Craftsmanship in virtual reality: digital development and evaluation of traditional South African beer brewing

Veronika Nemcova
Magnus Kornbeck Thomsen
Andrei-Calin Mares
Mafor Penn
Umesh Ramnarain
Kasper Rodil

Veronika Nemcova, researcher at The Technical Faculty of IT and Design, Department of Architecture, Design and Media Technology, Aalborg University. Czech.

Magnus Kornbeck Thomsen, researcher at The Technical Faculty of IT and Design, Department of Architecture, Design and Media Technology, Aalborg University. Danish.

Andrei-Calin Mares, researcher at The Technical Faculty of IT and Design, Department of Architecture, Design and Media Technology, Aalborg University. Romanian.

Mafor Penn, Science Lecturer at the Faculty of Education, Department of Childhood Education, University of Johannesburg. Cameroonian.

Umesh Ramnarain, Professor of Science Education at the Faculty of Education, Head of Department Science and Technology Education, University of Johannesburg. South African.

Kasper Rodil, Associate Professor at The Technical Faculty of IT and Design, Department of Architecture, Design and Media Technology, Aalborg University. Danish.

Craftsmanship in virtual reality: digital development and evaluation of traditional South African beer brewing

Veronika Nemcova
Aalborg University

Magnus Kornbeck Thomsen
Aalborg University

Andrei-Calin Mares
Aalborg University

Mafor Penn
University of Johannesburg

Umesh Ramnarain
University of Johannesburg

Kasper Rodil
Aalborg University

ABSTRACT

Maintaining unique traditions and cultures is becoming increasingly difficult due to the effects of globalisation, combined with the fleeting nature of intangible cultural heritage (ICH). The continuation of ICH traditions relies on the awareness and interest of young people, as it is passed from generation to generation. This study aims to protect knowledge and skills – specifically traditional craftsmanship (TC), in the use case of South African beer (umqombothi) brewing – by exploring how to digitally represent and disseminate ICH using virtual reality (VR). In the beer-brewing prototype, participants become fully immersed in a digital South African community to learn the practice of brewing and experience the ICH contextual elements such as rituals and togetherness. The results show that short-term use of the VR prototype enables novice participants to learn essential aspects of community ICH and the beer-brewing practice. Furthermore, we emphasise the importance of evaluating the dissemination potential of safeguarding solutions by assessing their transfer back to everyday life. For this reason, this study also captures and successfully demonstrates an evaluation in which the participants re-enact what they recall from the VR playthrough using real lo-fi props used for brewing.

Keywords

traditional craftsmanship, virtual reality, beer brewing, South Africa, re-enactment, evaluation, immersion, embodied learning

Introduction

The legacy of our cultural past is defined by UNESCO (2003b) as our cultural heritage. Cultural heritage includes concepts known as tangible cultural heritage (TCH) and intangible cultural heritage (ICH). TCH is primarily oriented to physical artefacts and sites, whereas ICH reflects the non-physical elements of cultural heritage. Although seemingly different concepts, they are often complementary. Kurin (2004) describes this balancing act intertwined with the concepts as follows: 'Tools are tangible, but plans, if thought are not, but if drawn are'. One of the categories that falls under ICH is traditional craftsmanship (TC), defined by UNESCO (2003c) as 'perhaps the most "tangible" manifestation of ICH'. The focus on tangible craft products can lead to the disregard of the craft process itself and of an essential aspect of TC for many communities – the contexts in which TC becomes manifested.

The performance of TC and its passage from generation to generation supplies communities with a sense of identity and continuity while also encouraging respect for cultural diversity and human creativity. Today, there are several conditions endangering the survival of TC as we know it. One of them is globalisation, which supports mass production and thus poses a threat because of the availability of low-cost alternatives and fast production requirements.

Another major problem is the migration of young people to bigger cities and the rising disinterest in community traditions. For example, South Africa battles with the effects of rural–urban migration as it becomes increasingly frequent (Mlambo 2018). This migration is not only caused by the marginalisation and stigmatisation of many Indigenous communities (Ossai 2010) but also the fact that, for many young people, mastering crafts is too demanding compared to other alternatives. Consequently, they seek work in factories or the service industry, where the work is less challenging and the pay is often better (UNESCO 2003c), breaking the line of passage and increasing the risk of extinction for these crafts (Kennedy 2010; UNESCO 2003c).

For TC to be protected, it needs to be practised (UNESCO 2003a). Thus, the goal of safeguarding is to ensure that the knowledge and skills linked with TC are passed on to future generations, particularly through formal and informal education (UNESCO 2003b, 2003c). Moreover, it is also important to include the cultural, religious, creative and social context when presenting the process of the crafts (Donkin 2001).

Currently, there exist several safeguarding solutions, such as workshops, written media, exhibitions, databases or inventories and conferences, with the living museum as perhaps the closest experience to the real TC practice. Some of these ways of dissemination benefit from the direct inclusion of craftspeople, but they are also often disadvantaged by being place-specific, time-restricted, resource-inefficient or because they do not provide any essential hands-on experience (for a recent review, see Rossau et al. 2019).

Challenges of digital safeguarding of traditional craftsmanship

Many of these disadvantages of TC transfer have been approached from a technological perspective. Recent advances have been made with computing applications (Isa et al. 2019; Partarakis, Patsiouras et al. 2020; Karuzaki et al. 2021), mixed reality (Carre et al. 2022), mobile applications (Ringas et al. 2022), motion capture (Ringas et al. 2022) and virtual reality (VR) (Rossau et al. 2019; Karuzaki et al. 2021) – all of which have been explored as options for safeguarding TC.

The topic of how to digitally capture, represent and disseminate TC through technological solutions has been discussed in many papers (Rodil and Rehm 2015; Zabulis et al. 2022; Partarakis, Zabulis et al. 2020), yet there exists little research on how to evaluate these solutions.

The current evaluations have mostly focused on the technologies themselves – for instance, usability and user experience (Carre et al. 2022; Karuzaki et al. 2021; Ringas et al. 2022; Rossau et al. 2019) – but also more promising examples of exploring the knowledge gain. A trend, however, is that these attempts have mostly been through questionnaires (Selmanovic et al. 2020), while some completely omit any evaluation on expanding knowledge from the view of the participants (Partarakis, Patsiouras et al. 2020; Schofield et al. 2018; Skovfoged et al. 2018; Isa et al. 2019).

These types of evaluations unfortunately tell us little to nothing about how well the craft skills and knowledge learned can be replicated and performed in real life. As

we have reported before in this journal, human skills and human values must be rightfully embedded into any technology responsible for making human culture a digital representation (Rodil and Rehm 2015; Rodil and Winschiers-Theophilus 2018). Afterall, TC is not only the process and knowledge of how to perform it but also the underlying cultural values and world views that have shaped and continuously shape TC in the minds of performers. We would claim that one should not assess the theoretical, digital knowledge transfer in isolation, but seek ways to understand more holistically how a mind-body performance transfers meaningfully from the TC practice through a digital medium and back into the physical world. Any safeguarding technology in this case is a means to bypass disadvantages previously mentioned – not to remove their end manifestation in the physical world.

In the following section, we place emphasis on the opportunities of VR as the technology responsible for this transfer.

VR as a technology to facilitate situated learning

In recent years, the general interest and use of VR has greatly increased (XRToday 2022), also in education and skills training. This is most likely because the majority of research in this field has shown that VR has major advantages compared to traditional learning methods (Dede 2009; Allcoat and Muhlenen 2018; Christou 2010; Kavanagh et al. 2017; Durlach, Mavor and Newby 1996).

These advantages include the ability of VR to produce a highly immersive and embodied experience by allowing for multisensory interaction and active learning. This supports students' ability to retain information and transfer the learned skill and knowledge to different contexts (Dede 2009; Allcoat and Muhlenen 2018; Christou 2010; Kavanagh et al. 2017; Durlach, Mavor and Newby 1996; Johnson-Glenberg 2018). Furthermore, requiring interaction and encouraging active participation rather than passivity improves user engagement (Dede 2009; Allcoat and Muhlenen 2018) and motivation (Kavanagh et al. 2017); VR education has also been shown to induce positive emotions and decrease negative emotions (Allcoat and Muhlenen 2018; Kavanagh et al. 2017).

Additionally, transfer is also improved by enabling situated learning, the digital mimicking of authentic contexts and activities, which provides a tight coupling between symbolic and experiential information (Dede 2009; Bowman et al. 1999; Durlach, Mavor and Newby 1996; Mei and Sheng 2011).

VR can be an efficient learning tool, as it is a commercially viable and a safe alternative to situations that would be hard, if not impossible, to stage in the real world (Christou 2010). Furthermore, the use of VR often saves resources, such as money, time and materials, since the experience can be repeated any number of times without much additional cost. These advantages have resulted in the increasing popularity of VR in classroom education (Christou 2010).

Overall, VR is a promising tool for representing and disseminating TC. Not only does it provide the option for embodiment and immersion (Dede 2009; Johnson-Glenberg 2018), it can enable situated learning which leads to better transfer of skills to real life (Dede 2009; Durlach, Mavor and Newby 1996; Mei and Sheng 2011).

Invigorating the South African STEM curriculum with intangible cultural heritage

Zooming in from this broader discourse, the following sections will report from a larger international project on how safeguarding ICH can invigorate formal disciplines, helping ICH, TC and science, technology, engineering and mathematics (STEM) education enable one another.

In a recent review in this journal, Labrador (2022) distinguishes how the current landscape of heritage in education has been integrated into STEM learning and how 'teaching through heritage has increased, as educators turn toward non-didactic methods in a broader epistemological context that positions culture as an undercurrent flowing through all subjects' (23). Labrador's notion of 'education through heritage' accurately captures our approach in a bidirectional sense, whereby young South African learners find relevance in both the heritage and STEM content.

The lack of culturally relevant resources for STEM learning means school learners in South Africa and other African countries are disadvantaged in their learning experiences (Ramnarain 2021). The use of VR simulations that are anchored in local culture can support cultural diversity and preserve the traditional knowledge of

Indigenous peoples through place-based learning that immerses learning experiences in local cultures. The application of such culturally anchored simulations adopts an embodied, situated, distributed cognition perspective to learning (Hardy-Vallee and Payette 2008) that affords learners an experience that is socioculturally situated in indigenous cultural practices and physiologically embodied in VR experiences.

Young South African learners struggle to see the relevance in periodic tables, laws of physics and so on. Therefore, the premise of the project is how to transfer ICH from remote rural communities to the urban young population and make learners aware that ICH has application in most STEM fields. TC is not some romantic past – it has been performed, tuned and validated through generations, also nowadays, and whether the focus is on the community practices of leather tanning or the Xhosa tradition of beer brewing, it has an explanation and place, also in the STEM fields.

An Umqombothi beer-brewing VR prototype

For the sake of both explaining the TC and the technical and graphic details of the VR prototype, the following text will describe how the TC was embedded into the VR prototype. For this article, we leave out the STEM elements, but it is important to note that the TC relates to the ICH of brewing and the STEM element is the beer brewing as a formal understanding of the chemical processes. One literally dives into the beer in VR and becomes embedded in chemical bonds. The overarching vision is to show how cultural practices and beliefs are viewable from a natural science or STEM perspective as well as to show that no explanation triumphs over the other – as both perspectives have a place in understanding the subject.

The sources of information for mapping out and designing the TC experience were gathered through South African collaborators, literature and community interactions. This section focuses on how an example of TC, specifically umqombothi beer brewing, was brought to digital life and subsequently evaluated from the perspective of participants in a physical re-enactment set-up.

Umqombothi is a traditional Xhosa craft beer. In the past, the beer was traditionally brewed by older women, though mostly consumed by men. These crafters used an age-old method of beer brewing, with diverse techniques handed down by their forebears; sometimes they were self-taught (Konfo et al. 2021; Lues et al. 2009). The beer plays an important role in cultural, social and spiritual events – such as contacting ancestors (*amadlozi*) and celebrating the homecoming of young men (known in Xhosa culture as *abakwetha*) after initiation and circumcision rituals – as well as in funerals, traditional meetings, weddings and other life celebrations (Hlangwani et al. 2020; Lyumugabe et al. 2012).

Beer brewing itself is a craft, as it requires a special skill in the brewing techniques used and a lot of patience. Unlike cooking, this brewing process does not just require a recipe but needs an understanding of the fermentation processes, colour changes, brew consistencies, catalysts, dealing residues, hygiene and time frames for process completion. In fact, it is believed to be a craft as it is not only a hand but also a process skill.

The brewing of home-made sorghum beer is practised throughout the continent of Africa, but the VR prototype discussed here specifically portrays the Xhosa community in South Africa. This was reflected in the environment building, the architecture, voice lines uttered by animated characters and the clothing of the community.

The VR application development has been based on the real context and processes of brewing umqombothi beer for the occasion of the harvest. The brewing process is split up into four days, where the user is supplied with the equipment needed on each day. The 3D equipment was modelled after the equipment traditionally used during umqombothi brewing; see Figure 1 showing all the models and their real-life reference.

Besides educating the users about the TC, the goal was also to provide the users with the context, which is essential for the community. By showing the TC and context through the use of a narrative, the users would get a better understanding of the life and customs of the community and emphasise its relevance, instead of reducing the TC to a sequential process alone. The experience is split into two parts: the outside brewing scene taking place in the community and the inside scene, where the user takes part in the drinking ritual in the hut.

The prototype was implemented in Unity, using two VR packages: OVR and Unity XR. The application was

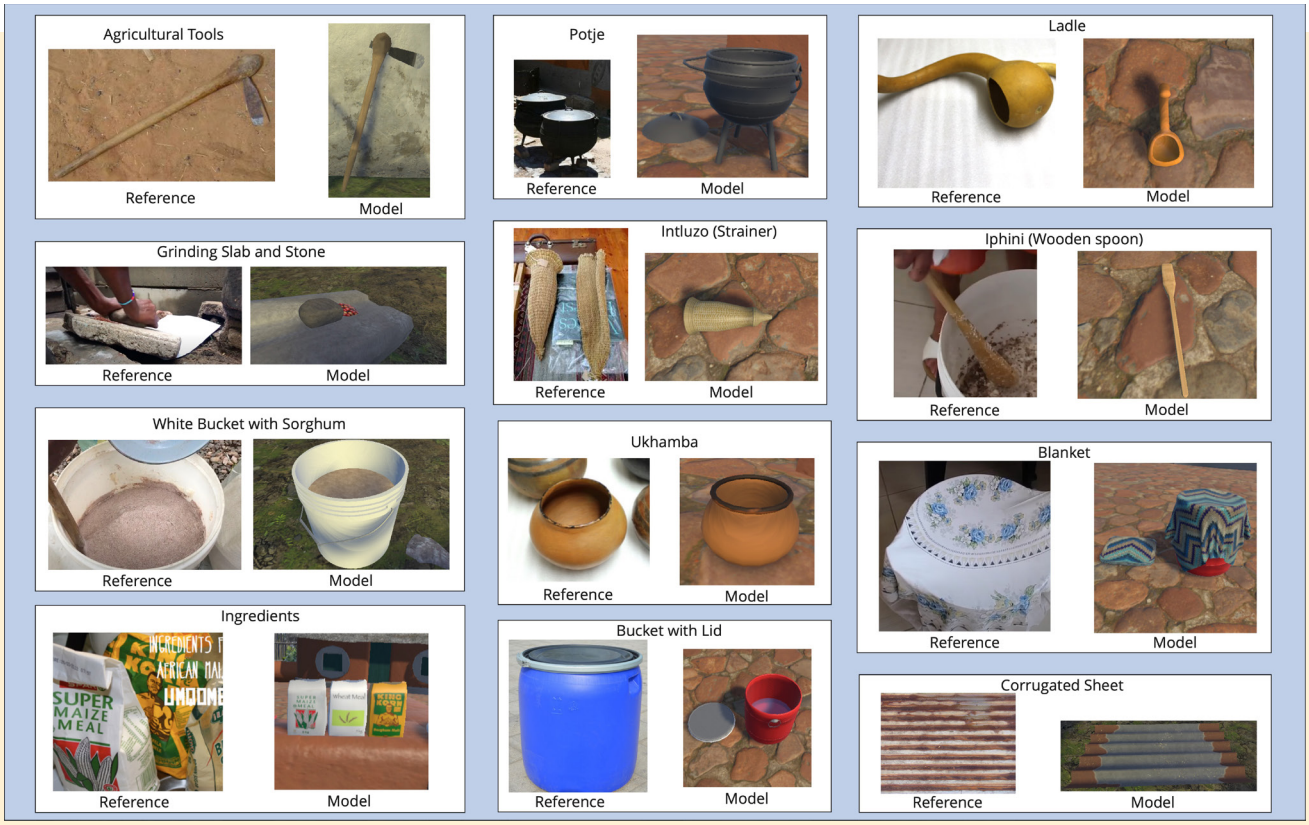

Figure 1
The figure shows a side-by-side comparison of the reference objects and the produced 3D objects.

developed for the Oculus Quest 2 headset. The majority of the 3D models were created in Blender or Maya and from freely available packages on the Unity asset store.

The brewing of Umqombothi made interactive

The first scene takes place in the community in open air. The reference for the buildings, vegetation and other landscape features represents a real Xhosa community. Additionally, the environment was brought to life through the inclusion of virtual community members. They were present in the application both visually and through animation, as well as from an audio perspective. During the brewing, the player can see and hear members of the Xhosa community of all ages going about their daily lives: conversing with each other in Xhosa, working in the fields, playing or just relaxing in front of their huts. The environment hints at the reason behind the celebration – the end of the harvest season – by including the field workers harvesting the sorghum crops. Each day more crops are gathered and more collection baskets are visible in the scene to give a sense of progression; see Figure 2 showing the outside scene view.

Besides the life in the background, direct interactions with the community are also implemented. As the user is brewing, two members of the community visit the player. In the first case, a local woman comes and brings ingredients, which she gives to the player, along with wishes of good luck. This experience provides the users

Figure 2
The figure shows an outside scene from the prototype.

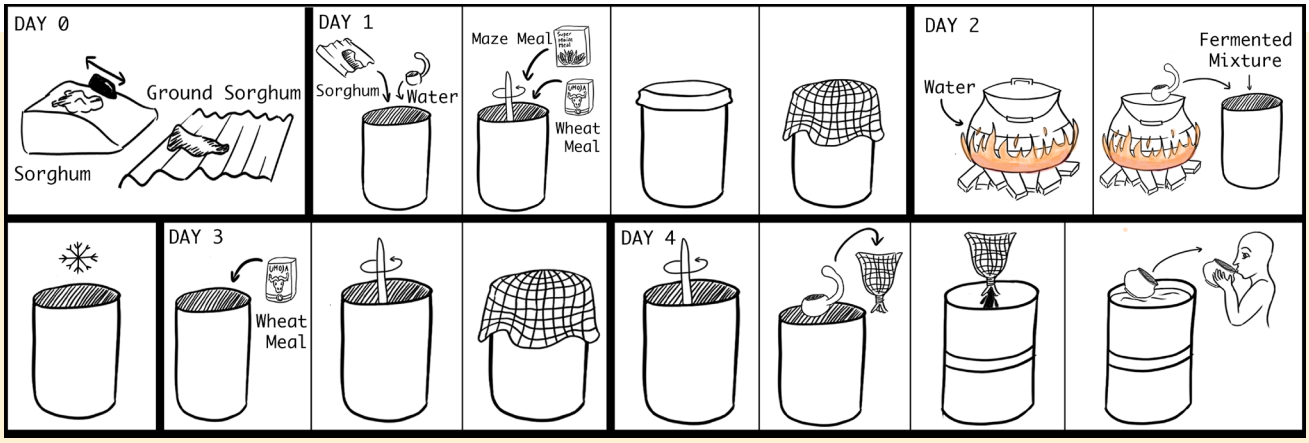

Figure 3
The figure visualizes the brewing process.

with a sense of community and accurately represents the fact that, during the communal brewing, neighbours often encourage and aid the brewer (McAllister 2003). The user continues to brew beer over a period of four days, aided by signifiers, such as a semi-transparent ladle scooping water and pouring it into a bucket, that show each step of the process. The whole brewing process can be seen in Figure 3.

After the beer is made, the user interacts with another member of the community. This time, an Elder comes to collect the beer after it has been brewed. He offers thanks to the player and moves to the hut to start the ceremony, then the second scene begins.

The second scene takes place inside of the hut and represents the ceremony itself. This scene was added to portray the Xhosa beer-brewing customs accurately and further increase the feeling of community as well as explain the occasion of the ceremony. As the scene starts, the user is situated inside of the hut, sitting in a circle alongside other male members of the community, as per tradition. The elder makes a short speech about the event and gives thanks to the ancestors (McAllister 2004). He then drinks from an ukhamba, a traditional drinking container, and proceeds to pass it to his right. Each man takes a sip of the beer and passes it on. The player waits until they receive the ukhamba from the man sitting to the left. The player takes a sip and puts down the ukhamba on a table, ending the playthrough; see Figure 4 showing the inside scene.

Figure 4
The figure shows the second scene with the drinking ritual inside the hut.

Evaluation of VR prototype

An evaluation of the prototype was conducted to ensure transferability of the TC into a digital, experiential context and explore users' impressions, attitudes and insights after the VR experience in isolation. More specifically, the goal was to achieve a deeper level of understanding of the contextual aspects of the community, its members, the rituals and habits surrounding the brewing process. This evaluation is labelled below as 'Day one'.

The day after this evaluation, we gathered the participants again to investigate to what degree they could re-enact in real life what might have been transferred from the VR playthrough. This evaluation is labelled below as 'Day two'.

In an effort to increase readability, both evaluations are treated independently, complete with results, rationales and supplementary details. The set of participants was

consistent throughout.

Before the evaluation was realised, usability and technical testing were performed to remove potential errors.

Participants

A total of 10 participants, five women and five men in their 20s, were invited to the evaluation. Seven out of 10 participants had previous experience with VR. However, their experience was usually very little, and most of them mentioned trying VR only one time before this test. The participants were all students of Aalborg University in Denmark, some from the Architecture and Design and the Urban Design studies programmes, with the purpose of gathering participants with little to no VR experience and no knowledge of the TC.

The reason for not evaluating South African learners yet, although these learners would also originate from a range of different cultural settings, was to get as unbiased data as possible to better unravel to what degree VR contributed to a potential improved understanding of both the community ICH and brewing practice.

Day one: VR playthrough and experience sharing (evaluating contextual experiences)

Procedure

On the first day of the evaluation, the participants were asked to perform a VR playthrough of the prototype. Following the playthrough, we interviewed the participants on their new TC experience and organised a paired collaborative review. This was done to get insights into how participants perceived their experience and what kind of impact it had.

After the participants gave consent, the procedure of the experiment was explained to the participants, and they were handed the VR headset and controllers and were directed to a specific part of the room. The application was started and they were taken inside of the virtual environment. No further instructions were given to the participants unless a problem occurred that prevented them from continuing the playthrough. During the VR playthrough the participants' interactions were videorecorded inside and outside of the simulation. See Figure 5 showing recordings from outside and inside VR.

After finishing the playthrough, the participants were asked to sit down and participate in a semi-structured interview, which was videorecorded. The participants were presented with questions regarding their contextual and emotional experience as well as their perception of the narrative.

Following the interview, a collaborative review was conducted to allow participants to more easily share and brainstorm their experiences with their friends or colleagues who had also participated. After the participants were gathered into pairs, they were given a list of topics on

Figure 5
The figure shows; left: the video recording of a participants interacting in the prototype, and the right side shows the in-game recording synchronized.

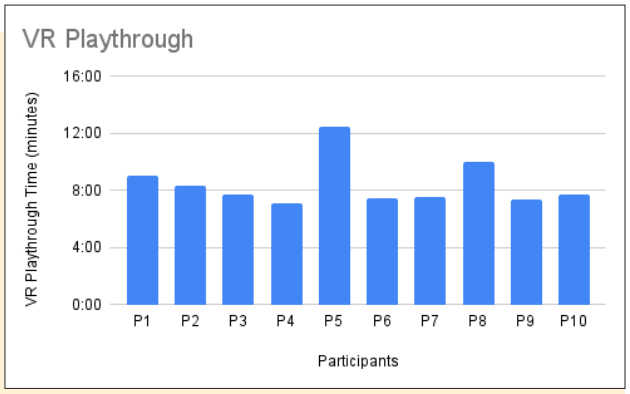

Figure 6
The figure shows the simulation completion times per participant.

different aspects of the VR experience to talk about with each other while being videorecorded. If the researcher noticed any interesting comments, they further prompted the participants for an improved understanding.

Data analysis

The qualitative data was analysed using a thematic analysis approach, described by Braun and Clarke (2006, 79) as a method for 'identifying, analysing and reporting patterns (themes) within data'. These themes present important findings in regard to the research question by showing a patterned response or meaning within the data. Thematic analysis goes beyond the surface meaning of the data, recognising and examining underlying ideas and assumptions. This method was used to analyse and code interview data on a deeper level as well as to extract relevant information and hidden meanings.

Results

In general, all participants were able to complete the playthrough without need for assistance. The completion times per participant are visible in Figure 6 below, showing that the playthrough lasted an average of eight and a half minutes and with no major outliers.

In the following section, quotes are used to support our findings and show insight into participants' personal experience. Each quote belong to a specific participant (P1–P10) and is taken either from their post-interview (denoted by a '-p') or their collaborative review (denoted by a '-c'). For example, (P2-p) is a quote from the second participant's post-interview, whereas (P2-c) is a quote from the same participant's collaborative review.

Interaction with VR

Despite participants' absence of experience with VR gameplay and lack of knowledge on the topic of this specific ICH, participants had no issue progressing through the playthrough on their own. During the playthrough, participants understood the tasks and quickly picked up the affordances of VR and the application.

> I have never brewed beer and I've never tried VR before, and I was confused as to what I had to do [...] But then eventually I saw the green lights [signifiers], and then I was like, that's what's going on [...] Once you get the hang of it, it's actually quite easy. (P1-p)

The interactions during the beer brewing highly engaged the participants, resulting in deeper immersion and embodiment:

> My favourite scene [was] the brewing beer part because you have to interact with all these kinds of materials and you have to understand, okay, what am I doing next? (P3-c)

On the other hand, having high engagement during the outside scene resulted in a lack of focus on details within the environment, where participants could not recall their surroundings while brewing:

> When I got the hang of it, I was so immersed; everything around me was blurred. [...] I wanted to spend more time taking it in but also I was curious what would happen when I finished the task. (P8-c)

Experiences of community and ICH

In general, participants expressed a positive attitude towards the experience as a whole. The environment was associated with positive emotions, such as peace and calmness:

> I liked the outside the most, children playing, it was very peaceful and you felt calm. (P7-c)

The participants enjoyed the brief interactions with the community so much that they often wanted more of them, expressing the need for a brewing companion:

> Felt kinda on my own; also, in real life I would like someone to guide me, have the experience with me. (P10-p)

The inside scene provided the sought-after interactions with the community, which in turn made the participants feel a stronger connection to the community:

> Drinking with, I suppose, the elders of the community. In that way I felt connected. (P3-p)

This community aspect also increased their interest:

> In the end there was a closer reference to how they perceive life and I suppose religion too and that was thought provoking. (P8-p)

This connection was also further strengthened when the participants identified as part of the community, taking on specific roles in the community, such as brewer or new tribe member:

> I was a part of a tribe [...] It made me feel special that I was part of something bigger for the community. (P7-p)

By taking on this role and contributing to the community, the participants felt special and that their actions meaningful:

> I definitely felt like I was contributing to something. Taking part in a tradition. (P1-p).

It seemed the participants grasped the importance of safeguarding ICH and supported it, without being introduced to it beforehand:

> So, you're doing this really important thing for your community [brewing beer] to keep the tradition going [...] It seemed like something that they had been doing for hundreds of years, and now you got to be a part of it. And that was really special, I guess you, you were chosen to do this. (P2-p)

In general, participants associated positive emotions with the community members, leading them to perceive the community as friendly and supportive:

> They all seem friendly. There was a good atmosphere. (P3-c)

> I just got to this village. I didn't have a home, but they were kind enough to welcome me in the village. (P5-p)

This led to participants' increased interest in the community and encouraged them to explore further:

> I wanted to explore more, look around more, [see] what they did on the field, the ox, the kids playing. (P8-p)

Without receiving any explicit explanations, participants correctly perceived a hierarchy during the inside scene, from the seating arrangements and order of drinking.

> I think maybe a feeling of mutual respect. If the man who took the first sip of the beer is more important than the others [...] because he took the first sip [...] and then I was the last person. (P1-c)

Furthermore, the participants got a deeper understanding of the culture, as they correctly perceived the hut as a privileged location and the ceremony itself as a sacred or special event. The participants accredited this to the presence of only a few, male, members of the community and the separation from the rest of the community, as well as sharing the drink. Two participants assessed this hierarchy:

> Maybe also celebration, which you said, but maybe only the higher-ups actually. 'Cause we were only what? Six people. (P4-c)

> And we all drank from the same cup, yeah. We weren't drinking from different cups. So it was obviously something of a ritual. (P3-c)

Reflections on the collaborative review

During the collaborative review, participants felt nervous at first, but after a while, a productive conversation began. Participants expressed their opinions more freely and could compare and discuss their different points of view. They were often surprised by the difference in their interpretations of the experience and proceeded to explain their stance to their partner. Participants were also not afraid to agree with each other and helped each other reach conclusions. The collaborative review gave participants reassurance and understanding to express themselves fully and connect over their experience. Multiple opinions were uncovered during the reviews that the participants did not mention during the individual interviews.

Day two: evaluating processual learning transfer through a physical re-enactment of beer brewing

The following day the participants were asked to re-create their VR experience in real life, which we term 're-enactment'. The participants were unaware of this succeeding evaluation day so that it would not influence them to place emphasis on the processual aspects. We were fortunate to recruit all the same participants again.

We were inspired by a study by Lohre et al. (2020), who studied how a VR surgical simulator was compared to a traditional learning method by having participants complete the surgical task in real life. During this process, the skill-transfer success was measured by a developed laboratory metric, verbal answers and time of task completion. We also clearly were inspired by the works on developing hands-on master–apprentice workshops by Karakul (2015), in which the author states that

> the aim of conservation is to sustain both the physical and intangible aspects of historical buildings and to transfer them to the future [...] Unfortunately, they have not hitherto been able to find an appropriate forum for the transmission of their skills to the current generation. (141)

Therefore, the method of re-enactment was chosen to evaluate the skill transfer of the VR application to a real-life scenario.

Re-enactment method and procedure

In our context, we are mostly interested in the qualitative outcomes of the re-enactment; it was not expected that users would memorise the procedure completely after one playthrough. Therefore, the overall comprehension of the process was more important, and in learning settings the playthrough can always be repeated, if needed. This meant asking the participants to use the 'thinking-out-loud' method to get a better understanding of their thought process. The thinking-out-loud method is where the participant is asked to explain the thought process behind their actions while performing them. The participants were observed and prompted to explain their actions in case they did not provide enough verbal information.

During this re-enactment evaluation, participants were given physical equipment representing the 3D objects they interacted with during the simulation. All tools were accessible at all times during the re-enactment, as opposed to being available depending on the day, as in the application. See Figure 7 for an annotated photo from the re-enactment set-up.

Furthermore, it was important to focus on whether

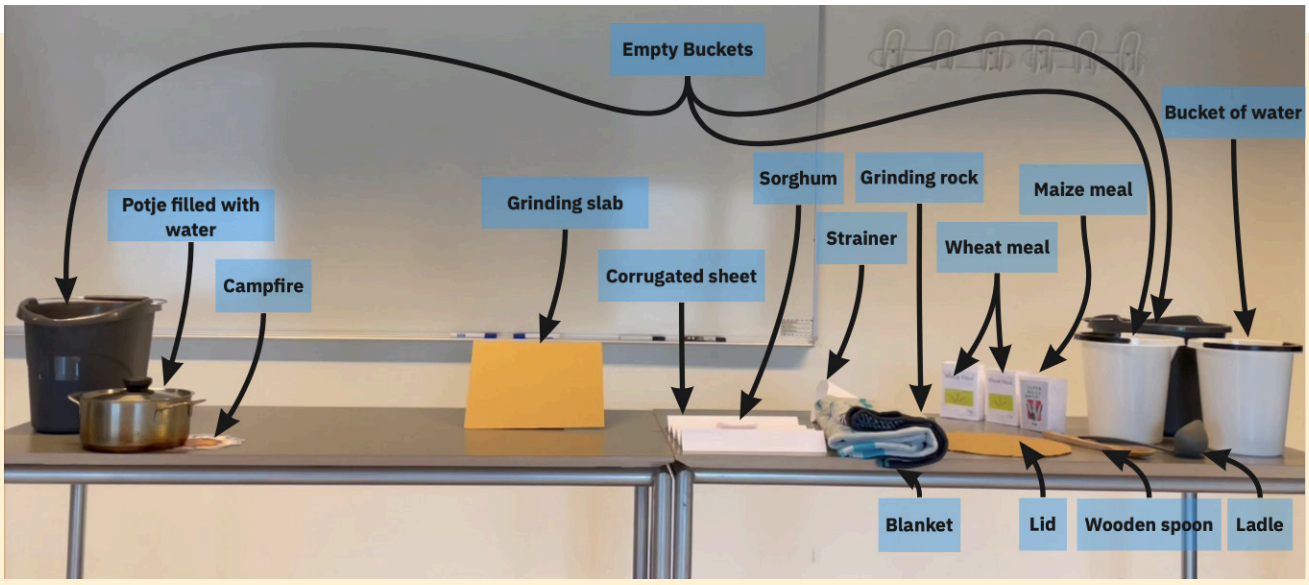

Figure 7
The figure shows the reenactment setup with annotation.

the learners could transfer the concepts of brewing, rather than merely visually recollecting the quantifiable procedural steps. For that reason, all objects – besides the maize meal, wheat meal and the wooden spoon – differed from their VR counterparts and therefore further evaluated the participants' ability to transfer the functionality of the equipment from VR to a real setting in the context of the TC as a practice.

Consequently, participants had to rely more on an understanding gained through the VR experience than just remember the order of tool usage. The participants were videorecorded as they attempted to re-enact the procedure from the day before; they did not receive help from the researchers.

Data analysis

The video footage from the re-enactment was viewed and analysed by splitting the whole brewing process into individual steps and comparing the different phases across participants, especially their performance and verbal comments.

Results

In terms of the re-enactment of the brewing, the participants were performing really well.

Figure 8 shows the completion times for the re-enactment per participant, which is quite short given the many pieces of equipment available and the fact that the majority of the participants demonstrated knowing about *all* the actions that needed to be performed.

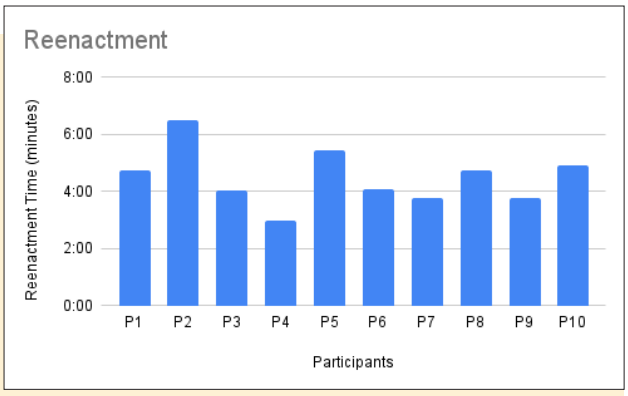

Figure 8
The figure shows the reenactment completion times per participant.

While some got confused by the order at a certain phase, they also in many cases corrected themselves. They added the correct ingredients, covered up the mixture and filtered it in the end, only sometimes forgetting to stir the mixture when necessary, which might be easier to remember when working with real-life ingredients.

Furthermore, it must be emphasised that most of the participants were novel users of VR, without any knowledge of sorghum beer brewing, and they only had a single playthrough of the procedure, which lasted on average only eight and a half minutes (including the hut scene). The participants did not know about the re-enactment beforehand, meaning they went through the experience without focusing on having to re-create it the next day. Additionally, during the re-enactment, the users had access to all the equipment and ingredients at once. This way, the re-enactment was based more on what participants remembered – for example, participants not noticing the water inside one of the buckets and consequently asking for it – instead of them automatically using everything accessible to them during each day. As some of the equipment had to be reused during the brewing process, users had to remember not only the correct order of the steps but also what the steps consisted of. Often, when participants made a mistake, they pondered about the correct step but ultimately opted for a different, incorrect one. In this way the method itself was useful to isolate gaps of understanding, and reviewing the video material made these phases very clear.

During the re-enactment, it was clear that the participants drew from the VR experience when re-creating the brewing steps. This was observed through participants' verbal reflection on the VR playthrough, for example, remembering the addition of the ingredients through the interaction with the virtual woman or describing the events that happened in VR:

> The lady came over and gave me two of these [ingredients], one wheat and one maize. (P3)

> Yesterday I put this [metal sheet] on the ground. (P8)

> I remember this part very well from the first step. (P7)

Often, participants stopped and wondered about the correct way to proceed, trying to recall their memories of the playthrough while also showing genuine care about

getting it right:

> I will take my time. (P6)

Similarly, one of participant performed hand gestures of the steps, with eyes closed, to remember better. This also suggests participants learned the procedure through the embodied interactions that VR enables.

Transfer was achieved as participants were able to map the process learned in VR into a real-life context, often adapting their knowledge appropriately – for example, boiling the mixture itself instead of adding boiling water or grinding the sorghum straight into the bucket instead of onto a sheet and then adding it in.

Overall, participants remembered the main principles of beer brewing – that is, making sure the mixture is boiled, the beer is left to ferment overnight and strained before it is served. Therefore, even if the participants did not manage to remember the entire procedure correctly, they still would have ended up with some kind of beer mixture in the end, as they understood the main concepts.

Discussion

Our results point to users having a high level of engagement, which corresponds with the previous findings of VR being an engaging medium (Dede 2009; Allcoat and Muhlenen 2018). This was caused not only by the VR interactions but also the content within the VR experience, since the users mentioned enjoying the brewing process itself. Participants described the experience as fun, as it was embodied and immersive:

> It was fun to actually do it.I (P4)

> It was a different kind of experience [...] not like a computer. (P8)

The finding that embodiment and immersion increased enjoyment supports the findings from previous studies (Allcoat and Muhlenen 2018; Kavanagh et al. 2017).

Surprisingly, albeit being novice users of VR and having little to no knowledge about beer brewing in general (and none about umqombothi), the participants had few problems playing through the prototype. They understood the signifiers, which guided them through the brewing process, and managed to finish the entire playthrough in a relatively short amount of time. This suggests the efforts to create a simple, easy-to-comprehend application that even novel VR users can understand was successful.

An increase in positive emotions was observed after the playthrough, which corresponds with the current findings (Allcoat and Muhlenen 2018; Kavanagh et al. 2017). Participants described the experience as 'fun' and the environment as 'happy' and 'peaceful'. During the post-interview, the participants seemed excited and enthusiastic when talking about their experience. They also mentioned perceiving the community members as 'helpful' or 'friendly', even describing the drinking ritual as 'the equivalent of having a beer with the boys'. This was a result of the combination of the use of VR as a medium and the virtual environment and the atmosphere of the virtual community. These findings suggest users associated the positive feelings experienced during the VR playthrough with the TC and the community members. Consequently, these gratifying emotions connected with the culture could lead to thinking more creatively, flexibly and in a more integrated way, leading users become more open to information, which is beneficial for learning (Fredrickson 2003).

Sparking an interest in ICH

One of the most interesting findings of our study was how much users' curiosity increased following the VR experience. Unlike studies that conducted their research on museum visitors (Schofield et al. 2018; Ringas et al. 2022; Hauser et al. 2022), who came to the experiment with the motivation to learn and had a learning experience before the VR playthrough, our participants were students with little to no previous knowledge and no specific interest on the topic. This is why it was surprising when the majority of the participants mentioned wanting to 'know more' when talking about the environment, the brewing process, the ceremony and the inhabitants. The experience sparked interest in the culture, as participants talked about interacting more with the community and the desire to know more. When asked about experiencing the event in real life, again, most participants enthusiastically expressed their desire to do so. The increased interest in the process as well as the community is a good indicator that the VR experience has the potential to safeguard these traditions as suggested by UNESCO (b, 2003).

Conclusion

The study contributes to the research agenda of digitally safeguarding ICH and the TC of umqombothi beer brewing by designing and implementing a fully functional VR prototype as well as evaluating it on inexperienced VR users, unfamiliar with the specific ICH. Furthermore, this article acknowledges the lack of evaluation methods for assessing the transfer from digital TC solutions into the physical reality and addresses this issue by proposing a re-enactment style evaluation, which explores participants' ability to re-create TC practice in real-life context.

TC is a unique category of ICH, as it not only consists of a specific procedure but also depends heavily on the context and tradition surrounding it. One cannot be without the other: if either the craft or the cultural importance would be disregarded, we would lose a piece of the heritage. Therefore, the evaluation was carefully planned to look at not only the cultural understanding of the participants (Day 1 of the evaluation) but also the interpretation and recollection of the procedure of the TC (Day 2).

Through the evaluation of the contextual experiences, we found an increased interest in the community and their traditions, a connection established with the community members, a positive perception of the craft and the experience in general and the desire to undergo the experience in real life. The re-enactment evaluation also served as evidence for skill transfer from VR to real life, as even novice users of VR successfully re-created the majority of the beer-brewing procedure correctly after one short playthrough.

By designing, implementing and evaluating ICH and procedural aspects of TC, specifically umqombothi beer brewing, we hope to inspire further research into how VR can serve as a strong educational medium for ICH, especially TC. In the case of this project, the future holds two aspects: how it is received by South African learners, and how ICH can promote an interest in – or even an 'enrichment' of – STEM education.

REFERENCES

- Allcoat, Devon, and Adrian von Mühlenen. 2018. 'Learning in virtual reality: effects on performance, emotion and engagement'. *Research in learning technology* 26.
- Bowman, Doug A., Larry F. Hodges, Don Allison and Jean Wineman. 1999. 'The educational value of an information-rich virtual environment'. *Presence: teleoperators & virtual environments* 8, no. 3: 317–331.
- Braun, Virginia, and Victoria Clarke. 2006. 'Using thematic analysis in psychology'. *Qualitative research in psychology* 3, no. 2: 77–101.
- Carre, Anne Laure, Arnaud Dubois, Nikolaos Partarakis, Xenophon Zabulis, Nikolaos Patsiouras, Elina Mantinaki, Emmanouil Zidianakis, Nedjma Cadi, Evangelia Baka, Nadia Magnenat Thalmann, Dimitrios Makrygiannis, Alina Glushkova and Sotirios Manitsaris. 2022. 'Mixed-reality demonstration and training of glassblowing'. *Heritage* 5, no. 1: 103–128.
- Christou, Chris. 2010. 'Virtual reality in education'. In *Affective, interactive and cognitive methods for e-learning design: creating an optimal education experience*, edited by Aimilia Tzanavari, Nicolas Tsapatsoulis and IGI Global, 228–243. Hershey, PA: Information Science Reference.
- Dede, Chris. 2009. 'Immersive interfaces for engagement and learning'. *Science* 323, no. 5910: 66–69.
- Donkin, Lucy. 2001. 'Crafts and conservation: Synthesis report for ICCROM'. https://www.iccrom.org/publication/crafts-and-conservation-synthesis-report-iccrom
- Durlach, Nathaniel, Anne S. Mavor and Gregory B. Newby. 1996. 'Virtual reality: scientific and technological challenges'. *Library and information science research* 18, no. 3: 278–280.
- Fredrickson, Barbara L. 2003. 'The value of positive emotions: the emerging science of positive psychology is coming to understand why it's good to feel good'. *American scientist* 91, no. 4: 330–335.
- Hardy-Vallee, Benoit, and Nicholas Payette. 2008. *Beyond the brain: embodied, situated and distributed cognition*. Newcastle: Cambridge Scholars.
- Hauser, Hansgeorg, Cynthia Beisswenger, Nikolaos Partarakis, Xenophon Zabulis, Ilia Adami, Emmanouil Zidianakis, Andreas Patakos, Nikolaos Patsiouras, Effie Karuzaki, Michalis Foukarakis, Aggeliki Tsoli, Ammar Qammaz, Antonis Argyros, Nedjma Cadi, Evangelia Baka, Nadia Magnenat Thalmann, Brenda Olivias, Dimitrios Makrygiannis, Alina Glushkova, Sotirios Manitsaris, Vito Nitti and Lucia Panesse. 2022. 'Multimodal narratives for the presentation of silk heritage in the museum'. *Heritage* 5, no. 1: 461–487.
- Hlangwani, Edwin, Janet Adeyinka Adebiyi, Wesley Doorsamy and Oluwafemi Ayodeji Adebo. 2020. 'Processing, Characteristics and Composition of *Umqombothi* (a South African Traditional Beer)'. *Processes* 8, no. 11: 1451.
- Isa, Wan Malini Wan, Nor Azan Mat Zin, Fadhilah Rosdi and Hafiz Mohd Sarim. 2019. 'Serious game design for Terengganu brassware craft heritage'. In *2019 IEEE Conference on Graphics and Media (GAME)*, edited by IEEE, 13–17. Piscataway, NJ: IEEE.
- Johnson-Glenberg, Mina C. 2018. 'Immersive VR and education: embodied design principles that include gesture and hand controls'. *Frontiers in robotics and AI*: 81.
- Karakul, Ozlem. 2015. 'An integrated methodology for the conservation of traditional craftsmanship in historic buildings'. *International journal of intangible heritage* 10: 135–144.
- Karuzaki, Effie, Nikolaos Partarakis, Nikolaos Patsiouras, Emmanouil Zidianakis, Antonios Katzourakis, Antreas Pattakos, Danae Kaplanidi, Evangelia Baka, Nedjma Cadi, Nadia Magnenat-Thalmann, Chris Ringas, Eleana Tasiopoulou and Xenophon Zabulis. 2021. 'Realistic virtual humans for cultural heritage applications'. *Heritage* 4, no. 4: 4148–4171.
- Kavanagh, Sam, Andrew Luxton-Reilly, Burkhard Wuensche and Beryl Plimmer. 2017. 'A systematic review of virtual reality in education'. *Themes in science and technology education* 10, no. 2: 85–119.
- Kennedy, Thalia. 2010. 'Safeguarding traditional craftsmanship: a project demonstrating the revitalisation of intangible heritage in Murad Khane, Kabul'. *International journal of intangible heritage* 5: 74–85.
- Konfo, Christian Tetede Rodrigue, Nicodème Worou Chabi, Edwige Dahouenon-Ahoussi, Martial Cakpo-Chichi, Mohamed Mansourou Soumanou and Dominique Coco Kodjo Sohounhloue. 2021. 'Improvement of African traditional sorghum beers quality and potential applications of plants extracts for their stabilization: a review'. *Journal of microbiology, biotechnology and food sciences*: 190–196.

- Kurin, Richard. 2004. 'Safeguarding intangible cultural heritage in the 2003 UNESCO Convention: a critical appraisal'. *Museum international* 56, no. 1–2: 66–77.
- Labrador, Angela M. 2022. 'Integrating ICH and education: a review of converging theories and methods'. *International journal of intangible heritage* 17: 18–36.
- Lohre, Ryan, Aaron J. Bois, George S. Athwal and Danny P. Goel. 2020. 'Improved complex skill acquisition by immersive virtual reality training: a randomized controlled trial'. *The journal of joint and bone surgery* 102, no. 6: e26.
- Lues, J. F. R., B. K. Ikalafeng, M. Maharasoa, K. Shale and E. Pool. 2009. 'Brewing and consumptions practices of indigenous traditional beer in a typical South African semi-urban area: indigenous knowledge systems, health, illness and healing'. *Indilinga African Journal of Indigenous Knowledge Systems* 8, no. 2: 163–174.
- Lyumugabe, F., J. Gros, J. Nzungize, E. Bajyana and P. Thonart. 2012. 'Characteristics of African traditional beers brewed with sorghum malt: a review'. *Biotechnologie, agronomie, société et environnement* 16, no. 4: 509–530.
- McAllister, Patrick. 2003. 'Culture, practice, and the semantics of Xhosa beer-drinking'. *Ethnology*: 187–207.
- McAllister, Patrick. 2004. 'Domestic space, habitus, and Xhosa ritual beer-drinking'. *Ethnology*: 117–135.
- Mei, Huang Hsiu, and Liaw Shu Sheng. 2011. 'Applying situated learning in a virtual reality system to enhance learning motivation'. *International journal of information and education technology* 1, no. 4: 298–302.
- Mlambo, Victor. 2018. 'An overview of rural-urban migration in South Africa: its causes and implications'. *Archives of business research* 6, no. 4: 63–70. https://doi.org/10.14738/abr.64.4407.
- Ossai, Ngozi Blessing. 2010. 'African indigenous knowledge systems (AIKS)'. *Simbiosis* 7, no. 2.
- Partarakis, Nikolaos, Nikolaos Patsiouras, Thodoris Evdemon, Paraskevi Doulgeraki, Effie Karuzaki, Evropi Stefanidi, Stavroula Ntoa, Carlo Meghini, Danai Kaplanidi, Maria Fasoula and Xenophon Zabulis. 'Enhancing the educational value of tangible and intangible dimensions of traditional crafts through role-play gaming'. In Interactivity and game creation: 9th EAI international conference, ArtsIT 2020, Aalborg, Denmark, December 10–11, 2020: proceedings, edited by Anthony Lewis Brooks, Eva Irene Brooks and Duckworth Jonathan, 243–254. Cham: Springer.
- Partarakis, Nikolaos, Xenophon Zabulis, Margherita Antona and Constantine Stephanidis. 2020. 'Transforming heritage crafts to engaging digital experiences'. In *Visual computing for cultural heritage*, edited by Fotis Liarokapis, 245–262. Cham: Springer.
- Ramnarain, Umesh. 2021. 'Exploring embodied, situated, and distributed cognition'. *Evidence-based inquiries in ethno-STEM research: investigations in knowledge systems across disciplines and transcultural settings*, edited by Iman C. Chahine and Josef De Beer, 309–321. Charlotte, NC: Information Age.
- Ringas, Christodoulos, Eleana Tasiopoulou, Danae Kaplanidi, Nikolaos Partarakis, Xenophon Zabulis, Emmanouil Zidianakis, Andreas Patakos, Nikolaos Patsiouras, Effie Karuzaki, Michalis Foukarakis, Ilia Adami, Nedjma Cadi, Evangelia Baka, Nadia Magnenat Thalmann, Dimitrios Makrygiannis, Alina Glushkova, Sotirios Manitsaris, Vito Nitti and Lucia Panesse. 2022. 'Traditional craft training and demonstration in museums'. *Heritage* 5, no. 1: 431–459.
- Rodil, Kasper, and Heike Winschiers-Theophilus. 2018. 'Why is she naked?: an iterative refinement of the digitisation of ICH with the OvaHimba tribe in Namibia'. *International journal of intangible heritage* 13: 144–154.
- Rodil, Kasper, and Matthias Rehm. 2015. 'A decade later: looking at the past while sketching the future of ICH through the tripartite digitisation model'. *International journal of intangible heritage* 10: 47–60.
- Rossau, Ingeborg Goll, Milo Marsfeldt Skovfoged, Jedrzej Jacek Czapla, Miroslav Kalinov Sokolov and Kasper Rodil. 2019. 'Dovetailing: safeguarding traditional craftsmanship using virtual, reality'. *International journal of intangible heritage* 14: 103–120.
- Schofield, Guy, Gareth Beale, Nicole Beale, Martin Fell, Dawn Hadley, Jonathan Hook, Damian Murphy, Julian Richards and Lewis Thresh. 2018. 'Viking VR: designing a virtual reality experience for a museum'. In *Proceedings of the 2018 Designing Interactive Systems Conference*, 805–815. n.p.: ACM.
- Selmanovic, Elmedin, Selma Rizvic, Carlo Harvey, Dusanka Boskovic, Vedad Hulusic, Malek Chahin and Sanda, Sljivo. 2020. 'Improving accessibility to intangible cultural heritage preservation using virtual reality'. *Journal on computing and cultural heritage* 13, no. 2: 1–19.
- Skovfoged, Milo Marsfeldt, Martin Viktor, Miroslav Kalinov Sokolov, Anders Hansen, Helene Høgh Nielsen and Kasper Rodil. 2018. 'The tales of the Tokoloshe: Safeguarding intangible cultural heritage using virtual reality'. In *Proceedings of the Second African Conference for Human Computer Interaction: Thriving Communities*, edited by Heike Winschiers-

Theophilus, 1–4. n.p.: ACM.

- UNESCO. 2022a. 'Kit of the Convention for the Safeguarding of the Intangible Cultural Heritage'. Accessed 30 August 2022. https://ich.unesco.org/en/kit#2.
- UNESCO. 2022b. 'Text of the Convention for the Safeguarding of the Intangible Cultural Heritage'. Accessed 30 August 2022. https://ich.unesco.org/en/convention.
- UNESCO. 2022c. 'Traditional craftsmanship'. Accessed 30 August 2022. https://ich.unesco.org/en/traditional-craftsmanship-00057.
- XR Today. 2022. 'Virtual Reality Statistics 2022'. Accessed 30 August 2022. https://www.xrtoday.com/virtual-reality/virtual-reality-statistics-2022/?fbclid=IwAR3fPNprRTS5CtmJ5ul176TMmk6jEj5mYtaSzh768NKKn3aSPlK14r4s0Ig.
- Zabulis, Xenophon, Nikolaos Partarakis, Carlo Meghini, Arnaud Dubois, Sotiris Manitsaris, Hansgeorg Hauser, Nadia Magnenat Thalmann, Chris Ringas, Lucia Panesse, Nedjma Cadi, Evangelia Baka, Cynthia Beisswenger, Dimitrios Makrygiannis, Alina Glushkova, Brenda Elizabeth Olivas Padilla, Danae Kaplanidi, Eleana Tasiopoulou, Catherine Cuenca, Anne-Laure Carre, Vito Nitti, Ilia Adami, Emmanouil Zidianakis, Paraskevi Doulgeraki, Effie Karouzaki, Valentina Bartalesi and Daniele Metilli. 2022. 'A representation protocol for traditional crafts'. *Heritage* 5, no. 2: 716–741.