Designing Reality: A Mapping-Based Participatory Toolkit for Drone Experts Addressing Integration into Critical Infrastructure

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ABSTRACT

The increasing deployment of drones in critical infrastructure settings underscores the need for effective collaboration between drone experts and relevant stakeholders. Yet, existing approaches often lack a structured methodology to facilitate meaningful communication and mutual learning among participants. This paper addresses this gap by developing a scenario-based participatory design (PD) workshop protocol, supported by a domain-specific toolkit, that empowers drone experts to engage stakeholders in co-design activities effectively. Through iterative evaluation with drone experts and researchers, this study demonstrates how this workshop approach uses tangible artifacts and structured scenarios to enhance co-creation, mutual learning, and reality confrontation, to bridge knowledge gaps, and support the collaborative development as part of research in critical infrastructure. The proposed approach fosters shared understanding and aligns technical expertise with operational realities. This research provides a practical, adaptable methodology that advances PD practices in complex, safety-critical domains, ultimately contributing to more context-sensitive and realistic drone integration strategies.

KEYWORDS

Participatory Design - Co-Creation - Mutual Learning - Reality Confrontation - Communication

1 INTRODUCTION

Despite their potential to automate and improve human safety in critical infrastructure, drones remain underutilized, not yet meeting the needs of those who can benefit from them most. As novel technologies emerge, so does the need for appropriate research techniques. When investigating the implementation of novel technologies in high-stakes environments, e.g. drones in critical infrastructure, it is essential to ensure human acceptance and support of the implementation. An approach to conducting research with people in an environment fraught with complexities and issues, hereunder regulatory and safety compliance issues, is through participatory design (PD). PD offers approaches that integrate stakeholders, i.e. people in the research domain, in development processes, and utilizes their thoughts and opinions as design requirements. As such, the stakeholders are important actors in PD processes because they shape the foundation upon which development is conducted. However, drone experts often lack a systematic approach to engage stakeholders when the process demands both technical realism and domain-specific knowledge, resulting in specific considerations that should be addressed during development. As such, PD can be a useful approach in involving various stakeholders, facilitating conversations about areas of concern and the development of new ideas.

This paper addresses the research question:

How can a scenario-based participatory design workshop protocol and domain-specific toolkit be leveraged to aid drone experts communicate with stakeholders in critical infrastructure?

The main contribution of this research is a unified approach to expert-facilitated workshops within critical infrastructure, consisting of a workshop protocol coupled with a domain-specific toolkit. This approach empowers drone experts to act as facilitators of communication, guiding collaborative discussions, and confronting the realities of drone implementation with other stakeholders through PD. Through the focus on communication and collaboration, this approach integrates the perspectives and expertise of various groups of actors, referred to as diverse stakeholders, into the development and implementation of drones in critical infrastructure; an application domain that can be difficult to gain access to and conduct research with.

By building on established participatory design principles and previous exploratory studies, this research refines a workshop protocol that not only supports discussion but also fosters visual literacy and reality confrontation. This is accomplished through scenario-based exercises and a tangible toolkit, approaching research on mutual learning and communication within critical infrastructure rather than simply providing tools to discover ideal drone behavior. Through iterative development and evaluation, this approach demonstrates how drone experts can create shared understandings with stakeholders, leading to actionable insights and usable design solutions for the use of drones in critical infrastructure.

2 RELATED WORK

I have previously researched, hosted, and documented a workshop investigating utilizing drones in the surveillance of critical infrastructure. In the preliminary study, I documented the process of discovering what co-design based research had already been conducted, specifically on drones in surveillance and how a workshop based on this research was planned and conducted. As a conclusion to the preliminary study, I provided an overview of the knowledge gained from the workshop, both knowledge regarding drones in critical infrastructure and knowledge regarding improvements to the workshop approach. The preliminary study detailed research conducted within the fields of drone applications, PD, artifacts, and

using workshops as an approach to research and how this knowledge was used to design the first iteration of the workshop approach. This section focuses on highlighting additional related work that, more specifically, explore various aspects of the aforementioned research question in addition to the related work outlined in the preliminary study.
[12]

2.1 Participatory Design in Praxis

Within PD, many definitions of this approach to design have emerged since the practice was proposed in the early 1970's [2]. For example, Simonsen and Roberson define PD as "a process of investigating, understanding, reflecting upon, establishing, developing, and supporting mutual learning between multiple participants in collective 'reflection-in-action'" [22, p.2]. Analogously, Sanders and Stappers define PD as "an approach to design that attempts to actively involve the people who are being served through design in the process to help ensure that the designed product/service meets their needs" [20, p.19]. For the purposes of this paper, I amalgamate the two aforementioned definitions into one, focusing on their shared characteristics. The amalgamated definition of PD is: *an approach to design that involves end users in development and reflection to ensure the designed product/service respects and meets their needs and wants.* By involving end users in design processes to establishing dialogues that ensure the development meets their needs, as well as being technically feasible; mutual learning is established, a concept at the core of PD [18]. Mutual learning is a process in which designers and participants teach the other about their expertise in an attempt to develop a shared understanding of the problem domain [18].

In 2018, Bødker and Kyng proposed altering the current approach to PD, about 50 years after the approach's emergence. This was proposed to ensure that any PD conducted matters, to revitalize participation as a medium for end users to influence larger issues. In this article, the authors propose five elements that form the core of *PD that matters*. To summarize, the five elements are: the research field requires changes, stakeholders are included and seen as major drivers, facilitators act as both researchers and activists, cooperation between stakeholders and facilitators, and ensuring democracy in the entire PD approach [2]. Based on this, the workshop protocol from the preliminary study align with the five elements, which is further elaborated upon in subsection 3.1. By conducting PD with end users and other stakeholders, thereby transforming them into participants, they are given a voice during the design process of a technology that they are the intended end users of [20, 22]; thereby making it a democratic process.

Literacy forms the basis of democracy, and therefore, democratic processes [15]. One approach to ensuring that PD remains a democratic process, is to develop a tool that fosters shared literacy. One approach to this is through visual literacy. Moore and Dryer, utilizing John Hortin's definition, define visual literacy as: "the ability to understand (read) and use (write) images and to think and to learn in terms of images... [it] is really training for visual thinking" [13, p.3]. Concordantly, Serafini defines visual literacy as "a process of generating meanings in transaction with multimodal ensembles that include written text, visual images, and design elements from a variety of perspectives to meet the requirements of particular social contexts" [21]. For the purposes of this paper, I follow the definition proposed by Serafini. Inspired by Serafini's definition of visual literacy and Sanders and Stappers viewpoint of physical artifacts being a corner stone of PD, physical artifacts can be used to help develop a mutual understanding of the problem domain, using the artifacts as "thinking tools throughout the process" [20, p.19][21]. The following subsections explore research into physical artifacts and how these can be used to facilitate co-design in PD workshops.

2.2 Visual Unification Through Mapping

In 2020, Agrawal et al. presented their approach to using mapping in conducting co-design with relevant stakeholders. In their paper, the authors presented design solutions that were derived from co-design sessions in which facilitators and participants collaborated to arrange physical artifacts, namely tokens and cards, on a map. This map was then used to design the layout of an interface for surveilling high-risk forest fire areas that increases situational awareness for the person interacting with the interface.
[1]

Additionally, Hoang et al. utilized co-design to investigate the challenges of multi-drone systems and how these should be designed to benefit the Danish emergency services during search-and-rescue missions [10]. Wojciechowska et al. leveraged co-design to research the possible implementations of drones in Sub-Saharan Africa from novice drone users' perspectives [24].

Huybrechts et al. proposed a participatory design approach that uses mapping as a visual literacy tool. In their workshop approach, facilitators, referred to as moderators, guide participants through two scenario iterations in which they collaboratively (re)arrange a variety of artifacts and tokens on top of a large map depicting the space investigated in an attempt to answer a research question or design. The refined workshop protocol follows the MAP-it approach of mapping in participatory practices. The following subsection explores how artifacts can be used in PD.
[11]

2.3 Communication Through Physicality and Tangibility

As previously mentioned, Sanders and Stappers view physical artifacts as thinking tools in PD processes, helping participants explore the problem domain through visual literacy afforded by the tangibility of the artifacts [20]. Similarly, Hansen and Dalsgaard conducted a PD workshop in which the participants created 3D characters of themselves, and moved these characters around a blueprint map of a library to involve librarians in the process of designing the implementation of new technologies at their work place. In their workshop, Hansen and Dalsgaard used the physicality of the map and the tangibility of the artifacts to *provoke reflection*. They define the situations that *provoked reflection* as "instances where participants created situations that forced them to reflect on whether the current solutions were the best ones, or whether something else should be attempted" [p.671].
[8]

Dove et al. explored how data visualization, e.g. characters, game pieces, cards, etc., can be employed in creativity workshops to start

the creative process in participants to help them feel more engaged and able to collaborate [5]. Research conducted into different forms of data visualizations are explored below.

2.3.1 Cards for Information Visibility. Cards, used as physical artifacts, can be used as a basis for visual literacy. Raftopoulos describes the possibility of cards being an assistant in "creating an environment for better understanding the systems that are being designed and the user interactions and experiences that are being created"[p.1]. This is further corroborated by Nurain et al., who discovered the value in using various cards as a translational tool that aids in communication in between participants as well as between participants and facilitators [16]. Moreover, cards can also be used to help reduce tensions and disagreements between participants, because the cards depicts various aspects of the problem domain, even conflicting aspects, thereby visualizing different ideas and opinions. By having the cards contain different ideas and perspectives, each participant can form their own opinion, potentially derived from a card, and in visualizing the origin of the idea, any differences can be addressed as a result of different cards being used as inspiration and less as a personal wrongdoing.
[17]

Roy and Warren investigated the usage of card-based tools in a variety of use cases. In their investigation, Roy and Warren found that certain characteristics of card sets, specifically utilized in user research, are advantageous. The authors found that the main advantages of using cards were:

- the tangibility and movability of cards resulted in the artifacts becoming engaging
- cards concisely and simply explain information and practices
- cards can provide structure and facilitate conversation
- cards become a visual literacy tools between participants and facilitators

[19] Nurain et al. proposed design cards, a tool that functions as a translational tool for clearer communication between participants and facilitators from different backgrounds. By providing design cards, the facilitator aids the participants' understanding of the scope, offering more concrete information regarding specifics [16]. Similarly, Hilden et al. and Caraban et al. both propose various forms of cards to aid in ideation. Hilden et al. explores the purpose of Context Cards and how they can be employed in a workshop to help ideation in early design process workshops [9]. Caraban et al. present *The Nudge Deck*, a card deck used to visualize different ways to nudge preferred behaviors and the different factors that influence or are influenced by that type of nudging [4]. Lastly, Halskov and Dalsgård developed and presented the *Inspiration Card Workshop*, a collaborative approach to ideation that involves Domain Cards and Technology Cards, each depicting and explaining these two aspects of the research domain. With these cards, the participants collaborate to combine Domain and Technology Cards to generate ideas using various combinations of the cards provided [7]. The following subsubsection details how tangible artifacts, namely game pieces, can be used to further facilitate communication in PD.

2.3.2 The Tangibility of Games in Workshop Approaches. One approach to tangibly exploring research topics with stakeholders is through the utilization of serious boardgames. Gennari et al. reported on the development and implementation of a boardgame used to empower children as protagonists in co-design workshops [6]. Mora et al. found that board games can be translated into online games, where the authors define translation as "a process of arranging heterogeneous interests into a new order, thereby creating something new" [14]. Additionally, Mora et al. found that sitting together, be that around a game board or a large table-top computer, enhances collaboration and communication between the actors and that game pieces can be used as a means of interactivity [14].

Ullmer et al. developed the token+constraints framework, where tokens and constraints are mapped to develop a physical mapping of computational operations [14]. In their presentation of this framework, Ullmer et al. define tokens as physical objects that depict and represent digital information and constraints as "confining regions that are mapped to digital operations".
[23]

With this overview of the Related Work used to inspire and guide the work documented in this paper concluded, the following section explores how the workshop approach presented was designed and developed.

3 METHODOLOGY

The purpose of this Master's thesis is to develop a participatory design workshop approach that combines mapping, cards and 3D artifacts to provoke reflection with relevant stakeholders in research into the usage of drones and their applicability in critical infrastructure [8]. Furthermore, this approach is used as a communication tool based on mutual learning between relevant informants through the interaction with the workshop's physical elements. This is subsequently used to address various contentions that might arise in real world scenarios, e.g. if a power plant has two drones, and only one is charged, what actions should be prioritized and at what expense?. This section starts by detailing potential improvements to various aspects of the workshop protocol from the preliminary study. Afterwards, the redesigned workshop protocol and toolkit are presented.

3.1 Improvements from Preliminary Study Workshop Protocol

As previously mentioned, the work documented in this paper builds upon the workshop detailed in my preliminary study [12]. In relation to Bødker and Kyng's elements that ensures approaches leveraging PD matters, all five of the elements were respected [2]. The research field in the preliminary study was implementing drones in surveillance protocols at power plants in critical infrastructure, that must adapt alongside the dynamic fluctuations in national security. In the preliminary study workshop, five stakeholders at a power plant in Denmark participated to ensure that the proposed implementation of drones respected their current systems, approaches and protocols. As a result, these stakeholders were seen and included as major drivers in this change to surveillance. To ensure that the stakeholders were, and could be, major drivers, the two facilitators acted both as researchers, when planning the workshop, and activists, during the workshop, helping the participants use the

provided toolkit to map out and act out their current understandings of their workplace and the ideas generated throughout. As the facilitators acted as activists, this drove the cooperation between stakeholders and facilitators. Lastly, democratic interactions were supported in the dialogues and through the toolkit, because the dialogue kept building on the artifacts present and each person contributed their expertise which allowed the conversation to respect multiple aspects of the created reality.

Three words can be used to encompass the purpose, results, and approach of the workshop conducted as part of the preliminary study: co-creation, mutual learning, and reality confrontation. For the purposes of this paper, these three terms are defined below.

- Co-creation: the act of collaborating with other people present to make something. Essential in co-creation is the engagement of relevant stakeholders in a design process, because it focuses on developing something new or altered for some stakeholder involved in the design process; specifically aimed at driving collaboration and ensuring value generation and creation [25].
- Mutual learning: a process in which people of different work and educational backgrounds come together to learn from one another to develop a new and shared understanding of the reality with the problem domain that the PD activities focuses on [12, 18]. To facilitate mutual learning, it is important that the collaboration develops something concrete upon which the participants can interact and engage in mutual learning.
- Reality confrontation: the act of using representations of the problem domain to act out ideas or design within the limits of the reality in which they are supposed to be implemented. This is similar to *provoking reflection* from Hansen and Dalsgaard, which forced the participants to reflect upon their ideas within a mapped context [8]. Both of these force the participants to acknowledge and adapt to certain limitations discovered during the PD activities.

As a result of the workshop conducted in the preliminary study, reality confrontation was a cornerstone of that workshop. The importance of reality confrontation experienced in the preliminary study[12], also emphasized through *provoking reflection* by Hansen and Dalsgaard[8], is further iterated by Huybrechts et al.'s *facilitating risk taking*[11]. Huybrechts et al. developed the MAP-it approach, which this workshop approach is based on, with the main purpose of facilitating risk taking, for participants and facilitators alike, in participatory design [11]. The aforementioned three terms were used to guide the editing process of the workshop protocol and the redesign of the map, the cards, and the remaining artifacts. Based on the preliminary study, three necessary alterations were noted:

(1) **The flow of the workshop should be optimized:** the preliminary workshop flow presented four scenarios with little to no overlaps, meaning that the facilitators had to reset the map every time a scenario changed. Additionally, the participants discussed a wide variety of occurrences at the power plant, but these discussions overlapped multiple scenarios, making it difficult to register what scenarios had been implicitly addressed. To rectify this, the redesigned workshop protocol consists of five steps, where each step uses the mappings developed in previous steps to continue ideation within constraints and conditions previously imposed, rather than changing topic with each new scenario. The altered flow and subsequent workshop protocol is further detailed in subsection 3.2.

(2) **The artifacts should encourage the participants to interact:** A variety of artifacts were developed for the preliminary study, but the participants only interacted with a few of them. To increase the interaction with the artifacts, the new artifacts were designed to imitate game pieces from board games, in accordance with Mora et al.'s view of game pieces being means of interactivity [14]. All artifacts were made 3D, to make them appear similar to game pieces, as well as being color-coordinated; e.g. artifacts representing people and drones from the power plant were printed in light colored filament, and dangers representation artifacts were printed in red filament. Additionally, the artifacts are inspired by Ullmer et al.'s definition of tokens and the map is used as the constraints.

(3) **The cards should direct the conversation:** the cards developed for this iteration of the workshop toolkit are inspired by a variety of different cards, previously presented in subsubsection 2.3.1. The cards in this workshop have more information available as well as potential considerations, intended to make the cards feel less intimidating. Additionally, a designated space has been added to the map for the express placement and usage of the cards.

The main change to the workshop protocol presented in this paper in comparison to the preliminary study, is increased focus being placed on *act-it-out* elements within the workshop flow to facilitate visual literacy. Based on the aforementioned improvements, the refined workshop protocol and toolkit's development processes are detailed below.

3.2 Development of Workshop Protocol

With the redesign of the workshop protocol and toolkit, the following paragraph provides an overview of terms and definitions used for the remainder of this paper. The term *workshop protocol* refers to the the flow depicted in Figure 1 and each of the aforementioned steps. The term *toolkit* refers to the map, cards and other tangible artifacts provided for the participants to interact with. And lastly, the term *workshop approach* is used as a collective term encapsulating both the workshop protocol and the toolkit.

For the redesign of the workshop protocol, new focus is placed on the physicality of the workshop and building upon previous scenarios and discussions. The redesigned workshop protocol follows the 5 step Design Sprint proposed by Nurain et al. [16]. By following the 5 step Design Sprint, the workshop flow follows a structure that expands upon the previous steps, meaning that ideas and discussions that were previously expressed can form the foundation for continual designing. Additionally, by building upon previous steps, the participants continually reflect upon their ideas and redesign throughout, rather than just thinking about an idea once and having to restart their ideation process as a new scenario is proposed. Figure 1 shows the workshop flow proposed.

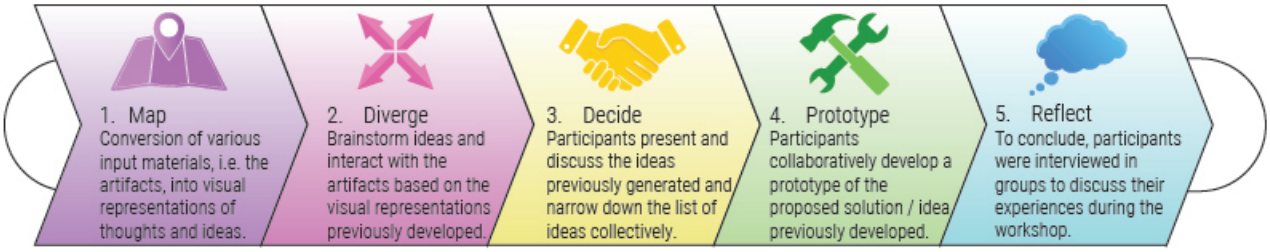

Figure 1: Workshop Flow Diagram inspired by Nurain et al. [16]

the following subsubsections further explore each step of the workshop, including the intentions behind each step, the intended usage of the artifacts provided, and the specific prompt presentation shown to the participants can be seen in Appendix A.

3.2.1 Step 1: Mapping. In the first step of the workshop, *Mapping* as seen in the purple section of Figure 1, the participants are asked to consider a day at the power plant in which no unusual actions occur. The first step asks participants to map drone behavior for normal surveillance, without looking for dangers or intruders, i.e. anything external that is not an everyday occurrence at the power plant.

While discussing *Everyday Drone Behavior*, the participants used artifacts to show their thinking. Once the conversations concluded, the participants were prompted to continue their conversation, while considering battery life, the number of drones available, the prioritization of drone tasks they had previously mentioned, and how their ideas would change based on various weather conditions. Once this is addressed, the participants progress to Step 2.

3.2.2 Step 2: Diverging. In Step 2, the participants are asked to explore their ideas from Step 1. In Figure 1, this step is represented by the pink section. For this workshop, this step specifically addresses various *what if* questions and how the discussed drone behaviors from Step 1 would be altered if and when these *What If* scenarios become real. In addition to talking and moving the artifacts around on the map, the participants are also asked to focus on the prompt cards to progress their conversation. This is intended to help unify the topic being discussed between participants.

The intention of this step is to challenge the participants' ideas with real-world scenarios that should be considered. Some other considerations that can be used to challenge the participants are: the levels of autonomy, human intervention, and types of hardware mounted onto the drones. Once a variety of *what if* are discussed, the participants are encouraged to proceed to Step 3.

3.2.3 Step 3: Deciding. After discussing usual drone behavior and alterations to this in various conditions, the participants proceed to Step 3. In Step 3, colored yellow in Figure 1, the participants are asked to agree upon a universal drone behavior protocol, based on their discussions and experiences in the two previous steps.

This step was included to help establish agreement between participants in how drones should behave in various circumstances and how this should change based on factors like threat level, number of drones, human involvement, etc.. This agreement is important to ensure that the participants understood each other during the previous steps, and any misunderstandings can be addressed before continuing.

3.2.4 Step 4: Prototyping. In this step, as seen in the green section of Figure 1, the participants are asked to *prototype* the decision they made in Step 3. In Nurain et al.'s approach, this step asked the participants to develop their ideas through sketching or physical prototyping, leading to the generation of a physical prototype [16]. In this approach, Step 4 tests the decided drone behavior using the toolkit to act out drone behavior when intruders are detected. Through this, the participants are asked to test, and thereby validate, their decisions with the toolkit prior to any real-world implementation. This step affords the participants the opportunities to see the possibilities and limitations of the protocol they had previously agreed upon as well as enacting any changes to the protocol before finalizing it.

The inclusion of this scenario in the workshop protocol, affords the participants an opportunity to consider a worst-case scenario and alter responses to ensure efficiency and compliance during emergencies. Once the participants have prototyped their drone behavior protocol, the physical part of the workshop is over, and they are led to the last step, Reflecting.

3.2.5 Step 5: Reflecting. In the final step of the workshop, shown in blue in Figure 1, the participants are debriefed from the workshop. This was done to help understand their experiences in the workshop, specifically when using the toolkit. This step also allows the participants to add any last thoughts regarding all of the workshop, not just what is addressed during each step. The four questions provided, see the blue slide in Appendix A, are used to facilitate the debrief, but the participants are encouraged to share their thoughts, regardless of the questions and the order in which they are presented.

During all five steps of this approach, various physical artifacts are available to the participants to help them in expressing their ideas, as documented by Dove et al. [5]. The development of the

artifacts included in the toolkit is detailed in the following subsection.

3.3 Development of Workshop Toolkit

The preliminary study focused on facilitating *Make* techniques as proposed by Sanders and Stappers. For the redesigned workshop toolkit, I focus on facilitating the *enacting-making-telling* model used for conceptualizing opportunities in design spaces [20, p.258]. In this model, facilitators and participants engage in an iterative process of collaborative co-creation to generate and develop ideas and concepts for use in the future to address a specified problem. The focus is on designing the proposed concepts rather than exploration, as is the case with say-do-make techniques.
[20]

To facilitate co-creation and visual literacy during all five steps, the participants were provided with a map and artifacts. They were asked to interact with these, by (re)placing and moving them around as they discussed their individual ideas and points of view on top of a map of the power plant. The map of the power plant can be seen in Figure 2.

Figure 2: A1 Map used in Workshop

As seen in Figure 2, on the right-hand side, three card slots are included to ensure a specific place for prompt cards. The prompt cards are 10.5 cm by 15 cm cards that show various aspects of the application domain, namely specific items or events at a power plant and various drone-related technologies. On the front, a title, an image, and a short description of the card can be seen. On the back, a more thorough description is found, alongside examples or instances in which this is relevant. Figure 3 shows an example of the prompt cards used during the workshop. The remainder of the cards used in the toolkit can be seen in Appendix B.

To depict the physicality of the application domain, 3D artifacts were developed, so that the participants could (re)arrange them on top of the map as their discussions progressed. To see the completed toolkit, please refer to Figure 4 in the following section.

With the artifacts developed, the workshop approach is evaluated with two user groups through two different workshops, one workshop including three drone implementation experts and one

Figure 3: Example of Prompt Cards. Left: Front, Right: Back

workshop with one drone researcher. The evaluation workshops are detailed in the following section.

4 EVALUATIONS

To evaluate the proposed workshop protocol and toolkit, I conducted two evaluations with different interest groups. The first evaluation workshop was conducted with a group of three drone experts, who work with the usage and implementation of drones in critical infrastructure. This interest group was included to test this approach with representatives of one of the groups that can use this workshop approach in their daily work. The second evaluation workshop was conducted with an expert in drone research. The participant for the second workshop was chosen to represent another group of professionals who can utilize this approach in their work, researchers who wish to involve relevant stakeholders who have less knowledge regarding drones than the facilitators. Both workshops were filmed to document the utilization of the toolkit and the conversations that ensued based on this. The facilitator also took notes throughout the workshop. Once the workshops were concluded, the collected data was analyzed following a deductive, thematic approach, in accordance with Braun & Clarke [3]. For the deductive analysis, I reviewed the collected video data and noted any instances of three terms from the previous workshop, becoming the three main themes from these workshops: co-creation, mutual learning, and reality confrontation. These instances were then transcribed to be used as documentation. The following subsections detail each workshop and the analysis resulting therefrom.

4.1 Workshop with Drone Experts

For the first evaluation of the workshop approach, I invited three drone experts to conduct the workshop with, denoted as DE1, DE2 and DE3 when referencing the specific participant. These three experts have previously worked with automatic drone monitoring at power plants and are therefore relevant stakeholders to evaluate with. Figure 4 shows how the workshop was setup prior to the arrival of the drone expert participants.

Figure 4: Setup of Workshop Toolkit utilized with Drone Experts

Figure 5: Drone Expert Interacting with Toolkit

The workshop followed the approach detailed in subsection 3.2, utilizing the toolkit detailed in subsection 3.3. The main benefit of the toolkit and workshop protocol experienced during this workshop was the dialogue it facilitated. We, the participants and the facilitator, all had the same medium for understanding, the visual literacy facilitated by the protocol and toolkit, helping us converse and reach agreements. As previously mentioned, the three themes used for this analysis were: co-creation, mutual learning, and reality confrontation. The participants were Danish-speakers, and the workshop was therefore conducted in Danish. Therefore, any direct quote used in this paper was translated by the author, with emphasis on translating the meaning of the sentence rather than a word-for-word transcription. The following subsubsections detail how various instances of these themes were encountered during this workshop.

4.1.1 Co-creation With Experts: This workshop centered around the co-creation of a map artifact that depicted how drones could and should behave if used to autonomously surveil a power plant in Denmark, different from the one researched in the preliminary study. By using the toolkit, we, the participants and the facilitator, were able to make a concrete agreement about how the map of the power plant could be sectioned and how the drones should and could act in each section of the map, see Figure 5. As seen in Figure 5, DE1 interacts with the toolkit by drawing outlines on the map during the conversation. As a result of this drawing, we discussed applications of drones in the specified area, in this case, an area with fuel stacks and construction. After DE1 had finished outlining a section on the map, I attempted to summarize the idea the participant had proposed.

> "But this here [a drone] would be a two-for-one that would both need to keep an eye on whether people are wearing the right things and some monitoring of heat signatures? - Facilitator
> "Yes, it is because the two areas are laying right on top of one another" -DE1

Having the map toolkit, we were able to create a shared understanding of the application domain and a specific task that a drone could maintain. In the instance showed in the quote above, a single drone would be used to surveil person safety and heat monitoring when deployed to fly over the fuel stacks, which were drawn into its own section on the map. By having the map available, we collaborated to create a new way of monitoring the people and actions around fuel stacks specifically, in a way that had previously not been considered. Having our conversation and moving the artifacts around the map, we were able to easily address various aspects of implementing drones at a power plant, as well as learn from one another's perspectives.

> "And then these charging stations would be running on their own?" (Facilitator)
> "Yes, if it is not running on its own, then we need a central point, where they all would need to fly to and that would just make it really problematic if we want a lot of uptime. We can have a control point where a man would stand and change the batteries manually, but then you should probably say that you only send them [the drones] out once every two hours." (DE1)
> "Yes, then there would be new restrictions on how the drones are flown and how surveillance is conducted" (Facilitator)
> "Exactly" (DE1)

In this reciprocal conversation, we an agreement between two parts that both utilized the same toolkit to explain their ideas, concepts and practices. By working through the workshop protocol with the provided toolkit, we were able to create a new and shared understanding of how drones could be implemented for surveillance at the power plant, while considering specific requirements and limitations specific to this power plant.

4.1.2 Mutual learning With Experts: Another purpose of the workshop approach was to facilitate mutual learning between drone experts and other stakeholders who were involved in the process of implementing drones in surveillance at power plants, but without expert knowledge of drones and their capabilities. By interacting with the toolkit while discussing, the participants expressed that they had an easier time clearly explaining drone implementation and tasks to me, the facilitator, who is less knowledgeable regarding drones. An example of improved clarity occurred When discussing the possibilities of drones and potential attached hardware. The conversation transitioned towards the topic of hardware possibilities;

what types of hardware can be mounted on a drone and how many sensors and cameras can one drone carry. When asked about the number of sensors that could be placed on a drone, the participants answered "unbelievably many... for example, ours [our drone] had both a multi-spectral camera and a normal camera" (DE1). By initiating the discussion of how many possible drone implementations were present, I gained an understanding of how many changes could be made to ensure that the deployed drones were useful in the context in which they were used. Reciprocally, the participants learned to clearly communicate with other stakeholders that had less technological knowledge, and addressing any knowledge gaps.

By using the toolkit, the participants expressed that they could teach me about drones, their possibilities, and how they could be implemented in a manner that made sense for their understanding of the strengths and weaknesses seen at the power plant.

> "It might look nice and manageable with the map like this and this big drone here, but it is larger than one would expect... If we take the case over there [pointing at the section with fuel stacks], if you want to properly know and to properly inspect what they [the personnel] are wearing, then it won't do much if you have a drone flying 100 meters in the air. Because you might see the site faster, but you won't see what you need to see." DE1

By having the concrete representations of the application domain, even if the size comparisons were not true to reality, it helped the participants explain various roles and considerations when using drones at this specific power plant. In return, I was able to introduce the participants to this workshop approach, which facilitates the discovery of new ways to communicate with the necessary stakeholders in a clear and concise manner, afforded by the visual literacy derived from this approach.

Another instance of the workshop protocol and toolkit establishing mutual learning, was seen when the participants experienced unexpected disagreement regarding a scenario proposed. In this instance, the participants were asked whether they saw greater benefit in having more drone or more charging stations in relation to one another, to facilitate increased up time of the deployed drones. During this conversation, the participants experienced some disagreement regarding which solution seemed most ideal, with two participants agreeing that more drones and fewer charging points was beneficial, and the last participant believed that more charging stations and fewer drones would result in increased, total up-time of the drones.

> "... I would be on more drones, fewer charging stations" (DE3)
> "We would still need to teach someone how everything works, so what is easiest to get to work? No matter what, if a charging station completely breaks, and a drone also completely disintegrates; regardless, we need external contact. If it is small problems, what would then be easiest to fix, would it be a drone or a charging station? Regardless, we need to train someone, on site, to take care of the things... therefore, charging stations over drones." (DE3)
> "Well, I think more drones than charging stations because we will need to educate some kind of drone expert. Now you [DE3] say that you can create a system if something goes wrong with charging stations, but you can also do this for drones... [if we had infinite budget], then I would think that more drones are more optimal because of [increased speed] and more uptime. You would use less time on a drone scanning everything. In the perfect world, I would say more drones, fewer charging stations." (DE2)

Once this disagreement was expressed, the participants elaborated that they had implicitly expected to be in constant agreement through all scenarios and questions, but the toolkit and scenario had provided clarity into disagreements that had not previously been addressed, but were then discussed and an agreement was then reached. Another instance of slight disagreement arose when discussing whether a drone should fulfill one role or multiple roles.

> "So what do you all prefer? You said one drone, multiple roles [DE1]. You sounded a bit more convinced with one drone, one role and then we can dispatch [DE3]" (Facilitator)
> "I'm probably more for multiple roles, but that we are open to the idea of [other approaches] and then potentially doing it to allow for this." (DE3)
> ... "And what about you [DE2]? If you were *Lord of all the Power Plants*, what do you think would be most ideal?" (Facilitator)
> "One drone, multiple roles" (DE2)

The concrete nature of this approach helped the participants express and learn about their different thoughts, "when we talked about drones and charging stations, we disagreed with one another. Because we looked at this [the map] while talking, we realized we didn't agree, but we didn't expect to" (DE3). Through this discussion, an internal form of mutual learning was established, thus helping the participants avoid misunderstanding and confusion since this unexpected disagreement was addressed before it had the opportunity to escalate.

4.1.3 Reality confrontation With Experts: One of the main results from using this toolkit is the possibility to establish immediate reality confrontation between drone experts and other stakeholders. During the evaluation of the workshop approach, reality confrontation was also established. The main way reality confrontation was established during this workshop was through the tangibility of the provided toolkit. During the workshop, the tangibility of the workshop facilitated decision making for the participants with regards to prioritization of drone tasks, distribution of drones over Asnæsværket, the amount of autonomy the drones should function with, and how much human involvement or intervention could be reasonably expected. When asked about their thoughts on a standardized approach to surveillance at the power plant, the following conversation happened while moving artifacts around on the map and pointing to ensure we were talking about the same areas.

> "Maybe also a drone that does something else that can just go and check. Whereas I feel that, this area

over here [pointing at the section outlining the fuel stacks] there are the bio mass stacks, there are always people and traffic. There, we might want to have two at the very least, to have cover at all times " (DE3)
"To add a bit to what [DE3] said, then we should also remember that the batteries on the drones are also limited, so to maybe have a type of cycle where one drone checks and then goes back to charge and then another drone comes out. So to have this type of 24-7 coverage" (DE2)

By seeing a physical representation of their ideas, the participants expressed that the physicality helped in keeping the conversation as realistic as possible, and ensuring that the ideas and concepts developed were not only applicable in a utopian world. One way in which this was experienced was during our conversation regarding the number of drones at the power plant versus the number of drones in the air simultaneously.

"So, there are four [drones], but three in the air?" (Facilitator)
"Well, what would we prefer, do we want coverage or uptime?" (DE1)
"Well, I'm thinking, it is not a problem that they [the two drones in the section with fuel stacks] fly simultaneously; one is a bit like low altitude, keeping an eye on people and the other is more high altitude, like an overview. So they are never in danger of flying into one another" (DE3)
"Yes, we could also do that... the only problem is if one runs out of battery" (DE1)
"I don't think it is that critical that we need one to replace" (DE3)
"Alright, that is fair, you're right" (DE1)

By using the toolkit, the participants were able to make their conversations concrete and consider the exact arguments for and against using multiple drones and how these would collaborate. Another instance in which this was addressed, was when we discussed the installation of charging points at the power plant.

"If we were going to have this much [uptime], then we need an automatic charging system. Also because, if we say that the control center is here [pointing at the office buildings in the middle of the map]..." (DE1)
"I'll just add a marker for this" (Facilitator)
"Then we would end up using a lot of power just getting there [back to the charging point at the control center]" (DE3)
"That's just it. Then, we end up only flying for 20-30 minutes" (DE1)
"Then, maybe we could set up some drones port around, so that the ones [drones] in that zone have somewhere they can land and don't need to use 25% of their battery on flying to where they can actually recharge" (DE3)

In the quote above, the participants discussed how the battery life could influence the utilization of drones and how this could be remedied. This scenario confronted the participants with the real limitations of a drone's battery and how this must be considered to implement drones in a usable and sustainable manner.

By interacting with the toolkit, the participants were aided in generating a shared understanding of their individual ideas and collaborated to depict how this idea could be implemented for surveillance. Specifically, this approach helped the participants confront the realities of the drones at the power plant, but not just the ideal sides of drone implementation, also the limitations and trade-offs required to make this ideated version of drone implementation realistic and true-to-life. Through the participants' interaction with the toolkit, they were able to make concrete considerations regarding the reality of their ideas, and the subsequent limitations that these might face.

"Now that I'm thinking more about it, then I think it will almost be impossible to conduct the scan that checks the entire fence" (DE1)
"Then we would need multiple stops or something similar" (DE3)
"Well, we at least need to stop a couple of times. It might not be flying as much back and forth, but it needs to go around many places and then it might be far away from a control point where it runs out of battery. It might run out of battery over here [pointing at an area far away from the control point], then it needs to fly all the way back [to the control point], fly all the way back [to resume its designated flight path], and then it can take 20 meters more and then it needs to fly all the way back. This won't do" (DE1)
"Then, what do we do?" (Facilitator)
"Well, we can always add more drones" (DE3)
"But then, we would also need to add more charging points" (DE1)
"Most definitely, we can't just respect these [pointing at the drones closest to the central point]" (DE2)

In the quote above, the participants experienced the reality confrontation that this workshop approach was intended to provoke. By having something tangible to consider and respect, the participants were forced to reflect upon their ideas critically, from the perspective of physical tangibility. As such, they were confronted with the realities of implementing drones in surveillance on a large premises and what trade-offs must be considered to make their proposed solutions feasible.

4.1.4 Summary of Workshop With Drone Experts: To summarize the workshop with drone experts, the purpose of this workshop was to evaluate how conversations between drone experts, the participants, and other stakeholders, me as the facilitator, were guided and clarified using the proposed workshop protocol and toolkit. Overall, the experience of communication between people of different knowledge backgrounds was improved when compared to a simple conversation. This became evident when solving smaller conflicts between ideas proposed by the participants.

When conducting the workshop, the participants all interacted with the toolkit provided to help enact their ideas. One part of the toolkit that was not really utilized were the cards. A potential reason for this is because the participants placed more focus on engaging with the scenarios. For example, the physicality shown by the drone artifacts, in the air, was frequently utilized within a conversation, but the cards were used during conversations as a way to unify the topic discussed or as a way to address discrepancies between the supposed topic.

In this evaluation of the workshop approach, the participants expressed that this approach to drone research and mutual learning through conversation was made easier because there was a tangible way to communication. We used the conversations we had had throughout the workshop as an example in this evaluation, and the participants expressed that by having a medium for visual literacy, they found it easier to explain their ideas and their knowledge to me without our conversation and understandings being compromised by the difference in our knowledge levels.

4.2 Evaluation of Protocol with an Expert Drone Researcher

After the workshop evaluation was conducted with the drone experts, I conducted a second workshop to evaluate the same workshop protocol and toolkit with an expert in drone research. This workshop emphasized evaluating this approach in research and discovery contexts; rather than as a way to communicate with others, as was the emphasis of the previous workshop. In the second workshop, the participant was a visiting PhD student at Aalborg University, focusing on Human-Drone Interaction (HDI). We evaluated whether the workshop approach would be useful in research contexts, as well as it being a useful communication tool in critical infrastructure contexts.

To conduct this evaluation, the participant and the facilitator worked through the *Mapping* step from the workshop protocol, and briefly discussed variations from the *Diverge* step. For these steps, we discussed the proposed scenarios based on a map of the Aalborg University building we were in, as a way to gain familiarity with the toolkit. Additionally, neither the participant nor the facilitator had any hands-on knowledge of the power plant used in the previous workshop, and it was therefore decided that the workshop would start in an application domain that was familiar to both. Figure 6 shows the setup utilizing a map of the Aalborg University building.

Afterwards, we discussed the participant's experience, specifically focusing on interacting with the toolkit. Then, we worked through the *Prototyping* scenario as a way to interact with this approach once more. For this scenario, we interacted with the map that was used in the previous workshop, as a way to experience the workshop in the context of critical infrastructure and to visualize how larger groups of participants could work together with the toolkit to utilize visual literacy and establish mutual learning. Figure 7 shows the result of how we interacted with the map from the previous workshop and various elements from the toolkit.

To conclude this workshop, we discussed the participant's thoughts and ideas regarding this approach and if they were missing anything from the workshop protocol or toolkit. This workshop focused more

Figure 6: Map of Aalborg University Building Used for Workshop

Figure 7: Toolkit Setup After the Conclusion of Workshop with Expert Drone Researcher

the participant's preferences and ideas regarding the application and utilization of the workshop protocol and toolkit in his research into various aspects of HDI, when compared to the focus on actual usability and reality confrontation in the previous workshop.

4.2.1 Co-creation with Researcher: We started the workshop by discussing how drones could be implemented to surveil a building at Aalborg University. As previously mentioned, starting the workshop conversations in this lower-risk environment was done to familiarize ourselves with the toolkit and the application domain, prior to discussing more high-risk applications. The familiarity with the physical layout of the application area was a benefit experienced by the participants from the previous workshop, and was viewed and expressed as such, and I, therefore, attempted to replicate this. By starting with the more familiar map, we discussed drone surveillance with lower risks involved, which initiated the participant's interactions with the toolkit.

By creating this mapping of low-risk drone behavior, we were able to create a shared understanding of how this scenario could be realized. During this time, we also interacted with the toolkit to work through *what-if* scenarios, changing our original mapping to accommodate these new aspects of a reality that had not previously been discussed. Doing so, we realized that even though this

scenario was low-risk, the considerations that had to be made were still necessary and certain trade offs had to be considered, even in scenarios that were not seen as immediately pertinent. In having these discussions, we were able to start collaborating in our creative processes, as well as having universal conversations about ideas and realities as we encountered them through our conversations.

Once we had discussed how drones could be implemented in lower-risk environments, we proceeded to discuss how drones could be implemented at power plants. To ensure that the resulting conversations were realistic in terms of our knowledge of the power plant used in the previous workshop, we used the map from the previous workshop. By using the map that the drone experts had interacted with, we were able to utilize their knowledge of the power plant to structure our ideation with the map, e.g. using the sectioning drawn during the previous workshop to structure our conversation. Using the pre-defined limits already drawn on the map, we were able to discuss drone surveillance at a higher-risk location with more accuracy in terms of the physicality of the application domain. Afterwards, we were able to apply our ideas and collaborate to map and act out our ideas, even within an application domain that neither of us were familiar with. When asked if the participant felt that having the toolkit helped in facilitating our conversation, he responded "yes, it helps a lot. And, to have the elements to freely add conditions".

4.2.2 Mutual learning with Researcher: In working through the scenarios and the different risk-related instances, mutual learning was established as we talked about his expertise in HDI and my expertise in PD and the knowledge I had gained during the previous workshop. Although we facilitated some traditional mutual learning, the focus of this workshop was not to facilitate mutual learning by utilizing the workshop approach. The main purpose of this workshop was to evaluate how the aforementioned workshop approach could facilitate reality confrontation in research contexts. More specifically, the participant mostly expressed his thoughts and expertise in regards to the workshop approach, rather than the conversation being shaped by both of our expertise. We engaged in mutual learning, as previously mentioned, but it was not the main purpose of the workshop

One instance where the participant's expertise was used to shape the workshop approach's usage in research was through the design of the prompt cards. The participant suggested redesigning the prompt cards to depict various instances or occurrences that could happen at a power plant and then color-coding them in relation to the severity of the threat that the instance depicts; green cards being of low risk, yellow cards signifying increased risks that should be accounted for, and red cards signifying high-risk occurrences. The participant suggested using color-coded cards as a way to help ensure universal understanding of the scenario and of the severity thereof. By color-coding the prompt cards, we eliminate the discussions of how severe a case is and what factors contribute to this. It would become a medium for universal visual literacy, since multiple aspects of one type of artifact are predetermined by the designer and eliminate the ambiguity of these. In having this discussion, the participant was able to influence a part of a toolkit that could be used to conduct research, meaning that we conducted co-creation through mutual learning to develop this concept of color-coded cards based on severity of threat level.

4.2.3 Reality confrontation with Researcher: During the workshop, we discussed how this approach helps in shaping the conversation into a concrete depiction of an idea. In doing so, we removed the utopian and idealistic views of how drones can be implemented in critical infrastructure; as opposed to the conversations that are held during interviews, a comparison made by the participant. By actually having to test ideas and assumptions, this workshop approach forces participants to respect aspects of reality that could otherwise be neglected, e.g. what to do if all drones placed on the map are being used somehow and one is needed for an emergency. The participant has previous experience in conducting interviews with stakeholders, and in doing so, has experienced that simply talking, does not force people to confront aspects of reality that must be respected if the implementation of drones is to be applicable in the real world. By having tangible representations of the application domain, the participant faced the reality of their ideas and how these can be applicable based on the restrictions that were previously imposed on the map.

4.2.4 Summary of Workshop with Researcher: As a result of the evaluation of the workshop approach with an expert drone researcher, I learned how this approach can be useful for drone researchers who wish to conduct realistic stakeholder involvement when investigating HDI. In evaluating this workshop approach with a researcher, I gained insight into what PD approaches should emphasize and respect to be useful for the intended audience. To summarize the evaluation with the expert drone researcher, the workshop protocol was seen as a good way to structure a workshop, especially because each step is dependent on what was previously discussed and helps people consider an application domain that changes rapidly and can quickly become volatile. In having the steps and scenarios, the participants have something concrete to base their ideas and conversations on, ensuring that the gathered data respects the application domain. In relation to the toolkit, the participant expressed that he enjoyed having something tangible and realistic to use as a basis for our conversation. He expressed that he majoritively uses interviews when involving stakeholders in his research, and is currently missing a way to ensure that they are talking about the same thing. By having the toolkit, he had an easier time communicating because we were moving the artifacts around the map as our conversation developed. By having and interacting with the map, we had a continuous visual medium in which we could ensure we were talking about the same thing and if that was not the case, we could discuss disagreements or differences in understanding, where they came from and what the next steps are in both instances. Having a way to ensure agreement and open communication, the participant expressed that he had an easier time understanding different perspectives and in changing points of emphasis during the discussion, while ensuring that no one misunderstood the change in focus.

When asked if he missed something from the workshop protocol or toolkit, he mentioned two things. Firstly, the participant requested having color-coded prompt cards based on the severity and threat level of an instance depicted on the card. According to the participant, the color-coded cards would develop a universal

understanding of how severe an instance is and it would make task prioritization easier because the severity and threat level is clearly displayed. Secondly, the participant requested having tracing paper available as a way to propose drone flight patterns and areas that could then be removed in case it is not applicable throughout the entire workshop. Additionally, by having removable flight patterns and areas, the participant expressed the need to have the possibility to (re)move these, to help the participants feel more comfortable with drawing on top of the map, but without it being permanent.

With the evaluations complete, the following section discusses the results detailed in this section and compares them to the research outlined in section 2.

5 DISCUSSION

The work detailed in this paper, as well as the preliminary study, were developed in a year-long process, culminating in a Master's thesis. The result of the two studies is a communication tool, in the form of the workshop approach, that can be used by drone experts to clearly communicate with other stakeholders in high-risk application domains, affording them the opportunity to address contentions and real-world limitations prior to actual deployment. This section discusses the results gathered in this paper, compares them to the outlined research, as well as addressing the results in comparison to the three themes used to guide the development and evaluation of the workshop approach.

5.1 Comparing this Workshop with Preliminary Study

As previously mentioned, the work detailed in this paper builds upon a preliminary study conducted within the same field [12]. To summarize, in the preliminary study, I conducted a co-design workshop with drone novices to ideate how drones can be implemented at a power plant in Copenhagen, Denmark. The participants consisted of two security personnel members and three innovation consultants, all drone novices. During this workshop, we focused on the different nuances that implementing drones in a security protocol gave rise to, as well as collaborating to ensure that the designed behaviors and ideas respected both of the interest groups that the participants represented. This workshop setup was opportune when working with drone novices to gain an understanding of how specific drone behaviors could and should be implemented at their specific power plant. However, the resulting behaviors and preferences were only representative of that power plant and the results cannot be transferred to other power plants or other sectors of critical infrastructure without being re-validated and tested. Rather than proposing a workshop approach only usable with drone novices to design certain drone behaviors, I have expanded on this research in this paper.

In the refined workshop protocol and toolkit proposed in this paper, the intention is to provide drone experts with a specific approach to conducting PD, specifically co-design, with other stakeholders that focuses on the realism of implementing drones in their security protocols. This is accomplished through co-creation [25] and mutual learning [18], synthesized to facilitate reality confrontation. To conduct a workshop using the protocol and toolkit proposed, specifically using co-creation, the drone expert, seen as the facilitator for future use cases, works through the five steps, Mapping, Diverging, Deciding, Prototyping, and Reflecting, with participants while collaborating, conversing and altering to create a shared map. In working together to create this map through the five steps, co-creation is established. In addition to this, by following this intent and approach, mutual learning is also facilitated because each participant and facilitator bring their own expertise to the workshop and that expertise shapes their ideas and concerns when interacting with the map and the rest of the toolkit in response to the proposed scenario.

Each step after the first builds upon the work completed in the previous step, following the framework proposed by Nurain et al. [16]. This provides an opportunity to challenge the participants, to facilitate continuous consideration of their ideas from multiple perspectives, while also altering the focus of the conversation as the workshop progresses. This is a significant change from the workshop in the preliminary study [12]. In the preliminary study, each scenario was treated as a separate instance, meaning that the ideas proposed in earlier scenarios were not utilized to challenge and shape ideas proposed later on. This did not facilitate continuous reality confrontation as is the intention of this updated workshop approach.

Another change made to the workshop protocol and toolkit proposed in this paper compared to the workshop protocol and toolkit used in the preliminary study is the focus shift from using *Make* techniques to using *Enacting-Making-Telling* techniques as proposed by Sanders and Stappers [20]. In this iteration of the design of the workshop approach, the focus was on establishing the iterative cycle of *Enacting-Making-Telling*. We started by talking about the scenarios and our ideas. Then, we proceeded to utilize the toolkit and made a 3D depiction of our ideas and then we used this depiction to enact our ideas and visualize the application domain in which our ideas would reside. In the preliminary study, we focused solely on *Make* techniques when developing the workshop protocol and subsequent toolkit, which did not block off a specific time frame for the participants to discuss their ideas, which resulted in minimal interaction with the developed artifacts and a mostly spoken back-and-forth conversation inbetween the participants as well as with the facilitators. During these conversations, I encountered some disagreements and misunderstandings and, therefore, wanted to redesign the workshop approach to help encourage interaction and conversation simultaneously.

5.2 Interactions with the Tangible Physical Depictions of the Application Domain to facilitate PD

Drawing on well established PD principles [6, 8, 14, 18, 25], I developed this workshop approach as a communication tool. The workshop approach consists of a workshop protocol, inspired by Nurain et al.[16], and a toolkit of maps, various 3D artifacts and tokens, to depict various aspects of the application domain and the scenarios. This was inspired by Gennari et al. and Mora et al., both papers detail how using board games and board game pieces to help visualize the application domain and to make this more concrete through this visualization [6, 14].

All of these parts of the toolkit were also seen as data visualizations, something tangible depicting occurrences within the application domain. This was inspired by Dove et al. who proposed using data visualizations as starting points for the participants' creative processes [5]. The inclusions of data visualizations was also prompted by the experienced hesitation to interact with the toolkit during the workshop in the preliminary study. In this redesign, I aimed to rectify this by restructuring the workshop protocol to focus on the toolkit and the created designs. Additionally, I developed more artifacts and re-colored them to help participants in visualizing more aspects of the application domain, not just the people and drones from the preliminary study.

This alteration in making more artifacts that depicted multiple aspects of the application domain was inspired by Hansen and Dalsgaard, who used participant-made characters to help visualize the interior of a library as well as any alternations or location changes proposed during their workshop [8]. In addition to the increased number of embodied artifacts, I developed 3D tokens to help the participants in visualizing the application domain, as well as all changes, alerts and dangers therein. This was inspired by the work conducted by Ullmer et al., but rather than using tokens as representations of something computational, I used tokens as markers and alerts to bring the scenarios and instances to life on the map as they emerged in conversation [23].

Additionally, I designed prompt cards as another medium of data visualization. The cards were redesigned from the preliminary study because, as mentioned above, the participants were hesitant to interact with the entire toolkit, including the cards. These cards from the preliminary study were heavily inspired by the Domain Cards presented by Halskov & Dalsgaard [7]. The designed cards had a title, an image and a brief description. They were not used in the preliminary study. In an attempt to involve the cards more, both in terms of more focus being placed on them as well as increased participant interaction, the cards were redesigned into prompt cards for this iteration of the redesign of the workshop approach. The new prompt cards, see Figure 3, were inspired by different types of cards used in various types of workshops [4, 9, 17, 19]. By combining various aspects of the cards presented in the aforementioned papers, I developed the prompt cards that helped frame the conversations in the workshops detailed in this paper. The redesigned cards were used more during the workshops, but there is still room for improvement, i.e. restructuring the workshop protocol to revolve around the cards, to ensure that the provided instances, actors, hardware, etc. were used to structure and aid in ideation.

5.3 Interactions Shaping and Facilitating Reality Confrontation

The main purpose of the toolkit was to facilitate reality confrontation through visual literacy between drone experts and other stakeholders. By acting out ideas and being confronted by limitations present in the real-world, the participants were forced to reflect and consider their ideas before implementing them. This is reminiscent of Hansen and Dalsgaard's *provoking reflection*, where they hosted a workshop that used maps and characters to explore possibilities at a library, while reflecting upon their proposed ideas to ensure they were feasible on the map [8]. Additionally, by making conversations concrete through the usage of maps, we can facilitate mutual learning, because mutual learning requires the application domain to be concrete, which is not always ensured. But, by developing a tool that makes conversations concrete, mutual learning arises therefrom. In this, a medium of visual literacy was also developed, as it aids people of different backgrounds in having a clear conversation regarding the application domain while minimizing confusions or misunderstandings because all parts are interacting and looking at the same physical setup. This allows them to show their ideas rather than depending solely on verbal communication.
[13, 21]

Agrawal et al., Hoang et al., Huybrechts et al., and Wojciechowska et al. all detail various workshops that utilize mapping as a tool to facilitate visual literacy to help stakeholders communicate with one another within the same application domain [1, 10, 11, 24]. All four of the aforementioned papers specifically use mapping as a tool to facilitate visual literacy, which inspired the development of the workshop approach presented in this paper. The following section details the limitations that influenced this paper and ideas for future work that can be conducted to further expand upon this workshop approach.

6 LIMITATIONS AND FUTURE WORKS

While this research demonstrates the potential of a scenario-based participatory design workshop protocol and toolkit to support communication between drone experts and stakeholders in critical infrastructure, several limitations influenced the development of the workshop approach.

First, the study was constrained by the challenge of engaging with an external collaboration partner from the critical infrastructure domain. This target group is difficult to gain access to, and certain collaborations were not planned. As a result of this, the participants in the evaluations were not stakeholders from a power plant, but rather expert drone users at Aalborg University. This limited the extent to which real-world stakeholders could be integrated into the evaluation process.

Second, the workshop protocol and toolkit were specifically tailored to support drone experts in facilitating participatory design processes. While the approach shows promise for bridging communication gaps and fostering shared understanding, its current design focuses heavily on drone-specific scenarios, tools, and terminologies. As such, adapting this approach, as a communication tool, to other application domains or broader stakeholder groups would require additional tailoring and subsequent testing to ensure relevance and effectiveness.

Finally, the evaluation setup of the protocol flipped the intended facilitator-participant relationship: as a drone novice, I served as the facilitator while drone experts acted as participants. Although this inversion allowed for valuable testing of the toolkit's clarity and usability, it also shifted the perspective from an expert-led facilitation approach to one that discussed envisioned usage, as it was led by an interaction designer rather than a drone expert. Future studies should investigate the protocol's effectiveness when implemented by drone experts in situ at a power plant or other essential locations within critical infrastructure to fully validate its intended use.

7 CONCLUSION

This research has demonstrated how a scenario-based participatory design (PD) workshop protocol, supported by a domain-specific toolkit, can effectively facilitate communication and collaboration between drone experts and stakeholders within critical infrastructure. By leveraging the tangible artifacts and structured workshop flow proposed in this study, drone experts can transcend traditional communication barriers, fostering shared understanding and mutual learning across diverse perspectives.

The unified approach presented here not only supports the co-creation of ideas regarding drone usage for surveillance that reflect real-world constraints but also confronts the complexities inherent in the application domain. Through iterative testing with both drone experts and drone researchers, this research highlights the importance of grounding design discussions in the physical realities of the application domain.

This work provides a practical and adaptable methodology that enables drone experts to engage stakeholders in meaningful and clear communication, ensuring that newly adopted technologies respect a variety of stakeholder interests, even in complex environments. By empowering drone experts to act as facilitators in participatory processes, this approach enhances the potential for usable, context-sensitive, and innovative ideation into the use of drone solutions that can adapt alongside the evolving challenges of critical infrastructure safety.

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