The recorded gestures were merged with recordings from the VRROS, alongside the graphical dynamic sketches. **b** shows the student applying the graphical map to match the outside surroundings; **c** shows the student adjusting the size and rotation of the map. **d** shows the student picking up map elements from a screen to further process in AR through hand gestures

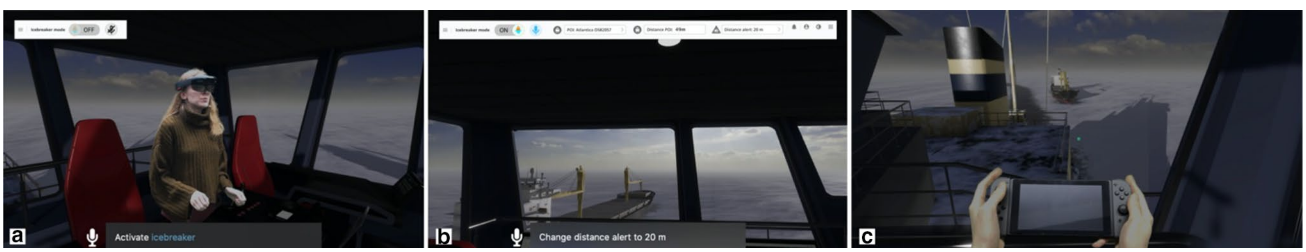

Fig. 6 Screenshots from a student group's video prototypes of three different ways of solving the same problem using different input and output mechanisms. **a** shows voice controls and gestures. **b** shows gaze and command jointly with graphics. **c** shows interaction with an AR headset and a portable tangible controller

the coherence and consistence of their design proposals across the modalities. They also achieved a greater sense of the situation themselves by playing out the proposals inside the VRROS.

4.1.5 Summary of the students' use of VRROS

Overall, we saw that the students could work creatively with VRROS without having any knowledge of the game engine itself. The students seemed intrigued by and engaged in visiting the virtual ship's bridge to become familiar with the context. Further, some of the groups developed techniques for exploring and implementing design ideas in video recordings from the VRROS in efficient and compelling ways that allowed for fruitful discussions about their design proposals at a satisfactory level of detail. Conversely, the students who did not leverage VRROS in their prototyping seemed to struggle with conveying several aspects of their proposals because they had not worked within dimensions of space and time.

4.2 Questionnaire responses

We developed a questionnaire to understand how the students experienced the use of VRROS. In this section, we summarize the students' responses to each of the questions in the questionnaire.

4.2.1 Did you accomplish what you expected (how/why not)?

The students had somewhat diverging expectations for the course, from few expectations to high expectations. Ten students achieved what they expected or more, three students were unsure what they expected or if they accomplished what they expected, and two students stated that they did not expect anything due to reduced access and competence in using the VR equipment.

4.2.2 How did you approach working with a complex user context?

All students were unfamiliar with both the ship's bridges and AR technology. Thirteen students sought additional research to learn about the user context. Although several of them tested the VRROS in the beginning, three students answered that they used the VRROS actively to gain insight into the situation. Two students did not answer this question.

4.2.3 How did you use the VRROS to understand the complex user context?

Seven students who used VRROS found the observation and analysis of the scenarios through the VR simulator useful, especially since the context, the operations, and the domain in general were unfamiliar to them. Two students did not test the VRROS due to voluntary COVID-19 isolation/quarantine. Six students did not answer this question.

4.2.4 How valuable and how useful was the access to the context through the VRROS?

Six students found VRROS valuable and useful. Some of them described how the VRROS contributed to their "mental images" of what they were designing for, which was useful in several parts of the design process conducted outside the simulator, spanning sketching to doing additional research. In addition, they mentioned that the VR simulation helped them understand the scenarios and the context of the situation—the time of day, weather, and light conditions—and what was happening inside and outside the ship. Further, they found the VRROS useful for prototyping "as a background and to test different placements of our user interfaces and our interaction concepts." Eight students did not explicitly answer this question.

4.2.5 How did you approach working with a new technology (if you worked with AR/VR)?

All students tested other prototyping techniques to convey the user experiences they aimed to design, such as through software programs, such as Figma, After Effects, Photoshop, etc., and twelve students described learning new forms for prototyping through this. Eight of the students said that they found it exciting to test the VR and AR equipment and that they had a good impression of how the technology worked. Two students said their approach of using the VR and AR equipment gave them a good understanding of designing for the technology. On student did not answer this question.

4.2.6 How did you relate to working within the time constraints imposed on developing each project?

Four students saw the time constraints as positive. Three students described the time constraint as a challenge. Four students described a steep learning curve and a greater feeling of mastery and satisfaction toward the end of the module. One student found the short-time constraint less comfortable than longer projects. Six students did not answer this question.

4.2.7 How did the COVID-19 measures affect your work?

All students answered that COVID-19 affected their work. Three students answered that they handled the measures well. Ten students answered that difficulties in sharing, discussing, and agreeing on ideas without being physically in the same room were experienced as challenging. Two students did not answer this question.

4.2.8 Summary of the questionnaire

The answers to the questionnaire emphasized that the COVID-19 measures affected the students' ability to do field research and their experience of being free to meet physically and to use the facilities they were actually allowed to use, such as the VR lab and the classroom. This resulted in a split student group, where one part of the students exploited the possibilities of using the VRROS and met physically to engage in teamwork, while the other part worked mostly from their homes, which reduced their ability to cooperate and develop refined prototypes.

5 Discussion

5.1 VRROS as a substitute

Overall, we suggest that VRROS offers students the potential to access and work with hard-to-reach contexts, such as ships' bridges, in an educational setting where time and organizational constraints often limit real fieldwork. Their use can be unlimited and effortless, and they can be revisited as often as the students are desiring. Regarding the special situation created by the COVID-19 measures placing restrictions on all access to real fieldwork, this proved to be highly important and was even advantageous when compared to the demands of real maritime fieldwork and the associated time, effort, and cost concerns.

The limitations of VRROS compared to real fieldwork are obviously its lack of reality, meaning its lack of real users and all their associated ethnographic aspects, such as culture, language, behavior, etc., that form the basis of what fieldwork actually is. Further limitations are the VRROS requiring a significant amount of time and competence to build a lifelike 3D environment that is realistic enough to be used. However, when VRROS are already developed, the threshold for reusing them for multiple purposes is low. Furthermore, there are a few reasons to develop new scenarios for each semester since the students' means of solving the assignment problems will be unique to each cohort.

5.2 Virtual fieldwork

The application of learning concepts in fieldwork is important for designers in both student and professional situations. To answer the RQ of *How can aspects of design-driven fieldwork be substituted with VRROS used in a VR simulator?* we used Anderson's revision (Anderson et al. 2001) of Bloom's levels of cognitive behavior (Bloom 1956) to compare aspects within the different learning concepts. The table lists the learning concepts in the left column, the most prominent aspects within each learning concept facilitated through design-driven virtual fieldwork in the middle column and design-driven field research (Lurås and Nordby 2014) in the right column. More aspects can be added and elaborated. Although some aspects may overlap between both methods, such as the possible range of fidelity variations in the design prototyping, the table intend to display the most expedient qualities and possibilities for learning in each concept.

5.3 The VRROS potential

Although virtual fieldwork implemented through VRROS cannot replace the interpersonal aspects of conducting real field research, this method should not be considered a deficient substitute for real fieldwork. During the module, we discovered that the students' use of VRROS' capabilities for manipulation were key for both their understanding of the situation and for prototyping. The VRROSs allowed the students to manipulate some parameters that were not possible in the real world, which are as follows:

- Time: VRROS allows students to oscillate in time as they like. They can freeze time and move slower or faster in time.
- Conditions: VRROS allow designers to change, adjust, and modify certain conditions.
- Situations: VRROS can allow designers to manipulate the situation and the course of action.

All the parameters that can be cross-manipulated result in different possible contextual states. By dwelling on and repeating situations, to modify the situation underlay for testing and to work under various conditions—both separately and cross-manipulated—the students were allowed to work in detail, at their own pace and under controlled circumstances. This strongly opposes the often more chaotic experience of real fieldwork, where conditions and situations are rapidly changing and where the student or researcher must seize opportunities rather than create them.

Our VRROS also offered interesting possibilities for low-threshold but still relatively high-fidelity prototyping. The equipment has a fairly easy setup and the students were able to work independently without further support after a general introduction. Some students spent much time on using the VR- equipment in order to be in the virtual world, while others were content with fetching recordings from the VRROS which they then worked further with in more conventional ways. In an educational setting, it is challenging to teach students about advanced technology design within short-time frames while still facilitating the creation of realistic prototypes. We argue that the quality of realism in prototypes is highly important for the students' understanding of the technology's possibilities and limitations as a design material. Therefore, we propose that the prototyping techniques developed in this module using VRROS in a VR lab are imperative and should be further examined. We would also like to emphasize the potential for implementing virtual fieldwork while undertaking preparatory work before fieldwork trips and to further process design work after fieldwork trips.

In previous research on use of field studies supporting design for safety critical workplaces we found that there was a risk for bias on interpreting the field data due to the designers limited exposure to field context (Lurås and Nordby 2014). We identified three common biases. We do not have the data yet to extrapolate similar biases in use of VRROS in design. However, based on our experience from field studies for design it is likely that there will be biases for interpreting the virtual scenarios in design that needs to be described and compensated for in design processes in further work.

5.4 Discussion summary

To summarize and reflect on our research question, we suggest that VRROS can substitute for the following aspects of design-driven fieldwork:

- Observing and analyzing the user context.
- Becoming acquainted with the scenarios regarding operation, time, and space.
- Understanding certain aspects of the situations, such as weather and light conditions
- Understanding what is happening inside and outside the ship from different perspectives
- Collecting background material (videos, images) for prototyping and testing.
- Understanding the design for AR technology on ships' bridges by prototyping realistic mock-ups.
- Working physically and virtually, together with a collective understanding and exploration of the context for which they were designed.

Based on the results, we propose that VRROS offers promising potential to function as a substitute for certain aspects of design-driven field research, such as familiarization and design reflection for prototyping. It is also likely that VRROS can supplement and support actual fieldwork. Although ethnography is excluded, prototyping and several forms of testing can be conducted. Also, aspects of reflection and familiarization, excluding the interrelated aspects of ethnography, can be supported. In our educational case study, VRROS worked as a useful substitute for canceled fieldwork due to the COVID-19 measures implemented. In a learning process with a short-time frame and a context that is difficult to access, we suggest that a VR simulator can actually work as a suitable substitute. Particularly during times of strict COVID-19 measures that limit the movement of people and the accessibility of contexts to a high degree, pragmatic solutions need to be considered good enough, given the circumstances.

6 Conclusion

In this article, we described VRROS utilization in a VR lab as a substitute for real fieldwork in the teaching of a master's module on multimodal and distributed technology for ships' bridges. We used two samples: the students' production data and a student questionnaire to answer the RQ: *How can aspects of design-driven fieldwork be substituted with VRROS used in a VR simulator?* Our results showed that VRROS can replace some aspects of the real-world fieldwork. Although important aspects, such as ethnography, cannot be included, the VRROS offers some promising advantages for being far more accessible, faster, and cheaper; they are also time-saving and easy to revisit whenever the designer desires. In addition, VRROS offers students more control in their ability to manipulate the premise of and conditions for testing (which real fieldwork does not), and VRROS enables the students to produce low-threshold, high-fidelity prototypes based on VR recordings when exploring the design possibilities for ships' bridges.

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Declarations

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Code availability Not applicable.

Ethics approval All procedures performed in studies involving human participants followed the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. The project reports to the Norwegian Center for Research Data.

Consent to participate Informed consent was obtained from all individual participants included in the study.

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