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Public libraries as a partner in digital innovation project: Designing a virtual reality experience to support digital literacy

Johanna Ylipulli [a,*], Matti Pouke [b], Nils Ehrenberg [c], Turkka Keinonen [c]

[a] Department of Computer Science, Aalto University, P.O. Box 15400, Espoo, FI-00076 Aalto, Finland
[b] Center for Ubiquitous Computing, University of Oulu, P.O. Box 4500, Oulu, FI-90014, Finland
[c] Department of Design, Aalto University, P.O. Box 11000, Espoo, FI-00076 Aalto, Finland

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ABSTRACT

We introduce a project titled as *Our Shared Virtual World* which aims at increasing public libraries' capability to provide knowledge on digital technology to general public. The practical goal of the project has been to produce a functional prototype of a virtual reality (VR) application that could be utilized freely in all the public libraries in Finland. In many countries worldwide, libraries' role is expanding from providers of traditional books to providers of information technologies and related new forms of literacy, and this development provides the broader backdrop for the project. The contribution of the article is two-fold: First, we describe how an immersive VR application can be collaboratively developed within this specific research context, namely within a network of public libraries, and introduce the tangible outcome of the project, the VR application called *Forest Elf*. Secondly, we scrutinize how results of such a design work can be sustained over time: through participatory design (PD), we aimed at creating conditions which would enable public libraries to continue developing and using the artefact also after the project. We provide insights on how to tackle the challenge of research prototypes ending up being abandoned, and what factors in the context of library partnership support or hamper sustainable digital innovation — digital innovation that is inclusive and equitable but also has a long-lasting impact.

1. Introduction

In this article, we introduce a research-through-design project aiming at developing an immersive virtual reality (VR) application for all the public libraries in Finland. The project titled as *Our Shared Virtual World* has been carried out as a collaboration with several public libraries and two universities, and it was launched in 2019. At the time of writing this article the main funding has already ended, but the process is still ongoing as several libraries are currently adopting the VR application for their uses. The practical aim of the development process has been to create an application that would be beneficial in libraries' activities targeted to general public and supporting lifelong learning, active citizenship, and different literacies, including digital literacy.

In recent years, scholars of different fields (HCI, design, STS) have become interested in public libraries as sites for studying socio-technical relationships. There exists a relatively novel body of work focusing, for example, on libraries' role in increasing digital literacy; library personnel as design participants; and libraries as nodes for technological empowerment [1–4]. As societal actors, public libraries intend to generate social good and reduce inequalities which makes them apt allies in *digital social innovation* (DSI) projects.

In Finland, libraries are perceived as respected and, at the same time, low-threshold cultural institutions and focal for democratic society. They act as centers of education, empowerment and equality [5], and they are relatively well-funded compared to many other Western countries. Before the covid-19 pandemic, the average number of library visits per inhabitant fluctuated annually between 9–10,3 [6]. Importantly, according to national legislation, libraries also need to provide services that enhance citizens' technological skills and digital literacy [4]. Therefore, public libraries are increasingly offering events and workshops about digital technology, covering basic digital skills and guidance. Other societal actors such as social services also actively tell people to seek help from libraries which sometimes puts a lot of strain on their services. [1,2,7]. More recently, libraries have started to offer also training and activities connected to emerging technologies such as robotics, 3D modeling and AI, and some libraries in the capital region have their own fab-labs (Fig. 1).

Thus, in order to support ICT research community's engagement in collaboration projects with public libraries, we intend to introduce the whole trajectory and the concrete result of our

* Corresponding author.
E-mail address: johanna.ylipulli@aalto.fi (J. Ylipulli).

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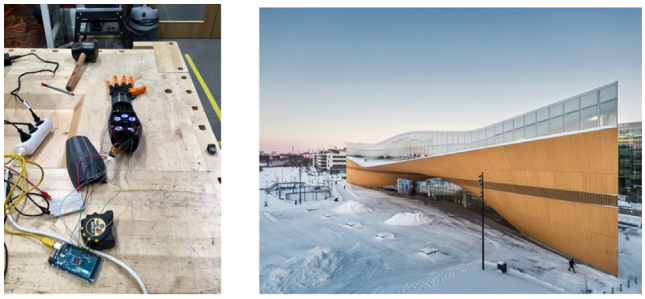

Fig. 1. Fab-lab at the Iso Omena library, Espoo, Finland (left). Central Library 'Oodi', located in Helsinki, Finland, was opened in 2018 and has a striking architectural design (right).
Image: Johanna Ylipulli and Kuvio.

project, the virtual reality application called *Forest Elf*. The overarching objective of our paper is to explore how public libraries can act as a collaboration partners in DSI projects, and how participatory design (PD) as an approach can work in such a process. We focus especially on describing and assessing how utilizing PD approach affected our decisions and specific design activities such as workshops, what kind of application was built based on the participatory activities, and how we attempted creating work that would last beyond the project.

The primary objective of the article is divided into two more specific goals that target two gaps in previous research: The research context (public libraries), approach (PD) and technology (immersive VR) provide a combination that has not been studied much before. Therefore, our work generates implications for other projects that focus on participatory design of VR or other emerging technologies in similar contexts. Further, in HCI literature the facet of participatory design that emphasizes sustaining work over time has received much less attention than field studies, workshops and prototyping [8]. However, creating lasting impact should be seen as a focal part of a PD process. The idea is to sustain project achievements (prototypes, practices, networks and/or platforms) through creating technical, organizational and/or social conditions that carry the results beyond fixed-term project work. Thus, we do not focus on evaluating the impact of the project or prototype on end-users (library patrons), but our focus is on conditions that unfold throughout the design process and that are prerequisites for broader adoption and broader impact. We consider this perspective focal for digital social innovation projects as it is difficult to gain broader, long-lasting societal impacts with digital innovation without considering how to sustain the work over time.

1.1. Related work: DSI, PD, and virtual libraries

In conjunction with the aforementioned efforts, libraries are becoming an important arena for devising initiatives for digital social innovation, DSI [9]. *Social innovation*, as we understand it, refers to innovating with social means to social ends; it is characterized by mobilizing social, shared intelligence embedded in society. It has also been defined as a new solution to social problem that creates value for society as a whole rather than for private individuals [10]. Hence, social innovation emphasizes granting the power to social networks, and recognizing the value of everyday experience and differing expertise, instead of following traditional market-based logics. Digital social innovation adds the aspect of digitalization and/or digital technologies to this framework. From a perspective of technology, DSI aims to reorient digital innovation to serve people's needs better and to empower people. Following the definition of Freire et al. [11], we consider that a digital social innovation is a novel ICT-based product, service or concept which is generated – or co-created – through new social collaboration and which can respond to certain social needs or even solve certain societal challenges in an efficient way. Our efforts can be mapped under the category of DSI as our project was intended to produce a new technological application *for* a civic community *with* a civic community in order to generate broader societal benefits. The project was commenced by one of the collaborating public libraries that also acted as the main applicant of the project funding. Further, it is important to note that throughout the process, we intended to follow the principles of participatory design (PD) which is a politically inclined design approach aimed at equalizing power relations, democratic practices, situation-based actions and mutual learning [12]. DSI and PD are overlapping in many ways: For example, Smith and Iversen [13] promote an "approach to participatory design as a sustainable practice of social change". This perspective very clearly resonates with DSI and with its focus on social good, highlighting sustainable nature of the change that is introduced through PD practices. There is considerable variation between PD processes applied in different design contexts, with some suggesting it is most easily viewed as a set of tools and techniques oriented towards engaging users in the development of better products [14]. Another approach is to look for commonalities between PD projects and to understand PD as a design platform for sharing experiences and for reflection and learning [15,16].

PD was the overarching approach in *Our Shared Virtual World* project. Initially, we set the goals together with the central non-academic stakeholders, i.e. with the library personnel, and throughout the process, the aim was to bring people with different kind of expertise together to create ideas jointly and also to develop and iterate them collaboratively. Blomberg and Karasti [17] define the central principles of PD as follows: the process must contain (1) respect for different knowledge, (2) opportunities for mutual learning, (3) joint negotiation of project goals, and (4) tools and processes to facilitate design. Overall, the goal of PD is to create better and more usable services, products, and concepts. Nevertheless, the principles entail also democratizing tendencies: one of the profound ideas of PD is that through processes of mutual learning non-technical participants gain insights into design processes, begin to understand the broader impacts of technology, and realize they have a choice what comes to future forms of technology. Moreover, researcher–designers gain crucial insights on use context and learn about the perspectives and values of the non-academic participants. Importantly, PD can be understood as a system of activities that are not only geared towards designing better products but towards generating long-lasting effects for participants [8].

PD has been utilized in library context before, for example, when designing e-services (library accounts) for public libraries [18] or when planning and designing new library spaces [19]. However, studies in which PD would have been used to produce a VR application for and with libraries are very rare. The study of Beheshti et al. [20] provides an early example; the authors utilized PD and non-immersive VR to develop a library-like search interface for children. Another example is the article by Pouke et al. [21] in which the authors describe an implementation utilizing contemporary immersive VR hardware. Although PD was utilized, the authors did not analyze the entire trajectory of the PD process but focused on analyzing the workshop approach [22] and the structure of the prototype [21].

Several other implementations exist where VR has been introduced to a library context; however, in these cases, the design process has not been the focus of the study. An early example of an immersive VR representation of a library was presented by Das Neves and Fox [23]. In this study, users were able to

navigate and search books in a traditional library environment using a CAVE system [24]; the purpose of the implementation was to study user search strategies when using clustering techniques and highlighting [23]. Similarly, the work of Borner [25] utilized a CAVE for navigating documents in a digital library, however, without any visual representation of the library space itself. Garau et al. [26] used a VR library as a setting for studying place illusion and co-presence [27]; in this case, the library provided a natural setting for investigating responses to virtual agents without the need to engage in verbal interaction. In addition to the examples above, some works utilized various 3D representations of libraries without immersive technologies. For example, Quake 2 engine was used to provide a game-like environment for a library to attract teenagers [28]. The aforementioned implementation by Beheshti et al. utilized non-immersive VR as well [20]. In addition, the Second Life multi-user Virtual World contained virtual libraries as well as librarians, as reported by Hill and Lee [29].

As can be seen, previous immersive VR applications depicting libraries were mostly developed for the purposes of research experiments, whereas some implementations utilizing traditional display systems have been developed for more library-related purposes, such as multi-user library-like VEs, or to introduce libraries for children using video game technology. We were able to find only two studies specifically focusing on the design process of VR library implementations. In addition, many VR library applications found in the academic literature are one or several decades old, highlighting the importance of developing new design approaches for this area. Moreover, while various VR applications, in general, have embraced VRs inherent possibility to distance oneself from physical reality, most of culture-related VR implementations in academia still appear to focus on the simulation of physical sites [30].

In addition to providing practical insights on how PD can be utilized in designing immersive VR for library context, our article aims at increasing understanding on how long-term impacts and sustainability of PD projects and produced artefacts could be increased, and what are the specific challenges and opportunities that we faced regarding this. This dimension of PD process has received significantly less attention in HCI than field studies and prototyping [8]. In PD literature it is referred to as *participatory infrastructuring* [31] which means establishing collaboratively social, organizational, and technical conditions which will enable sustaining the outcomes of the project. In previous research, participatory infrastructuring has been discussed, for example, in terms of creating open and adaptable technical platforms [8], and strong official and unofficial social networks [32]. Overall, participatory infrastructuring unfolds throughout the PD process, and cannot be described as a separate phase. It is also focal to note that we consider it as a different issue than the impact of the project, even though these two are connected [33]: without ensuring the sustainability of the project, especially long-term impact can remain on a superficial level. In the analysis and discussion sections we describe how we aimed at creating arrangements for sustaining the work over time within different phases of the project, and what factors connected particularly to library collaboration supported or hampered this endeavor. Evaluating the impact of the project on end-users will be part of future studies.

1.2. Research context: Finnish libraries and digital transformation

The objectives of the public libraries in Finland are set in the current Public Libraries Act (1492/2016) which became into effect in 2017 [34]:

(1) The objectives of this Act are to promote:

1. *equal opportunities for everyone to access education and culture;*
2. *availability and use of information;*
3. *reading culture and versatile literacy skills;*
4. *opportunities for lifelong learning and competence development;*
5. *active citizenship, democracy, and freedom of expression.*

The implementation of these objectives is based on sense of community, pluralism, and cultural diversity.

The library objectives are very much in line especially with *Sustainable Development Goal* (SDG) no 4, which focuses on inclusive and equitable quality education, and on promoting lifelong learning opportunities for all. In addition, the objectives also resonate with SDG 10 focusing on reducing inequality within and among countries, including the target 10.3.: "By 2030, empower and promote the social, economic and political inclusion of all, irrespective of age, sex, disability, race, ethnicity, origin, religion or economic or other status" [35]. Further, *Our Shared Virtual World* project must be seen in the light of the goals stated in the Public Libraries Act. In the broadest sense, libraries' goal is to provide *empowering encounters* [36,37] with new technology to all citizens. This, in turn, can support several objectives defined above, including versatile literacy skills and active citizenship [4, 38]. It is difficult, if not impossible to be an active and critical member of contemporary society without having adequate knowledge on digital technologies as technology has became such an ubiquitous part of everyday life. Versatile literacy skills include digital literacy which should be understood in this context in a very broad sense, covering also awareness of technologies' impact on society and knowledge on their possibilities, limitations and challenges. Thus, the focus of the *Our Shared Virtual World* project has not been to provide particular library services through VR but to create a versatile VR experience that could be used in library contexts with different groups of people and for differing purposes.

In recent years, several Finnish libraries have been experimenting with immersive VR with the aim of offering library patrons of all ages and backgrounds a chance to experience this new media in a form that is connected to library context. VR represents one of the relatively expensive emerging technologies and everybody cannot afford to have gear needed to experience virtual worlds. On the other hand, it is one of the enablers of the much-hyped metaverse. Some libraries have utilized existing VR applications or commercial games and offered some groups a possibility to try them out, but a few libraries have also created their own applications in collaboration with research institutions or companies. These experiments have been quite heterogeneous, but usually their intention has been to connect immersive virtual environments and literature, for example by reconstructing a scene from a novel or by building virtual environments that resemble certain literary genres (such as science fiction, fantasy). However, it is not very cost-efficient or sensible that every library intends to create their own VR application from scratch; therefore, an initiative aiming at building a common VR experience for all the libraries was established. The fundamental idea of the previous VR library experiments as well as *Our Shared Virtual World* is that the produced application could be freely used at the library premises. Another central goal is that it would be a useful tool in different kinds of events, workshops and gatherings arranged by public libraries.

Previous VR experiments carried out in library context provided a loose network, consisting of library staff and researcher–designers, who held knowledge and experience on the subject. This previous experience as well as the unofficial social network was very valuable when we planned the new broader project,

and we discuss in Section 2 how we used this previous knowledge. *Our Shared Virtual World* differs from previous experiments especially due to its scale: the previous VR applications built for library context have been usually located within one library but here we intended to create a shared VR environment for all the public libraries. Thus, the potential number of end-users (library patrons) was large and their needs diverse, and to reflect this diversity, also the pool of design participants (library personnel) was significantly broader compared to previous, local experiments. *Our Shared Virtual World* involved public libraries from four different Cities in the capital region of Finland, located in the south (Helsinki, Espoo, Vantaa, Kauniainen), as well as the Oulu City library, located in the north of Finland. Furthermore, two different universities, Aalto University and University of Oulu and their researchers have been involved. The project received funding from the Regional State Administrative Agency for Southern Finland. The fact that the main funding was applied by and granted for public libraries, has made the project library-led. Some tasks performed by the researchers were covered with the Regional State Administrative funding. Additionally, the project was linked thematically with the universities' other ongoing projects and research tracks to allow the researchers to allocate more time for collaboration. The main role of the university researcher–designers was to provide expertise on PD and facilitate the multi-stakeholder workshops, and they were also in charge of technical development of the application.

1.3. Methods and materials

The researchers participating in the project have their backgrounds in HCI, anthropology of technology, computer science and design. We have carried out research collaboration with public libraries already for a long time due to the societal role they have in digital transformation in Finland and in other Nordic countries [39]. This article is mainly based on *design reflection*, through which we look back at the whole process critically in order to learn and improve similar future processes. If such a reflection is conducted during the process, it can also steer the design towards a favorable direction. Design reflection is an established method in design fields [40], and for example, according to Reymen and Hammer [41], *Reflection on a design process is thus defined as a combination of reflection on the perceived design situation and reflection on the remembered design activities.* To clarify, a design situation refers to a certain moment in time; design process is the collection of these situations. The structured reflection process consists of asking a set of relevant questions; next, following Reymen and Hammer [41], *relevant facts are transformed into an image, which is then analyzed to come to answers to the initial questions*. The 'image' does not necessarily refer to an visual image, rather it is a mental image reflecting the design actions and their context as they were experienced. Thus, the design process as a whole, including all the recorded research materials from the PD workshops and user tests but also less structured material such as notes, discussions and meetings, act as our research data.

Further, to complement our researcher–designer perspective, we also analyze two interviews conducted with library staff members who participated in the project. These interviews were conducted as semi-structured interviews [42] by two researchers not directly involved in *Our Shared Virtual World*: this helped to avoid biased views. The interviews took 60 min each and were conducted online. The recordings were transcribed and analyzed to consider what challenges libraries may face when engaged in digital innovation together with researchers.

The rest of the article is structured to reflect the typical phases of a PD project, usually consisting of (A) field studies, (B) prototyping, and (C) implementation. We explain the practical steps taken and reflect our choices on the PD literature. To start with, the challenges that we needed to respond to when launching the project were (1) choosing the hardware, (2) responding to libraries' varying needs, and (3) responding to peoples' varying needs. The initial phase, which entailed co-creation of the ideas and preliminary concepts for the application, was followed by prototyping and development of the technology — and at the same time, the period when the covid-19 pandemic seriously affected our process. Thus, the pandemic appears as the singular main challenge in the middle part of the process. The adoption of the developed technology is currently ongoing but we already can trace and reflect on the multiple challenges connected to the implementation phase, including (1) technical support, (2) future development, (3) diversity of the users and uses, and (4) broader adoption. In concluding remarks, we highlight the main lessons learnt, especially in relation to sustaining work over time, and discuss how such a public library-led innovation project utilizing PD as an approach can respond to SDGs.

2. Field studies: Technical, organizational and end-user related questions

We began the project by having meetings and negotiations that brought together partners from different libraries and universities. The aim was to take into account the lessons learned in previous VR experiments and to discuss what it means to create a shared VR application that would work within different library contexts and with different users.

2.1. Technological performance or functionality?

The initial technical challenge we had was connected to choosing the hardware. After lengthy discussions between researchers and library personnel, we chose Oculus Quest as the target hardware for our project. Technically, it delimited the scope of our work quite dramatically since performance capabilities of Oculus Quest and similar standalone devices are limited compared to their tethered counterparts, which are limited only by the computer in which they are attached to. One of the ideas we explored in the beginning was that would it be possible to somehow integrate the previous Virtual Library prototypes with the new construct; the idea was that users could seamlessly transport themselves between various Virtual Libraries using the now-developed prototype as a hub. We did not investigate the technical implementation of this idea very far, though, since the choice of VR hardware already dictated that this type of integration would require more work than what we had resources for as the previous prototypes were not built for Oculus Quest. Furthermore, focusing on Quest, we had to pay significantly more attention to performance issues in terms of asset fidelity and level design compared to if we would have utilized tethered devices.

Our collaborators at libraries, however, considered that the resulting loss in compatibility and graphics fidelity was acceptable since standalone devices were simply so much more convenient in a public library context. Furthermore, we anticipated that in the future, perhaps the performance gap between standalone and tethered content would narrow. In the end, it was decided that the project would be developed as a room-scale VR experience in the Unity Game Engine, with Oculus Quest as its target hardware. Furthermore, narrative experience and overall usability was soon emphasized as the most important factors of the software. These negotiations resonate with the classical notions of Neumann and Star [43]: they discussed about different object worlds present in (participatory) design processes — designers and developers may be fascinated by the capacity of technologies but other design participants opt for more functional and convenient technology.

2.2. Designing for libraries' varying needs

Our second initial challenge was connected to the design context. In other words, we needed to decide how to create an application that would enable enough freedom and that would be flexible enough to appeal different libraries. We already knew we are designing for a set of very different libraries and all of them may not be interested in our initiative; they ranged from fancy flagship libraries such as Helsinki's Oodi (Fig. 1 right) to tiny branch libraries located in modest spaces in suburbs. Furthermore, library staff members pointed out early in the process the independent character of libraries, including both main libraries and smaller branch libraries. Even though libraries form networks, each library is also a very independent actor and conventionally they have had much freedom in developing their activities and events. The library partners of *Our Shared Virtual World* feared that these independently acting library units would not adopt a technical application and related activities developed by somebody else. This insiders' knowledge on Finnish library culture was, of course, highly valuable to us.

To tackle this challenge, we made several initial decisions with the library partners. First of all, we decided that the appearance of the Shared VR World must be chosen so that it is general enough and does not resemble any existing library. *Simulation* is a design choice often made when developing VR for public knowledge institutions due to VR's capability to generate a place illusion. This can be very useful when reconstructing historical sites with museums, for example [44], and it has been used also in some projects developing VR for libraries [5,23]. However, we opted for a different approach as it was deemed that simulating a certain existing library building would not make the application attractive to the rest of the libraries. Secondly, we decided that the application must be extendable in a sense that different libraries can freely develop it further, if they wish to do so — and this must be taken into account both in the visual appearance and in technological choices. Related to this decision we settled that the code must be as open as possible so that the libraries can continue developing the VR application after the project.

As the process moved forward, we discussed the appearance of the VR application further; we leaned on the knowledge gathered on previous VR experiments carried out in library context and decided to use *forest* both as a metaphor and visual reference point for the application. In other words, we decided that the Shared VR World will take the form of a forest. The previous projects had clearly demonstrated that users were enticed by elements from nature or complete environments resembling nature [21,22]. Our common, everyday understanding of forests' important role in Finnish peoples' collective imagination supported this choice [45]. We also knew, based on our previous co-creation experiments in library context, that VR library does not necessarily need to resemble a library building or premises but the relationship between physical space and virtual space can be more metaphorical [46].

2.3. Designing for peoples' varying needs

In addition to paying attention to different libraries' needs, we also needed to ponder how to make the application work for different kinds of people. This was our second challenge connected to the design context. We knew very well that 'the user as everybody' [47] is not a very good starting point for design and development of new technology, as peoples' skills, interests and life-worlds in general vary drastically. One of the challenges connected to this aspect was the fact that the age and digital skills of our prospective users would vary significantly because libraries wanted to be able to use the application with different kinds of people, from teenagers to elderly and from native Finnish speakers to immigrants. Thus, we needed to ponder how to create an application that would not be too complicated nor too simple.

Fig. 2. Visual representations of the 'preliminary concepts' for the Shared Virtual World, created in the workshops.
Images: Johanna Ylipulli.

We decided to draw from typical PD methods and hoped that *multi-stakeholder workshops* combining the expertise of library patrons, library staff and researchers working in the project would do the trick. Consequently, we arranged two workshops in different parts of the country bringing together adult library patrons, library staff and VR and design experts (24 + 11 participants). Furthermore, we arranged one workshop for teenagers and their teachers in Helsinki (25 participants). Adult participants were recruited with an open call that was spread broadly through libraries' webpages, newsletters and mailing lists. The workshops were facilitated by Aalto University researcher-designer, and members of the technical development team and a designer from University of Oulu also participated, as well as part of the libraries' project team. This resulted in a heterogeneous group of people: from retirees to students; from library staff to library patrons; and from VR specialists to complete novices. The workshop for teenagers was arranged as libraries would like to be more enticing places for this age group particularly. This last workshop had also participants with immigrant background and from a linguistic minority.

The workshops lasted for half a day and consisted mainly of group work; the basic structure was designed based on *creative metaphors*, which is an approach that we had used also previously in PD workshops [46,48,49]. The workshops were arranged in the libraries' premises and consisted of three imaginative and creative tasks carried out in small groups. The project, its aims and VR as a technology were introduced to the participants, who also had a possibility to try out immersive VR themselves: this was encouraged especially if they were not familiar with the technology. The participants were divided into diverse groups that consisted of people having differing knowledge and expertise. For example, we combined VR experts with people having no experience on VR, people representing different genders and age groups. The groups were provided with task cards and other visual material, such as empty sheets of paper, colorful paper, markers, random sets of images and printed posters for making notes. The tasks consisted of three parts that supported each other:

1. **The first task** was to ponder and discuss participants' most memorable library experiences, and write down keywords on a large sheet of paper.
2. **The second task** was about the real and imagined forest, and it was divided in two: in the first part, we asked the participants to think about their most memorable experiences about a forest with the help of a set of questions, such as *What happens in a forest? What kind of spaces a forest entails? What is above you, behind you, below you?* With these questions, we wanted to mobilize thoughts and ideas

about forest as a space and place, as VR is a spatial medium. The second part of the task was to think and converse about the most memorable imagined forest they had encountered in fiction — in literature, films or comics. The second part was supported by a rather similar set of questions than the first part.

3. **The final task** was to create a preliminary concept for *Our Shared Virtual Library*, again with the help of a set of questions. The central challenge was to reflect on what kind of experiences the Virtual Library Forest can provide. This was split into more specific questions, such as *What kind of elements, views and sounds the virtual forest can offer?* The groups were encouraged to use ideas from the previous tasks; we intended to steer the thinking of the participants and ease their work by consistently using the concept of experience in all the tasks. At the end of the workshop, each group presented their 'preliminary concept' to others followed by a joint discussion.

As a result of the PD workshops, we got a set of imaginative 'preliminary concepts' for the Shared VR World (Fig. 2). These included rich descriptions of the environment and its visual and auditory landscapes, and numerous propositions of what the user could actually do in the VR World. All the group discussions were recorded and group presentations were also shot with a video camera to provide us with rich research (and design) data. The recordings were transcribed, and we analyzed the transcriptions of the discussions and presentations with qualitative, thematic content analysis, using conventional analysis approach [50].

To analyze the role of different design participants further, we can summarize that we aimed at engaging two main groups of VR users in our PD process. First, the library personnel were a user group who would apply the VR World for teaching digital skills, introduce literature in a novel manner, disseminate digital innovations and on the most practical level maintain the new service offering. Second, the library patrons with their versatile interests, demographics and skills were the second group. Libraries played a key role in the process including planning, management, resourcing, information acquisition and solution generation. Following Arnstein's classic *ladder of citizen participation*, their intensive participation from the very beginning of the project met the criteria of genuine partnership and even gave them control over key decisions [51]. The library patrons, who can be understood as end-users, had less opportunity for initiative and formal decision-making power, but we aimed at engaging them as informants and co-designers respecting their insights and creativity.

3. Prototyping: Sustaining work during the pandemic

A central challenge in the middle of the project was undoubtedly the covid-19 and the resulting pandemic which affected the actual development phase of the project drastically. Soon after the final workshop, held in January 2020, the pandemic hit and basically all in-person contacts were cut off. Public libraries' physical premises were closed down as well as the university spaces. According to our original plans, we had imagined that we could build a loose 'designer community' around the design process: we had planned we could ask the workshop participants to test and comment the first version of the application as it was ready, and also expand the pool of library patron participants to make the design process more inclusive and diverse. Further, we had plans to test different versions of the application in public events connected to libraries or literature. The pandemic and the following restrictions meant that all of these plans had to be abandoned. This was a major challenge for our project as we were dealing with an embodied technology that must be used with wearable devices in order to gain the correct experience. It was impossible reproduce the immersive experience online. Furthermore, so few people own(ed) VR headsets that it would not have been feasible to ask people to test the application on their own at home. All the researchers participating in the project struggled also with their other projects and empirical studies, which meant we had very limited possibilities to ponder potential solutions for this particular process.

At this point, libraries took the initiative and resorted to option that was very natural for them as beacons of literature: the library partners suggested that we should hire a professional science fiction writer and ask them to write a comprehensive storyline for our application. The libraries also had a particular writer in mind — Finnish writer Anders Vacklin, who has written science fiction novels focusing on VR. Thus, the writer was already familiar with the technology and its future possibilities, and luckily, also interested in joining our project. The results of the multi-stakeholder workshops were still in a decisive role: We thematically grouped the most prominent, i.e. recurrent ideas for the Shared VR World that had came up in the workshops, and turned them into design guidelines which were discussed in our project meetings online. The science fiction writer was provided with these guidelines as well as other analyses made from the workshop material. Three broad, fundamental themes we formulated through the thematic content analysis were as follows:

1. **The Shared VR World supports discovering, exploring, wandering around, and adventure.** This means that the virtual environment (VE) must be large enough and visually and auditorily interesting; it must entail variation and surprising things; it must entail artefacts etc. the user can discover.
2. **The Shared VR World is divided into areas reflecting different forests that also contain different services or activities.** This means developing at least three different VEs.
3. **The Shared VR World and its content and elements change over time.** Typically, the participants also mentioned changing seasons or changing between day and night time. This means the different forest VEs must reflect different seasons and times of the day; there could also be a possibility for the library staff to modify the application and change its contents; also smaller, randomly changing elements can be used.

In the end this approach worked very well: The writer extensive utilized the material we gave him, and by August 2020, he had drafted a narrative which tied the fragmented ideas together. The resulting narrative introduces a protagonist, the *forest elf*, who needs to collect lost literary citations hidden in three magical forests. The virtual environments include numerous different interactive tasks, such as archery and fishing, that can also be played separately as minigames. It is possible to try to finish all the tasks, collect all the citations and arrange them in the bookshelf, but this takes a lot of time even for somebody used to immersive VR and video games. However, the user can also just wander around in the environments freely and familiarize her/himself with the immersive experience.

In the autumn of 2020 we tested the first version of the application among the core project group and provided feedback for the developers. During 2021 we had hoped to introduce it to library patrons, but the volatile nature of the covid-19 pandemic and constantly changing restrictions always prevented our plans. Finally, we were able to arrange user tests during the summer of 2021 in the Northern part of Finland, where the pandemic was less prevalent and public restrictions less strict. In short, we arranged a test session with 20 users belonging to two different

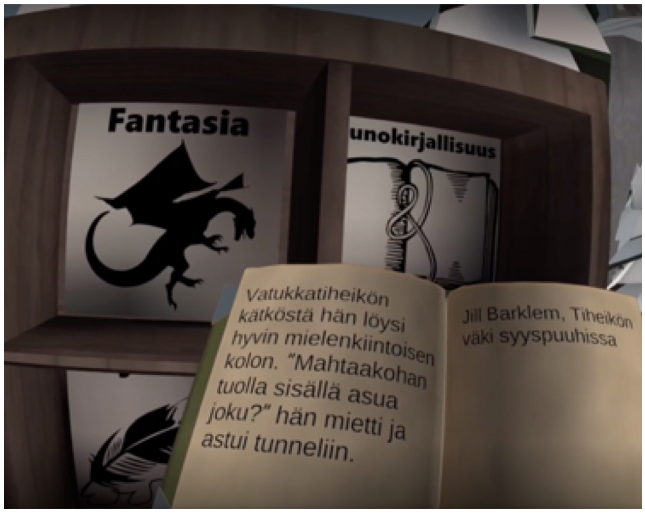

Fig. 3. A screenshot from *Forest Elf* application: The user can collect literary quotes to the magical book and try to place them within the correct genres on the bookshelf.
Image: Center for Ubiquitous Computing.

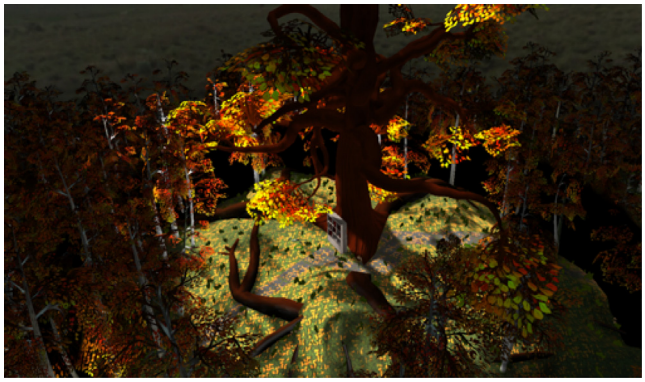

Fig. 4. A screenshot from *Forest Elf* application: The environment consists of three different forests, including the autumn forest with colorful leaves and a dark atmosphere resembling night time.
Image: Center for Ubiquitous Computing.

age groups and collected qualitative research data by recording their use sessions and by conducting thematic interviews. The results are analyzed in detail in Pouke et al. [52], but here we can conclude that the test confirmed that the application offered interesting experiences for different kinds of users, ranging from elderly adults with no gaming experience to young adults with a background in video gaming. Further, during the spring of 2022 the latest version of the application was used with small groups in different libraries. This resulted in some feedback, and among other things, fixes that made the navigation in the application easier.

3.1. Final version of the prototype application

The technical result of *Our Shared Virtual World* is a room-scale VR application called *Forest Elf* (Metsänhaltija) which is developed for Oculus Quest 1 and 2 hardware. The application was developed in Unity. Users can move around the virtual forests using a combination of natural walking and controller-based teleportation. To minimize discomfort, the application does not contain any continuous virtual locomotion [53], except during a short sled ride offered by one of the minigames. No other tracking equipment is used beyond the capabilities offered by the Oculus Quest hardware.

VR controllers are visualized as user's hands; using the controllers, the users can perform a variety of actions, such as pick up and throw objects, open menus using gestures, and play various minigames that are dispersed around the forests (see Fig. 3). The application contains three separate VEs with different themes and visual styles: a 'realistic' summer forest with a photorealistic visual style, a winter forest with an abstract visual style, as well as an autumn 'horror' forest with a dark, mildly creepy atmosphere represented with a cartoonish visual style (see Fig. 4). The user can transition between these VEs freely at specific "portal" locations.

The task of the user is to collect various objects that are related to different literary genres, and return them to a bookshelf, which in turn rewards the users with literary quotes that are placed on a virtual book carried by the user. Each of the VEs contain interactive minigames that are narratively tied to the overall theme; the user must complete the games in order to gain quote-bearing objects. Some of the objects are also hidden in the environment and the user can pick up these items upon encounter. A narrator voice ties the minigames to the overall story and instructs the user in their completion. The voice is triggered when the user arrives within a predesignated radius of the mini-game. In total, there are nine minigames. Some of the minigames are rather short, such as the sled ride, whereas other might contain prolonged tasks, such as fishing for objects and using these objects to solve puzzles. Other examples include manipulating wind to arrange letters, zapping evil robots with a magic wand, and archery.

4. Implementation: Adoption or oblivion?

At the time of writing this paper, all the libraries involved have acquired several sets of Oculus Quest hardware (some also had Oculus devices before the project). Furthermore, the application *Forest Elf* is provided for free to all interested public libraries. The library partners of the project arranged an introductory training session in February 2022 for library personnel. During the autumn of 2022 the library partners offered a thematic series of events for the general public which took place in different libraries simultaneously. This series of events was titled *VR October*, and most of the events were arranged in the libraries of the capital region. Due to the ongoing adoption we do not yet have a comprehensive view on the outcome. However, we have continued our discussions and meetings with the library partners, and one researcher has also participated in the training session targeted for personnel as well as VR October events. Based on our own reflection of the process and on the interviews with library personnel, we can provide some preliminary insights on this third phase and its challenges.

The following practical challenges are intertwined and connected to sustaining work over time and *infrastructuring* [54]. As we have highlighted in the related work Section 1.1. and in previous analysis Sections 2–3, participatory infrastructuring unfolds through the whole PD process. Sharing knowledge, creating different kinds of social networks, and developing flexible and open technologies contribute to infrastucturing and can create a sense of shared ownership. Further, to ensure continuity, it would be important to fit the designed artefact into existing organizational practices [55–57]. This was also part of our plans since the start — first of all, to enable further development of the application, it was decided in the beginning that the code is given to libraries and they can freely modify it depending on what needs may arise. Further, we carefully designed the application to respond to the interests of different kinds of libraries and

their different kinds of patrons. Originally, we also had a plan to collaboratively create a manual introducing different ways to use and develop the application in library context. Unfortunately, this plan had to be abandoned due to the changes in budget and scheduling caused by the pandemic.

4.1. Technical support

Libraries face challenges posed by limited resources when transferring *Forest Elf* application from development phase to implementation and broader diffusion of the new technology. Unlike commercially produced software products, digital systems created within or with research projects have a flavor of work in progress. Especially advanced use of the new systems involves certain amount of debugging. One of the interviewed library workers expressed that *"…I have just encountered a lot of glitches in it still... there has been a lot of...lot of critic about the glitches and sometimes people don't know what to do in the game and why something works the way it does, or doesn't work"*. This is connected to the phenomenon of *'disappearing technical support'* which often takes place when research projects end. It has for long been a challenge in academic design and development projects having a limited timeline, in particular in PD projects [58]. The code was handed over to the libraries as we planned in the beginning, but at the moment, the library personnel does not have the expertise to do small fixes and tackle bugs that are noticed now when the application is used more widely.

4.2. Future development

A lack of technical expertise at the libraries is also connected to the question of more extensive further development of the VR application — it was carefully designed so that it is easy to expand and develop further, but also this requires special expertise on VR. Further development could probably be done only through future projects. However, the library personnel structure, their competence profiles and financial resourcing for ensuring successful launch and integration of new technologies into libraries' regular activities seem scarce if not insufficient. For example, one of the municipalities that originally initiated *Our Shared Virtual World* project has twelve branch libraries serving over 200 000 residents, but they are employing only one person who is deeply involved in the project with adequate technical skills and who is able support its adoption and use within the library network. In the interviews, the expertise concerning VR and IT in general among the rest of the library personnel are politely characterized with expressions *'varying'* and *'requiring encouragement'* giving a clear indication that the competences would need updating. In the spirit of PD, one of the focal aims of our project was to increase library personnel's understanding on VR technology and on design process; however, the number of the participants was limited.

Our Shared Virtual World project decided to use Oculus Quest standalone devices for their ease of use and flexibility in library context. However, in the adoption phase of the project the initiating city had been able to invest in just four Quest glasses to meet the need of twelve branch libraries, which alone is a limitation almost ensuring that VR remains as a niche service. The libraries are aware of the need to follow up and evaluate the adoption and use of new services, and the necessity to develop and update *Forest Elf* for continued interest in the service. This has not happened at the time of the interviews. The libraries do not have any separate project funding allocation for developing VR environments further, services and competences and the resources for general development at libraries work are limited and shared between several other projects. There are differences between municipalities in their resourcing of libraries, but at least some of the key partners of *Our Shared Virtual World* are seriously hampered by the lack of resources for long-term development of IT systems. The legislation is equally binding for all municipalities to broaden the residents' digital literacy, but differences in cities' capabilities to allocate funding vary. In addition to budgetary limitations, it is possible that the libraries themselves underestimate the resources needed for diffusing IT innovations and have overly broad portfolios of development projects with optimistic expectations of easy adoption.

4.3. Diversity of the users and uses

The beginning phases of the implementation imply that the use of the VR application is not necessarily as varied as originally planned. As stated, we could not produce a manual that would have introduced different ways to use the application and suggestions on how to develop collaboratively its content. The lack of predefined, diverse ideas for use sessions with different target groups can lead to narrower use — it can be difficult to escape conventional genres, uses and audiences. In our case, the VR application is easily seen 'just' as a game that is targeted to children or teenagers. However, *Forest Elf* was designed to be a versatile experience, responding to the needs of different audiences; it is layered and built to accommodate different uses. The same applies to VR in general as it can provide numerous different experiences and be used for different purposes. However, it seems that VR content is often regarded as an immersive video game and also called as a game when advertising events connected to it. Probably this works for some (young) people, but not all potential users are interested in gaming.

One of the keys unlocking different ways to use VR is to integrate it in the libraries' existing activities targeted to different groups of people which may require developing ideas or concepts for different kinds of sessions. Now this work is carried on by a few enthusiastic librarians. For example, in one branch library, a Finnish Virtual Art Gallery application was used with students of vocational school having an immigrant background; it was used to support their language studies and multimodal literacy. The librarian in charge crafted a concept around the use, and is planning to use also *Forest Elf* in similar future sessions.

4.4. Broader adoption

The last challenge of the ongoing adoption phase is the involvement of other libraries — which is also closely connected to the infrastructuring and (the lack of) establishing the use of the application in the context. *Our Shared Virtual World* project was conducted within a broad but still limited network of developers and libraries. One of the challenges in the adoption phase is to engage the rest of the library network into the process. This requires learning how to use novel technologies, organizing new services for the library patrons that match the local client profile, and allocating physical space for using virtual reality, among others. The adoption without dedicated resources requires strong interest and commitment to the project and its goals from many new librarians.

The interviews did not reveal anything directly related to libraries and librarians being reluctant to adopt innovations created in development processes in which they did not have a role. However, the librarians underline that libraries have a strong bottom-up innovation culture aiming at empowering and supporting individuals who show interest in developing new services. In spite of national legislative and regional digitalization strategy guidance, Finnish library branches enjoy significant independence in their actions and development project portfolio

decisions. The culture of bottom-up innovation under circumstances of very limited resources indirectly indicates that the priority might be given to indigenous innovations. This might be an issue when aiming at diffusing centrally developed top-down innovations. The library partners have already reported that it is somewhat difficult to make libraries that were not part of the process interested in the application. The VR October event series is one attempt to tackle this problem. However, the libraries of the capital region of Finland are also currently drafting a new digital agenda and it has been proposed that the developed application would be part of these plans. Thus, it remains to be seen whether the application becomes a more central part of library network's practices.

The lack of technical expertise at the libraries, scarce resources for further development and for promoting broader adoption do not forecast a very positive future for *Forest Elf*. Nevertheless, we must bear in mind that the developed artefact itself and its future are not the only things defining the success or failure of the whole project, but also the assumed impact on non-academic participants' attitudes and thinking patterns is relevant: the intention of PD is to highlight how technologies are designed and how they are always based on certain choices. Thus, we can consider that the mutual learning process between researcher–designers and library personnel is valuable in itself. In the light of digital social innovation process, however, it would be a pity if the carefully co-designed application turns out to be just a short-lived experiment and broader public cannot familiarize themselves with immersive VR through a variety of different activities, as initially planned.

5. Discussion

In the following we discuss how PD as an approach and libraries as institutions work in such a processes involving the creation of digital technology for social good. We first summarize the central decisions and consequent steps we made during the design process. Then, we analyze further the central points of success and challenges framed above, and turn them into higher-level outcomes. These conceptualizations can be viewed as guidelines that can support similar future endeavors, and on the other hand, they can help to overcome challenges of such projects.

Forest Elf VR application differs from most of the previous Virtual Library applications because it does not intend to transfer any existing library services to VR, nor was it built to be a short-term research prototype tested in the library environment. It was designed to be a technology that public libraries could adopt and develop further, and use for various activities connected to increasing peoples' digital literacy. Using PD as an approach means that we designed the application in close collaboration with library personnel and made all the most important decisions together with them. Employing PD from the start of the process resulted in numerous design decisions, and we present a list of the most important steps below:

1. **Choosing the technology:** To accommodate flexible use, *Forest Elf* is built for standalone hardware, i.e. Oculus Quest. Using standalone devices results in loss in compatibility and graphics fidelity but this was considered acceptable since standalone devices are so much more convenient in a public library environments.
2. **Choosing the overall visual and spatial appearance:** The virtual environments of *Forest Elf* resemble forests. Thus, the application does not mirror any specific library or library building. It was deemed in the beginning of the process that this lowers different libraries' threshold to adopt the application and can be attractive for diverse end-users.
3. **Creating initial ideas for the content:** The application can be used with different groups of people having different digital skills and different interests, and it is not targeted to any specific age group, for instance. Differing needs and ideas of the end-users (library patrons) were explored through multi-stakeholder workshops.
4. **Developing a comprehensive storyline based on the ideas:** A science fiction writer was hired to write a narrative that tied together the central ideas created in the PD workshops. This approach replaced the follow-up workshops and other co-creations sessions with end-users which we could not arrange due to the pandemic.
5. **Building the prototype:** Based on the previous steps, a room-scale immersive VR application was developed. It can be played as a comprehensive adventure game including several interactive minigames that also work independently and demonstrate the possibilities of VR to the user. The user can also just wander around in the environment and explore the visual affordances of VR as a spatial medium. The library context was embedded into the VR application by using it as a theme in the overall narrative: The task of the user is to collect lost literary quotes.
6. **Implementation:** The involved libraries have acquired several sets of Oculus Quest hardware, and the application is offered for all the Finnish libraries for free. Participating libraries have also arranged an event for library staff members and series of events for general public to introduce the application.

Based on the design reflection we have presented in this article and on the analysis of the library personnel interviews, we can recognize several strengths in library collaboration, which made phases 1–5 successful. On the other hand, phase 6 has been hampered by some weaknesses that we were not able to anticipate.

5.1. Strengths of library collaboration

High ambition level and commitment to digital transformation – The libraries involved in *Our Shared Virtual World* project have high ambition in contributing to inclusive digital literacy. They are strongly committed to the Finnish Public Library act allocating libraries to promote new forms of literacy and civic participation. The libraries as institution and numerous individuals in the library network are proud of the legacy of libraries being low threshold venues for information and cultural content. They consider this legacy as a solid foundation for a library transformation towards interactive digital and explorative hubs that provide inclusive access to new technology, new skills, and new types of cultural content. *Our Shared Virtual World* project is an illustrative example of the ambition and confidence libraries have in taking active role in digitalization through proactive exploration and development rather than adopting off-the-shelf technologies.

Flexibility and open-door policy – The libraries have low threshold in engaging in digital innovation projects. Legislation and regional digitalization strategies give Finnish libraries a mandate to promote digitalization, but individual libraries have a lot of freedom in choosing which initiatives they launch and which they join. They do not have responsibilities to productize their innovations which enables being engaged in a broad range of exploratory initiatives. The same open-minded attitude characterizes libraries' ways to collaborate. Libraries provide an accessible venue for individual citizens, interest groups, and educational and research institutions to meet and collaborate. The access consists of physically accessible network of non-commercial public spaces

and the ideologically neutral democratic ground that libraries provide for participatory and collaborative development.

The principles of PD resonate with the democratic principles and ideals concerning civic participation very well, and thus, we consider utilizing this approach as a successful choice. The starting points of the process were defined through negotiations with researchers and library partners, and utilizing multi-stakeholder PD workshops combined with creative metaphors provided us with a set of rich ideas from the start. It also expanded the pool of co-creators as we invited library patrons of different backgrounds to participate. We also deem that the fact that goals, methods and technical starting points of the project had been decided together with different actors participating in the project made everybody more engaged – *Our Shared Virtual World* was not just a research project or just a development project, but everybody felt they have something at stake. Thus, in addition to having strong established networks, using PD as an approach clearly resulted in shared ownership and deep engagement as everybody wanted to continue collaboration throughout the hardships caused by the pandemic. It can be interpreted that following PD principles made the project more resilient and flexible.

5.2. Weaknesses of library collaboration

Service integration challenge – Libraries and the whole participant network in *Our Shared Virtual World* project focused predominantly in collaboratively developing the technology and interactive content for the virtual library world. Less attention was paid to anticipating and mitigating the challenges that come along with integrating the VR technology with the whole service offering of the library network. VR technology requires hardware, software, maintenance, guidance, physical premises, and communication approach to address key target clients. As the content of *Forest Elf* deals with literature, a linkage with topical literature themes and libraries' traditional core services of book lending needs to be planned and implemented.

Inexperience in innovation management and infrastructuring – Libraries who participated *Our Shared Virtual World* project have limited experience and skills in managing technology transformations and adoption processes. The clearest indication of this is seriously under-resourced launching and scaling-up phase. The effort for providing the new service that is still in advanced prototype phase has not been recognized and prioritized. There have been no dedicated allocations to personnel, hardware, and budgetary flexibility to ensure successful launch of *Forest Elf*. Libraries digitalization strategy underlines bottom-up innovation and experimentation, but the following adoption phase of digital innovation in libraries requires further elaboration.

Reflecting the process critically, a potential remedy would have been to transfer our knowledge on PD process as a whole to our library partners: We could have highlighted the importance of considering how to fit the VR application in its (future) use context and in existing practices, and ponder together with our partners what kind of sustainable networks could be built around the VR use in libraries (on networks supporting sustainability of PD, see e.g. [31]. In other words, we could have created opportunities to openly and explicitly discuss how to sustain the work over time. This boils down to accountability and also to knowledge sharing typical for PD: though we were not in charge of the whole project, we as researcher–designers have expertise and knowledge on similar processes. We somewhat missed the opportunity to emphasize the focal nature of infrastructuring to our library partners.

We must note that there are some limitation in our case study — the most significant being that the whole process is still not finished. We have not yet carried out any systematic studies on end-user adoption of the designed digital artefact as it is an ongoing and probably quite slow and long process. However, we consider important to share our insights with broader research and design community to enable addressing similar challenges that may rise in digital social innovation projects realized with libraries or other public knowledge institutions.

6. Conclusions

In this article, we have introduced a long-term research-through-design project aiming at developing a shared Virtual Reality (VR) application for all the public libraries in Finland. *Our Shared Virtual World* was carried out as a collaboration with several public libraries from five different municipalities and two different universities. It has been library-led as the main funding was applied for and granted for libraries; some tasks performed by universities were covered with the funding, and the process was also linked with other existing research projects to allow researchers to allocate more time in collaboration. On a more abstract level, the process has been situated at the intersection of public libraries' efforts to respond to the growing societal demand for digital support, digital training and digital literacy, and our research interests concerning participatory design (PD) and VR development.

Overall, public libraries' goals and objectives are aligned with Sustainable Development Goals (SDGs) which makes them highly relevant partners in IT development projects focusing on social good. They also reach a large part of population which means applications designed with and for them potentially gain a lot of attention. In the context of Finland, libraries' high ambition level and commitment to digital transformation increases their relevance to digital social innovation (DSI) projects. They can engage in exploratory digital innovation projects in a flexible manner, without having to worry about productizing the created artefacts. Their profile as low-threshold public spaces potentially encourages the participation of diverse populations, promoting equality and increasing possibilities to include versatile perspectives in technology design. The main challenges confronted are connected, firstly, to integrating the VR technology with the whole service ecology of the library network: here both expertise and financial resources were lacking. The second higher-level challenge we recognized is the limited experience and skills in managing technology transformations and adoption processes: this resulted in under-resourced launching and scaling-up phase. These challenges can have an adverse impact on how the results of the project are sustained over time and can potentially make the produced digital artefact a short-lived experiment.

What comes to PD, we argue it can be highly beneficial approach in processes framed as digital social innovation. In the case of *Our Shared Virtual World* it was very well aligned with libraries democratic goals and their nature as low-threshold public spaces for all citizens. The challenge is to ensure the long-term impact of PD work which requires continuous and careful engagement with the research participants and paying equal attention to all the phases of the design process, from the beginning to the implementation. PD needs to be utilized as an overarching approach which entails embedding the work to existing practices, and creating sustainable networks and platforms that do not dissolve when the project ends. As a final conclusion, though we have identified shortcomings especially in the implementation phase, we can still argue that overall, the project was a success. The researchers and the libraries participating in the project were satisfied and the libraries also wish to adopt the application for future use.

CRediT authorship contribution statement

Johanna Ylipulli: Conceptualization, Methodology, Writing – original draft, Writing – review & editing. **Matti Pouke:** Software, Writing – original draft, Writing – review & editing. **Nils Ehrenberg:** Investigation, Writing – original draft. **Turkka Keinonen:** Investigation, Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Part of the data is confidential, such as notes from meetings and discussions.

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Johanna Ylipulli is a docent (adjunct professor) in digital culture, especially anthropology of technology. She is currently working as a principal investigator in projects focusing on digital inequality in smart cities, artificial intelligence in public services, and transdisciplinary research methods at Aalto University, at the Department of Computer Science. Dr. Ylipulli's focus is on studying urban contexts and societal effects of digitalization, and she has been bridging social sciences, design, and computer science for the last 13 years. She has worked within diverse fieldwork settings and participated in planning several design-related empirical studies. Overall, she is interested in investigating how critically oriented anthropological thinking — with its capability to challenge normative structures and self-evident 'truths' — can be successfully combined with design research and technology development.

Matti Pouke is a postdoctoral researcher in the Perception Engineering research group at the Center for Ubiquitous Computing, University of Oulu, Finland. In his doctoral research he studied the transformation and visualization of real human activity in virtual environments. Since then he has been involved in many research and development projects involving the use of virtual environments in public urban contexts, including smart buildings, architectural visualizations, and libraries. His current research focuses on human perception in multi-scale virtual reality experiences as well as Presence and Plausibility. He is a member of ACM and IEEE.

Nils Ehrenberg is a postdoctoral researcher at Aalto University. He has a background in interaction design and his research explores autonomy and agency in the smart home as well as digitalisation and public participation. Prior to his doctoral studies Nils Ehrenberg worked as a researcher at Madeira Interactive Technologies Institute as well as Malmö University.

Turkka Keinonen (doctor of arts) is a professor of industrial design, vice dean of research and head of doctoral education at Aalto University School of Arts, Design and Architecture. Previously Keinonen has worked as industrial designer for Finnish technology industries including ship building, paper machinery and medical equipment, been a principal research scientist at Nokia Research Center and visiting associate professor at National University of Singapore. Keinonen's publications include Mobile Usability (2003), Product Concept Design (2006), Designers, Users and Justice (2017) and about 100 other publications on human centered design, product concept design, design strategy and ethics of human centered design.