Exploration Systems

Using Experience Technologies in Automated Exhibition Sites

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BY
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AALBORG UNIVERSITY
DENMARK

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PROFILE

Rameshnath Krishnasamy received his master's degree in information technologies and interactive digital media from Aalborg University in 2012. He started working as a teaching assistant upon receiving his degree, assuming the position of a lecturer and supervisor and later research assistant. In 2016, he became a Ph.D. fellow in the Department of Communication and Psychology at Aalborg University, part of the research unit Center for Interactive Digital Media and Experience Design. In the years leading to his Ph.D. candidature, his focus was primarily on *human–computer interaction* and *game design*. However, over the years, his interests gravitated toward *experience technologies*: computer technologies as an evocative medium to create meaningful user experiences.

In his Ph.D. thesis, he examined the use of emerging technologies to create engaging user experiences in automated exhibition sites by designing *exploration systems*—mobile applications designed to instigate curiosity and foster exploratory user behavior inspired by motivational qualities from adventure games and playful interactions.

ENGLISH SUMMARY

User experiences in museum exhibitions are influenced by the bicameral concepts of enlightenment and experience. In this study, enlightenment and experience are examined in a context in which the user experience must be facilitated through computer-mediated technologies in a situation that requires self-guidance—an automated exhibition site, i.e., exhibition sites that operate without human personnel.

In this thesis, the concepts of enlightenment and experience are framed within the human–computer interaction research arena to design and evaluate user experiences in exhibition sites void of human personnel. The work presented in this study conceptualizes and implements a framework that expands the use of game design and experience technologies to support users in exhibition sites by drawing parallels between museum exhibitions and adventure games to form a knowledge playground. Within this framing, the central terms, curiosity and exploration, to design digital experiences that synergize with physical exhibition sites are formed.

In this study, it was hypothesized that experience technologies (i.e., computer technologies as mediums for user experiences) could be utilized to mediate the dynamics of enlightenment (i.e., the didactic, educational, factual, forming, and informative) with experience (i.e., the emotional, engaging, entertaining, imaginative, involving, narrative, and playful) through curiosity and exploration. From this hypothesis, the research question is: How can experience technologies mediate explorative exhibitions in automated sites?

Through various explorative studies, two mobile applications were developed and tested to investigate this framework utilization in field studies. *Explore the Redoubt* is a context-aware mobile game designed to motivate users to explore an automated exhibition site through game design. *ARATAG* is a wayfinding application that uses elements from games to provide trails of informative content through an exhibition site.

The contribution of this thesis shows how computer-mediated technologies can facilitate explorative experiences in automated exhibition sites, through curiosity and exploration.

DANISH RESUME

Brugeroplevelser i museumsudstillinger skabes og udvikles i et spændingsfelt mellem en opfattelse af museet som et middel til befolkningens oplysning og som et mål for besøgendes oplevelser, her beskrevet som koncepterne oplysning og oplevelse. I afhandling undersøges oplysning og oplevelse i en kontekst, hvor brugeroplevelsen skal faciliteres gennem computermedierede teknologier i ubemandede udstillingssteder - det vil sige udstillingssteder, der opererer uden personale.

I denne afhandling er begreberne oplysning og erfaring indrammet inden for forskningsfeltet human-computer interaction for at designe og evaluere brugeroplevelser på udstillingssteder uden personale. Det arbejde, der præsenteres i denne undersøgelse, konceptualiserer og implementerer et rammeværk, der udvider brugen af spildesign og oplevelsesteknologier til at støtte brugere på udstillingssteder ved at drage paralleller mellem museumsudstillinger og eventyrspil for at danne en videnslegeplads. Inden for denne ramme opstilles de centrale termer, nysgerrighed og udforskning, for at designe digitale oplevelser, der fungerer i synergi med fysiske udstillingssteder.

I denne undersøgelse blev det antaget, at oplevelsesteknologier (dvs. computerteknologier som medier for brugeroplevelser) kunne bruges til at mediere oplysningens dynamik (dvs. det didaktiske, pædagogiske, faktuelle, formende og informative) med oplevelse (dvs. det emotionelle, engagerende, underholdende, fantasifulde, involverende, fortællende og legende) gennem nysgerrighed og opdagelse. Ud fra denne hypotese opstilles forskningsspørgsmålet: Hvordan kan oplevelsesteknologier formidle eksplorative udstillinger på ubemandede udstillingssteder?

Gennem forskellige eksplorative undersøgelser blev to mobile applikationer udviklet og testet for at undersøge dette rammeværks anvendelse i feltstudier. Explore the Redoubt er et kontekstbevidst mobilspil designet til at motivere brugere til at udforske et ubemandet udstillingssted gennem spildesign. ARATAG er en wayfinding applikation, der bruger elementer fra spil til at give spor af informativt indhold gennem et udstillingssted.

Bidraget fra denne afhandling viser, hvordan computermedierede teknologier kan facilitere eksplorative oplevelser på ubemandede udstillingssteder, gennem nysgerrighed og opdagelse.

PREFACE

This thesis is based on a Ph.D. project in the Department of Communication and Psychology at Aalborg University. It comprises 10 original papers, two software applications, a physical board game, and the summary that frames the project's hypothesis, research questions, research design, and summary of the contributions. Reprints of published papers are included and referenced in this thesis. The materials were resized to fit the layout of the thesis without alterations to the content or layout. The thesis is written in partial fulfillment of the requirements for a Ph.D. degree from Aalborg University.

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Most importantly, I would like to thank my supervisor, Professor Jens F. Jensen, for seeing me through the Ph.D. project. Sparring with you yielded new perspectives on my thesis. Furthermore, your systematic approach to analysis and information representation has influenced my way of thinking.

I thank the people I collaborated with during this period and the Our Museum research program for making this entire journey possible.

I would also like to thank all my colleagues at Aalborg University, especially those in the Center for Interactive Digital Media and Experience Design and the technical administrative personnel at the Department for Communication and Psychology. Too many names to include here, but thanks to each one of you.

A big thanks to the Exertion Games Lab at RMIT University for hosting me as a visiting researcher. My stay there has certainly helped shape this thesis. Much love to the entire XGL-squad for an amazing time together in the lab and wild.

A special thanks to Kasper Løvborg Jensen for introducing me to the world of research and launching me into the HCI research arena, and to Claus Rosenstand, for introducing me to the research group of which I am a part. Also, a special thanks to Peter Vistisen, who provided invaluable insight and feedback for my study and even more for being a good friend since I started my academic journey many years ago. It's all in the reflexes!

Finally, I thank my family and friends for all the antics, encouragement, and support throughout the period. Houlkær is with me, wherever I may roam!

CONTRIBUTIONS

The main body of this thesis comprises a summary and 10 papers' contributions. The summary introduces and motivates the research, presents the contributions, and discusses the limitations and implications of the work. The papers were published as follows:

[P01] Vistisen, P., Østergaard, C. P., & Krishnasamy, R. K. (2017). Adopting the unknown through the known: Supporting user interaction of non-idiomatic technologies in exhibitions through known idioms of conventional technologies. *The Design Journal, European Academy of Design*, *20*, S3696–S3706. https://doi.org/10/ghzc7v

[P02] Vistisen, P., Selvadurai, V., & Krishnasamy, R. K. (2020). Applied gamification in self-guided exhibitions: Lessons learned from theory and praxis. In O. E. Hansen, T. Jensen, & C. A. F. Rosenstand (Eds.), *Gamescope: The potential for gamification in digital and analogue places* (1st ed., Vol. 1). Aalborg Universitetsforlag. https://vbn.aau.dk/files/279738444/Applied_Gamification_Gamescope_Chapter.pdf

[P03] Krishnasamy, R., Khan, S., & Germak, C. (2018). Mixed reality game using bluetooth beacons for exhibitions. *Proceedings of the Conference on Electronic Visualisation and the Arts*, 39–40. https://doi.org/10/ghzc7t

[P04] Krishnasamy, R. (2018). Integrating smart objects into self-guided exhibitions: Challenges of supporting self-guided exhibitions through non-idiomatic technologies. *Proceedings of the 6th Workshop on Interacting with Smart Objects, 2082*(6), 17-22.

[P05] Khan, S., Krishnasamy, R., & Germak, C. (2018, August 14–18). Design challenges in promoting inclusion for cultural heritage contents through low-cost technology. *DS 91: Proceedings of NordDesign 2018, Linköping, Sweden.*

[P06] Krishnasamy, R. (2019). Towards game-guided exploration systems for self-facilitated exhibitions. *Proceedings of EVA London 2019 (EVA 2019)*, 164–171. https://doi.org/10.14236/ewic/EVA2019.32

[P07] Krishnasamy, R. (2019). Designing digital exploration games for automated exhibition sites. *Proceedings of the 12th European Conference on Game Based Learning*, 104. https://doi.org/10/ghzc7s

[P08] Madsen, K. M., & Krishnasamy, R. (2020). Our museum game: A collaborative game for user-centered exhibition design. In A. Brooks & E. I. Brooks (Eds.), *Interactivity, game creation, design, learning, and innovation* (Vol. 328, pp. 427–435). Springer International Publishing. https://doi.org/10.1007/978-3-030-53294-9_31

[P09] Krishnasamy, R., Selvadurai, V., & Vistisen, P. (2021). Designing context-aware mobile systems for self-guided exhibition sites. In A. Brooks, E. I. Brooks, & D. Jonathan (Eds.), *Interactivity and game creation* (Vol. 367, pp. 21–44). Springer International Publishing. https://doi.org/10.1007/978-3-030-73426-8_2

[P10] Krishnasamy R., & Vistisen P. (2022). Exploration game for automated exhibition sites: Design and evaluation of a mixed reality mobile application based on exploration and experiential learning for a self-guided cultural heritage site [Manuscript submitted for publication]. *ACM Transactions on Computer-Human Interaction.*

Through the course of the research period, two software systems and a physical board game have been developed:

[XTR] ***Opdag Skansen*—**mobile application for Android/iOS.

- Android http://noid.link/XTR-android
- iOS http://noid.link/XTR-ios

[ARA] ***ARATAG***—mobile application for Android/iOS.

- Android http://noid.link/ARA-android
- iOS http://noid.link/ARA-ios

[OMG] ***Our Museum Game***—a physical board game.

- Website https://museumga.me

STRUCTURE

The thesis comprises seven sections structured as follows:

SECTION 01: PRIMER introduces the research arena (HCI), agenda (enlightenment and experience), area of interest (automated exhibition sites), research perspectives (exploration via experience technologies), and concludes with the articulation of a hypothesis, the research question, and three sub-questions. Literature reviews and state of the art are presented and discussed throughout the entire section.

SECTION 02: SETUP lays out the research methodology by setting the scope and aims of the work. Then, the research design is presented to explain how the research question and sub-questions are addressed.

SECTION 03: FRAMES sets the theoretical framework for the thesis. The nature of technology's role and applications in exhibitions is analyzed, and the core concepts are discussed, specifically the context sensitivity of interaction in exhibitions. The importance of experience technology is discussed, and the concept is redefined to fit the perspective of studying exploration systems for exhibitions.

SECTION 04: STUDIES presents and summarizes the individual paper's contributions to the thesis.

SECTION 05: RESULTS discusses the limitations and implications of the research regarding existing work, and the research questions are revisited to form the conclusion. Finally, some perspectives for further work and research are given.

SECTION 06: REFERENCES presents a bibliography of all cited references.

SECTION 07: APPENDIX contains all appendix items, such as data captured, documents and paper contributions, and declarations of authorship.

OVERVIEW

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SECTION 01

Time moves in one direction, memory another. We are that strange species that constructs artifacts intended to counter the natural flow of forgetting.

William Ford Gibson

1. PRIMER

The area of interest in this thesis is experience technologies in a museum exhibition context and how they can be used as an approach for designing and developing exploration systems for exhibition sites. Its overall objective is to identify the criteria and principles for creating interactive digital systems for exhibitions positioned within the broader human–computer interaction research arena. This was achieved through a sequence of studies that collectively sought to expand and add to the existing field of knowledge within human–computer interactions in museum exhibitions. The contributions link the design and development of systems for exploration in exhibitions by generating knowledge about state-of-the-art technologies, emerging applications, and the resulting user experiences.

The following sections outline the background for the field of research leading to the theoretical positioning of this research project, the programmatic point of origin of this project, and the research question that confines the thesis. These sections establish the foundations for expanding the field and initializing the project through a working hypothesis, articulating the research questions and leading to the subsequent section detailing the design of the studies.

1.1. Research Arena: Human–Computer Interaction (HCI)

The world in which we live has become suffused with computer technologies. Over the past 50 years, computers have evolved from megalithic mainframes to personal computers into mobile companions and are currently seamlessly integrated into artifacts, materials, objects, and environments. In parallel with the physical form factor changing over time, so are their features, functions, and roles in our lives, impacting our lifestyles. The way we access information, act, and interact with and through ubiquitous and pervasive computing technologies has become a widespread phenomenon that infuses and influences our experiences. The result is a nebulous constellation of users and technologies with many aspects of everyday analog activities that have become infiltrated with digital layers and computer technologies. This is evident in the explosive growth in devices, applications, systems, tools, and other technological artifacts that strive to augment, extend, and support user experiences, interactions, and communications (Bell & Dourish, 2007; Harper, 2008; Jensen, 2011; Rogers, 2004).

The merger of human interaction mediated by computer technologies has become more apparent in applications that have emerged over the past years. For example, physical activity, such as running, can be extended with a narrative layer, augmented with game features, such as explorative elements, resource gathering, and utilizing the user's contextual and biometric data to offer both progress tracking and incentivizing and supporting exertion and a healthy lifestyle (Jensen et al., 2010; Kan et al., 2013). Or playing a game can involve trekking distances in physical places to collect items and interact with other players and motivate the player to explore areas that augment the physical place by linking it with digital spaces (Montola et al., 2009). Even traveling can be enriched through game-guided access to location-bound information through interactive scavenger hunts that utilize context-aware computing technologies that encourage, guide, and support users to explore in a playful way (Krishnasamy et al., 2010, 2011). The examples presented above demonstrate how computers have extended their technical capacity and computational capability far beyond their original purposes and can now roam wherever we may.

The development can be explained by Moore's[1] and Bell's[2] eponymous laws, which led to a gradual downscaling in form factor and an upscaling in numbers to constitute a cluster of increasingly diverse computing technologies. In the late 1980's and early 1990s, Mark Weiser and his colleagues at XEROX PARC envisioned a future where "the most profound technologies are those that weave themselves into the fabric of everyday life and disappear" (Weiser, 1991, p. 1). This vision guided entire research agendas that positioned computing machinery in a different paradigm, one in which the technology fades into the shadows and the user's interaction and experience is emphasized (Weiser, 1993). Today, the integration and coupling of user and machine has trail-blazed different types of computer mediated technologies, where applications emerge based on new paradigms, such as location-based and context-aware interactions, which link working lives, social lives, and personal entertainment (Harper, 2008), spanning areas such as healthcare, education, entertainment, tourism, banking, and governance (Bell & Dourish, 2007; Rogers, 2006; Weiser & Brown, 1997).

As a result of technological advancements, the technologies themselves have become tightly interwoven into the fabric of everyday life, radically transforming the way we live, work, and play. At the frontier of this development, HCI researchers are studying, creating, and testing prototypes of future computer technologies, systems, and digitally mediated experiences.

HCI as a tradition is defined as "a form of mediated communication between the end user and the system designer, who must structure the system so that it can be understood by the user, and so that the user can be led through a sequence of actions to achieve some end results" (Dourish, 2001, p. 56). As a discipline, HCI is defined to be "concerned with the design, evaluation and implementation of interactive computing systems for human use and with the study of major phenomena surrounding them" (Hewett et al., 1992, p. 5). Finally, it is used to describe the field, including its methods, theories, and approaches, and is fundamental to other disciplines and fields concerned with researching and designing computer-based systems for people (Sharp et al., 2019, p. 9). For example, academic disciplines, such as engineering, computer science, and social sciences, design practices, such as graphic design, product design, and the film industry, or interdisciplinary fields, such as cognitive

[1] Moore's law states that the number of transistors in a dense integrated circuit doubles approximately every two years, based on observation and a projection of historical trends. (Moore, 1998)

[2] Bell's law describes how types of computing systems form, evolve, and eventually expire and that new emerging classes of computers create new applications, resulting in new markets and new industries. (Bell, 2008)

engineering, human factors, and information systems (Sharp et al., 2019, p. 10). The primary difference between the disciplines is the arsenal of methods, philosophies, and lenses they use to study, analyze, and design products (Sharp et al., 2019). In other words, HCI provides an overview of design practices, tools, methods, and methodologies. Although, as a research arena, since HCI was established in the 80s, it has been described as boundless and in a state of flux (Barnard et al., 2000, p. 223) because the theory driving the research is changing, a flurry of new concepts and advanced applications are emerging, the domains and type of users being studied are diversifying, and new design practices and approaches are echoing evolving computing and interaction paradigms (Rogers, 2004).

Over time, as HCI has evolved, a range of traditions, disciplines, approaches, and practices, such as those mentioned above, have coalesced and redefined HCI. Thus, many frameworks, practices, theories, and principles have been appropriated and have become part of the HCI arena (Rogers, 2004, pp. 88–90). For instance, design principles and patterns were introduced to guide the design and development of interactive products. The principles are derived by synergizing theory-based knowledge, experience, and praxis (Sharp et al., 2019, p. 26) to help designers improve and explain their designs (Thimbleby, 1990).

For example, *findability* (Morville, 2005), *visibility* (Norman, 1988), and two of the more central concepts, such as *constraints* and *affordances*, which were imported from Gibson's (1969, 1978) ecological approach stemming from psychology and adopted in the HCI community to examine how humans interact with artifacts, are examples of how other academic disciplines, design practices, and traditions have become part of the HCI arena (Gaver, 1991; Kirsh, 2001; Norman, 1988; Rasmussen & Rouse, 1981; Rogers, 2004; Vicente, 1995; Woods, 1995).

Social scientists, such as sociologists and anthropologists, came into HCI with new frameworks, theories, and ideas about technology use and systems design, thus reconceptualizing interactions as social phenomena (Button, 1993; Heath & Luff, 1991). This movement examines the context in which users interact with technologies. *Interaction design* was a term that emerged as a way to focus on <u>designing</u> interactions rather than on the components of HCI: the human and the computer (Rogers, 2004). The term generally refers to the practice of "designing interactive products[3] to support the way people communicate and interact in their everyday and working lives" (Sharp et al., 2019, p. 9). Terry Winograd described it as "designing spaces for human communication and interaction" (Winograd et al., 1997, p. 160). John Thackara viewed it as the "why" and "how" of everyday interactions using computers (Thackara, 2001, p. 50), and Dan Saffer highlighted the artistic aspects, stating that it is "the art of facilitating interactions between humans through products and services" (Saffer, 2006, p. 4).

[3] The term *interactive products* generically refer to all classes of interactive systems, technologies, environments, tools applications, services, and devices (Sharp et al., 2019, p. 36).

Richard Buchanan (2001) broadly defined interaction design as the study of "how human beings relate to other human beings through the mediating influence of products." (Buchanan, 2001, p. 11) provided a broader understanding of interaction design by defining it as both physical and digital constructs and immaterial phenomena, such as services, policies, and systems. This definition disengages with the material bias within the interaction design discourse (Kolko, 2011; Moggridge, 2007) and emphasizes interaction design as a phenomenon. Regarding *useful*, *usable,* and *desirable* (Buchanan, 2001, p. 15), Buchanan argued that the experience of a system is the overall synthesis (i.e., the content and structure of the *performance*, *affordances,* and emotional *voice* of the products), which corresponds with what others have discussed as factors in investigating user experience design (Buchanan, 2001). This will be discussed in the following paragraphs using two central paradigms that have shaped the discourse around interaction design—*usability engineering* and *user experience*.

In praxis, usability engineering is a central paradigm for researchers and practitioners in designing systems. With roots in human-centerd design (HCD) and human factors, usability focused on systems design with attention to pragmatic design principles (Nielsen, 1993). Usability continued the HCD approach, particularly for quantitative evaluation (ISO 9241-11, 2018). Thus, usability engineering focused on efficiency, effectiveness, and subjective satisfaction and was primarily related to the task and work pertinent to user cognition and performance in HCI. Gradually, usability has become something that users expect and is only noticed when it is absent. In other words, "people are no longer pleasantly surprised when a product is usable, but are unpleasantly surprised by difficulty in use" (Jordan, 2005, p. 3). In this context, the limitations in the usability engineering paradigm have oriented HCI researchers and practitioners to examine the *user experience* paradigm, which offers an approach that goes beyond engineering to also focus on emotions, motivations, values, etc. (Jensen, 2013a, p. 184). The term "user experience" was itself invented to broaden the scope of designing interactive products to integrate all aspects of the end user's experience into the system (Norman et al., 1995) with a sharpened focus on emotional and evocative aspects of the interaction between user and system as "pleasure-based" approaches (Jordan, 2005, p. 4).

In retrospect, HCI focused on designing and engineering computing systems, while interaction design was viewed as broader, concerned with the theory, research, and practice of designing experiences for several technologies, systems, and products (Benyon, 2019). The term *experience* in HCI has a wide and diffused spectrum of meaning, exemplified with a selection of theoretical models stemming from different foci, such as "affect" (Forlizzi & Ford, 2000), "emotion" (Desmet & Hekkert, 2007), "empathy and experience" (Wright & McCarthy, 2008), "pragmatism" (Cockton, 2008), "pleasure" (Jordan, 2002), "ambiguity" (Gaver et al., 2003), "beauty" (Diefenbach & Hassenzahl, 2009), "hedonic/aesthetic variables" (Hassenzahl & Tractinsky, 2006), and "technology as experience" (McCarthy & Wright, 2004). In other words, it is the "experience that comes about through the use of (interactive) products" (Hassenzahl, 2010, p. 2).

1.1.1. EXPERIENCE TECHNOLOGIES

Newer design approaches have emerged, such as *experience design* and *user experience design* (Jensen, 2013b), which borrow theories and principles from interaction design, usability engineering, user experience, etc. Experience design and user experience design are described as both practices (Resmini et al., 2010) and as design approaches and fields of knowledge (Roto et al., 2011). Jensen (2013b) provided a systematic mapping and discussion of the paradoxes in user experience, experience design, and user experience design to understand and define the three concepts. Experience design is a design approach in which the users and the quality of their experiences are central, whereas user experience design focuses on the system's interaction potentials. User experience design is considered a subset of experience design closely related to HCI, while experience design is oriented toward product and service experiences. Essentially, this trend in HCI communities foregrounds experience-centered approaches to technology, which are reflected in both theory and design practices (Jensen, 2013a, pp. 179–208), emphasizing sensual and emotional conditions of interaction with technology (McCarthy & Wright, 2004).

Many researchers have strived to describe the experiential aspects of a user experience as exemplified by the nebulous mapping of the term "experience," which is often described regarding how users perceive a product and their emotional reaction to it (Hornbæk & Hertzum, 2017). In this context, Hassenzahl (2010), Forlizzi and Batterbee (2004), and Pine II and Korn (2011) provided theoretical foundations to understanding how experiences can be defined through analog and digital dimensions and how technology-supported experiences can improve value to the user. Hassenzahl's (2010) model of user experience conceptualizes it as a hedonic and pragmatic aspects. Hedonic denotes how evocative and stimulating the interaction is to the user, while pragmatic denotes how practical and simple it is for the user to achieve their goals (Sharp et al., 2019). McCarthy and Wright (2004) stated that user experience is now becoming central to our understanding of the usability of technology, a movement within HCI that had been underway for a while. Their *technology as experience* framework provides a holistic and metaphorical description of the essence of human experience regarding sensual, cerebral, and emotional threads (McCarthy & Wright, 2004).

Perhaps it is best summed up by the following quote: "The old computing was about what computers could do; the new computing is about what users can do. Successful technologies are those that are in harmony with users' needs. They must support relationships and activities that enrich the users' experiences." (Shneiderman, 2002, p. 2). In closing, the term <u>experience technology</u> in this thesis refers to an expansive array of technologies designed primarily to mediate and facilitate user experiences through useful, usable, and desirable systems (Buchanan, 2001, p. 15). In other words, computer technologies are a medium of user experience: an experience evoked by technology.

Today, the scope of HCI has expanded to the extent that the difference between human–computer interaction and interaction design has been dissolved (Churchill et al., 2013). Also, usability engineering and user experience paradigms have become integrative disciplines within HCI.

Multiple theorists and practitioners have focused on different domains using different lenses to study them. Hence, HCI has become an expansive research arena that contains many disciplines and practices, including an armory of methods, design approaches, theories, and principles from varying traditions. Multiple application domains have emerged, where technology foregrounds the experience and establishes itself as context-and domain-specific cells within HCI to reflect how humans experience the evolving information and communication technology (ICT) era. For example, *Human–Computer Confluence* describes a research area that studies how the emerging symbiotic relations between humans and ICT can be based on radically new forms of sensing, perception, interaction, and understanding (Ferscha, 2016; Khot et al., 2017; Mueller et al., 2016, 2018; Mueller & Young, 2018; Patibanda et al., 2017; Stephanidis et al., 2019), while *Human–Computer Integration* refers to the relationship in which humans and software act with autonomy, inducing patterns of behavior requiring holistic consideration (Farooq & Grudin, 2016; La Delfa et al., 2018; Semertzidis et al., 2019; Stephanidis et al., 2019). *Human–Computer Symbiosis* introduced in 1960, which envisioned a future when computing machines and human brains are tightly coupled together, could "think as no human brain has ever thought and process data in a way not approached by the information-handling machines we know today" (Licklider, 1960, p. 1). The term symbiosis in this context stems from the co-existence and interactions of two counterparts: humankind and intelligent computer systems that exhibit characteristics typically associated with human behavior and intelligence, such as understanding language, learning, reasoning, and problem-solving (Stephanidis et al., 2019). These fields of research within HCI describe very specific research agendas to generate knowledge and expand upon. In a similar approach, the research arena is narrowed down to specific agendas that are central for this study's focus: *player–computer interaction* (SIGCHI, 2014), *human–exhibition interaction* (Wang, 2018; Wang & Xia, 2019), and *human–computer interactions in museums* (Hornecker & Ciolfi, 2019). These will be unpacked and explored in subsection 1.4.

The above introduction of HCI and, in extension, through a presentation of the user experience and the role of computing machines as experience technologies, was to establish a terminology by clarifying concepts to frame the following research program and position this project.

1.2. Research Program: *Our Museum*

This Ph.D. project is part of the national research and development program, Our Museum (OM), and is one of 13 Ph.D. projects and comprises five Danish universities and eight museum partners. The program facilitates new forms of civic engagement by developing and studying how museums interact with the public. This includes understanding how museums' innovative practices of public interaction handle the concepts of *enlightenment* and *experience* since these concepts operate as key dimensions of museums' societal engagement in the past and today. The aim of the 13 individual research projects [A2; A5; A6] is to design, document, and evaluate how forms of public interaction and societal engagement have changed—and can change—to benefit citizens and society at large. The expected output from the program is a combination of theoretical, empirical, and practical contributions that can benefit both research and praxis by advancing current museum communication strategies, both nationally and internationally [A1; A4].

The foundation of OM is built on past and ongoing initiatives that link research and praxis in collaborative settings, such as the Danish Research Center on Education and Advanced Media Materials (DREAM), European National Museums (EuNaMus), MeLa* European Museums in an age of migration (MeLa) and Europeana, etc.

The program's thesis states that exhibition sites have, retrospectively, been created and developed in a tension field between the perception of the museum as a space for public information and enlightenment and as a place for experience and entertainment [A1;A4]. The premise of the program and its 13 projects is that this historical tension field is particularly visible in current communication practices and that the ongoing discussion regarding the enlightenment-experience relationship is dynamic and expansive, with different positions ranging from dichotomic to symbiotic (Christensen & Haldrup, 2019; Floris & Vasström, 1999; Kirshenblatt-Gimblett, 2000, 2000; Sæter, 2004).

The 13 projects are split into two research tracks to investigate the overriding thesis: historical and contemporary [A4; A6]. The historical track is tasked with studying the relationship between enlightenment and experience through historical literature and documents to inform the contemporary projects, while the contemporary is a mix of evaluative studies on existing museum practices and explorative studies to investigate museum communication, experience, design, and development. Thus, the program addresses the interplay between enlightenment and experience and how it influences museum communication. In this discussion, "enlightenment" denotes didactic, educational, factual, forming, and informative, while "experience" denotes emotional, engaging, entertaining, imaginative, involving, narrative, and playful (Jensen, 2021).

The OM research program examines the relationship between enlightenment and experience by splitting the challenges Danish museums are experiencing into 13 research projects. Among the 13 projects, contemporary projects are installed in programmatic research through design configuration (Bang et al., 2012) in a collaborative constellation between the research program, museums, and universities.

1.3. Research Project: Automated Exhibition Sites

In 2016, this research project was designated *PROJECT 07: Automated Exhibition Sites*. At the time of inception, the objective was to investigate how to design digital experiences at exhibition sites devoid of human personnel. Automation implies removing personnel, installing time locks, security measures, such as alarms, cameras, and sealing artifacts in glass displays. This description gave a foundation to this project, and its aim is to investigate, design, develop, and evaluate digitally mediated museum communication for automated exhibition sites. This thesis was positioned within the human-computer interaction research arena while applying for the Ph.D. candidature because the project's framing revolved around human users interacting with computer technologies as central concepts set in an exhibition context. Naturally, many unknown variables were undefined until initial research was conducted on-site, such as users, context, and what it would mean for the site to transition from a traditional site to an automated one. Investigating these variables was part of the first phase initialized with this project's collaborative case museum: the Historical Museum of Northern Jutland (HMNJ). HMNJ is an organization that maintains and operates 15 museums in Northern Jutland. Their first role was to establish a research agenda rooted in an ongoing challenge articulated in specific research inquiries presented in 1.3.2. Additionally, as collaborators, they provide exhibition sites to conduct research and provide domain-specific knowledge to align the research project with HMNJ's objectives.

Initially, three sites were part of this project in 2016: a Circus Museum in the forest village of Rold, a Collection of Local History in the country village of Hadsund, and a Redoubt in the coastal village of Hals. The initial plan was to transition the three sites from traditional to automated sites in a sequence that allowed for three different studies that could investigate how to design digital experiences in three different exhibition contexts. Therefore, all three sites were part of the initial research conducted as part of this project in 2016 and 2017. However, two of the three sites were removed due to organizational changes. Thus, the two sites were excluded from this project, and the third site will be the primary focus of this project: the Hals Museum and Redoubt. This site was originally set to transition from a traditional exhibition to an automated site after the conclusion of this research project, but the transition plans were accelerated due to the revisal of HMNJ's resource strategies. The site, therefore, began redesign and construction in 2017 and finished in May 2018. In addition, due to these external factors, an aqua zoo was affiliated with the OM program and included as a secondary "auxiliary site" to conduct tests: The North Sea Oceanarium. Both sites are detailed in the papers in which they are studied. However, Hals Museum and Redoubt will be presented in more detail because it is the primary site of this study.

1.3.1. RESEARCH SITE

The Hals Museum and Redoubt (HMR) is a cultural heritage site and historical house museum. It is located within a redoubt from the Rennaissance, built in 1653–54. This is a type of museum/heritage site where the entire building, its content, and the surrounding area are part of the display and immerse the visitor within the exhibit in a literal sense. During the second world war, it served as the local headquarters for the German occupiers. In 1972, the place was turned into a museum. At the end of the 19th century, the old gates at the two entrances of the ramparts were demolished due to excavations, and earth dams replaced the two bridges over the ravine at the western entrance.

Presently, two main buildings remain: the powder chamber and the armory. Both are located within the redoubt, which is recognizable for its star-shaped ramparts surrounding the site (Figures 1 and Figure 2). Today, the museum exhibition is located inside a building that previously served as the armory.

Figure 1: An overview of the redoubt near the coastal lines of the fjord in the village of Hals. Source: Google Maps.

Figure 2: Left: An aerial shot of the exhibition site. Source: Google Maps. Right: The exhibition building inside the armory and the powder chamber behind it. Source: Hals Museum.

Inside the armory, the exhibition was divided into four exhibition themes divided into zones (Figure 3). The yellow zone illustrates the entrance/exit with a tourist information kiosk, leading to exhibition zones in both directions. So, the visitor can start with either construction of the redoubt or maritime. The red zone exhibits an exposition of the construction of the redoubt. The orange zone contained World War II-related objects. The green zone is a combination of everyday life in and around Hals, and finally, the blue zone contains maritime-related objects.

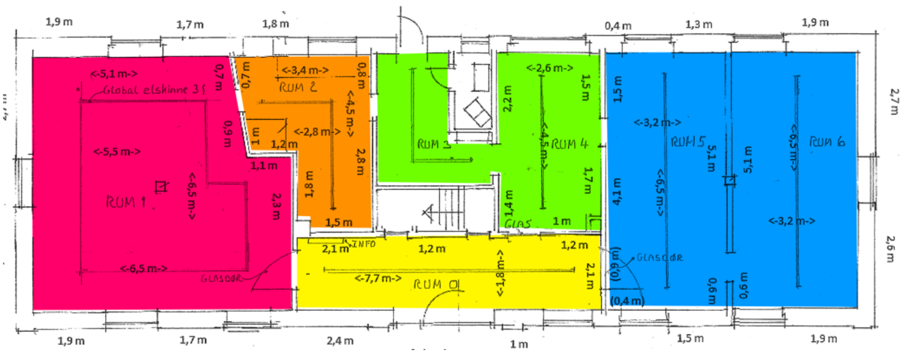


Figure 3: The armory's interior comprising four exhibitions thematically divided as red, orange, green, and blue with the fifth, yellow, which is the entrance/exit.

The site is preserved, meaning that there are strict regulations for modifying or physically altering the site and structures. The site is run by a host[4] who takes care of cleaning, ticket admissions, and opening and closing. The museum communication is restricted to artifacts with accompanying text labels. The exhibition design is devoid of digital technologies or interactive elements. Since May 2018, the site has operated as an automated site with no human personnel present.

1.3.2. RESEARCH INQUIRY

In Denmark, museum institutions have come under severe long-term challenges (Lindqvist, 2012) due to political agendas that urge exhibition sites to compete with experience centers, such as theme parks, or to become experience centers themselves (Skot-Hansen, 2008). This development has forced some museums to adapt, evolve, or expire, leading to centralization strategies and efficiency measures that imply decommissioning smaller exhibition sites and laying off employees, etc.

In response to rising challenges, some institutions consider automation and self-guidance strategies for extant exhibition sites. Therefore, the operationalization of automated sites and self-guidance strategies were articulated in collaboration between the research program and the museum institution collaborators, resulting in this research project (see appendices [A1; A4; A5; B2]).

The articulation upon inception included the following predefined inquiries to frame the research project extracted from the documents in the appendices [B2; A5] (author's translation):

- How can exhibitions and museum communication be designed for automated sites, with attention to an active user experience?
- How can digital technologies support museum experiences that are location-bound?
- How can enlightenment and experience be equilibrated in the design?

The premise of HMNJ's participation in the research program was to develop a self-driven site using digital technologies to communicate, facilitate, and mediate to users as an alternative to their current traditional communication via posters, labels, and displays. Their primary concern was how the removal of human personnel would affect the visit. They presumed that digital technologies could be used and operated without the need for human personnel on-site. On a conceptual level, the project focused on investigating how and which digital technologies could be useful in providing location-bound museum communication while retaining a focus on user experience and considering the OM program's foundations throughout the design process. The project description also detailed that methodologically, the design project should focus on research through design, action research, and user experience design,

[4] The term "host" is HMNJ's title for an exhibition professional that oversees a site. Their roles vary greatly, from site to site, but in the smaller sites, the host has multiple responsibilities, such as guiding and deciding the narrative that goes into the exhibition.

while the evaluation should consider user research methods, such as qualitative and quantitative data collection and ethnographical studies of the context, found in appendix [B2].

The collaboration provided an opportunity to investigate, design, develop, and evaluate digital experiences on an exhibition site that would transition from traditional to automated. In other words, the framing in the description created a clear and specific area for the project but was still open for exploration and experimentation. The framing, however, also introduced unknown variables that were required to contextualize the research project further before articulating a research question.

From the predefined research inquiries, the following questions were articulated. What defines an exhibition experience? What constitutes communication in exhibitions? What constitutes experiences driven by computer technologies? What type of technologies are at play, and how are they utilized? What does it mean for a site to become automated? How does automation affect facilitation? And where do the concepts of enlightenment and experience fit into all of them?

Additional unknowns were site-specific, for example, information about the users and how they interacted with Hals Museum and Redoubt and how the personnel and users interacted or contextual information about the site itself. These unknown variables were treated as parameters to conduct the initial investigations executed through the reconnaissance of the Hals Museum and a literature review.

1.3.3. RESEARCH INITIALIZATION

In this thesis, exhibition sites are broadly defined as a wide range of informal educational institutions and museum-like institutions, such as historical homes and cultural heritage sites; nature, science and technology centers; arboretums, aquaria, botanical gardens, and zoos; national parks and other similar settings, as well as the traditional museum biomes: art, history, and natural history sites (Falk & Dierking, 1992). However, as described by Genevieve Bell in *Making Sense of Museums* (Bell, 2002), each exhibition context has its ecology. She defines exhibition ecology through three common components across various exhibitions: *liminality*, *sociality,* and *engagement* (Bell, 2002, pp. 5–6). Liminality refers to the sense that exhibitions embody experiences set apart from the rest of life (i.e., transitional. Sociality refers to both the social constellation of visitors and their appropriation of exhibitions as spaces to engage in social activities, and engagement refers to exhibitions as learning spaces that are reshaped by a dyad of expectations: the desire for education and the desire to be entertained (Bell, 2002, p. 6).

The exhibition ecology provided a systematic framework to make sense of the data retrieved from the reconnaissance of HMR and the literature review and was therefore used to structure the first study conducted to initialize the project. Additionally, the third component, engagement, is directly linked to the research program's overarching antithesis regarding enlightenment and experience, which will be reintroduced and discussed in 1.4.1 and 0.

1.3.3.1 Scientometric Review

In 2016, a literature review was conducted to understand the exhibition context through the lens of HCI. The resulting literature included books, anthologies, and peer-reviewed studies. The latter were included in a systematic review [C1_TAB1], which was based on a combination of PRISMA and snowball methods (Moher et al., 2010; Wohlin, 2014). The search method for identifying studies focused on the top 20 HCI journals and conferences on Google Scholar Ranking. Unfortunately, some databases were deselected due to weak relevance or because they did not follow a peer-review procedure.

Studies were identified by searching electronic databases, scanning reference lists of articles, and by hand searching. The following databases were the primary sources: ACM, SpringerLink, IEEE, Taylor and Francis, and Elsevier. However, additional papers were included from other sources following guidelines for snowballing in systematic reviews. Also, Google Scholar was included as a supplement to look for references within the chosen publications from other databases. The review was based on the three predefined research inquiries of the research project to clarify the area of concern and identify gaps in the knowledge. Studies were identified using the following strings: "museum" OR "museology" OR "museum studies" OR "cultural heritage" OR "exhibition" AND "design" OR "experience" OR "guidance." The complete scientometric review can be retrieved from appendix [C1_TAB1].

The bulk of the reviewed literature identified using the above queries was 1.707, where the initial reading of titles and abstracts concerning the scope of the research project reduced the number to 84. The process included second filtering with the following terms: "HCI/Human-Computer Interaction," "Interaction Design," and "Human Centered Design" to sort out studies that overlap with HCI and museum exhibitions. The full text of these was then read and subject to the same delimiting process by relating them to the project's inquiries, which resulted in the final list of included studies with 34 entries.

The overview in appendix [C1_TAB1] identified the current state of research in digital museum communication in 2016, which was a mix of technological trends of the day and iterations of past implementations. For example, augmented, mixed, and virtual reality (Jung et al., 2016; Kang & Gretzel, 2012; Schuemie et al., 2001), pervasive and ubiquitous computing (Kuflik et al., 2011), context-aware technologies (Chen et al., 2014; Nivedha & Hemalatha, 2015), audio guides (Heller et al., 2009; Zimmermann & Lorenz, 2008), interactive installations (Antoniou et al., 2015), and games and playful systems (Ballagas et al., 2008; Coenen et al., 2013; Wakkary et al., 2009). The implementations utilized were a mix of both stationary and mobile technologies, with the latter being more widespread. Their primary purpose was to address issues and challenges related to wayfinding, navigation, and guidance. Furthermore, the technologies were used to bridge both digital and physical (Damala et al., 2013; Damala et al., 2008, 2007) and connect users within the exhibition space through shared activities found predominantly in games and interactive installations (Antoniou et al., 2015; Ballagas et al., 2007; Coenen et al., 2013; Vlahakis et al., 2002; Wakkary et al., 2009). Likewise, these activities shared a common trait, encouraging users to engage in exhibitions in an explorative and playful way (Ballagas et al., 2007; Vlahakis et al., 2002).

After the initial review, it became clear that *automation* required more attention; thus, a more focused review was conducted subsequently, which, as an afterthought, should have been part of the initial review. The automation-focused review is presented below.

As new technologies offer more efficient and cost-effective ways to communicate exhibition content with the promise of greater accessibility, museums continue to make an effort to incorporate digital methods into their practices (Besser, 1998). This is also the case for the automation of exhibitions. Automation in museums is frequently linked to the proliferation of technologies in museums, which affects information handling in museum environments (Besser, 1997b), and increasingly powerful computers, coupled with a more computer-literate population, will force museums to rethink traditional separation between systems for handling exhibitions and museum automation systems (Besser, 1997b, 1998). The type of automation and facilitation presented here is confined to research and practice that focuses on exhibitions that operate without human presence on-site through digital technologies, which implies self-guidance and self-facilitation. Other types of automation, such as robotic-centric or information centralization and optimization in databanks, were factored out in this project.

Automation can be traced back to the 1960s and 1970s with the introduction of electronic audio guides, roughly a decade after the dawn of humanities computing in the 1950s (Parry, 2007; Tallon & Walker, 2008). Since then, automation strategies seem to have followed the technological trend of the time, using web-based technologies in the 1990s (Besser, 1997a) and robotics in subsequent decades (Burgard et al., 1999; Kai Oliver Arras & Burgard, 2005). In recent times, there has been a surge in augmented, virtual, and mixed reality applications, artificial intelligence, machine learning algorithms, and context-aware technologies, manifested as mobile guides, chatbots, smart guides, and human guides disguised as virtual representations (Avouris & Yiannoutsou, 2012; Bekele et al., 2018; Berryman, 2012; Billinghurst et al., 2015; Damala et al., 2008; Jerald, 2016; Kim et al., 2018; Pascoal et al., 2018; Schmalstieg & Wagner, 2007; Suskind, 2019; Van Krevelen & Poelman, 2010; Yung & Khoo-Lattimore, 2019). State of the art applications iterates on past implementations of automation, such as context-aware mediation in the exhibition through audio guides that react to user position in the exhibition (Antoniou et al., 2015; Chun, 2016; Rich, 2016), content that is unlocked based on user location or interaction (Cork, 2016; Lang, 2015), and installations that respond to user presence or interactions and mobile and location-based services (Jensen et al., 2014).

An overwhelming number of studies were based on mobile technologies, with an increasing focus on the user's own devices, such as handheld and personal mobile devices over stationary installations. A trend that is attributed to the mobile-centric development that has gained momentum over the past decades. While most research highlights technical challenges that need further engineering, some point to the negative effects, such as disrupting the social experience or distracting users from the exhibition contents (Cosley et al., 2008; Petrelli & O'Brien, 2016). None of the studies specifically targeted automated sites or exhibition sites; some studies reported on supporting users in museum exhibitions through self- and technology-guided facilitation (Ballagas et al., 2007; Park et al., 2007; Vlahakis et al., 2002; Wakkary et al., 2009). These are, however, often an optional layer of activity during the visit and not the primary method for facilitation, which allows for speculation about how they would fare in an automated exhibition.

Facilitation denotes the practice of making exhibition content accessible and communicating it to the users, which can be achieved through either live facilitation (i.e., guided) (Simon, 2007) or self-facilitation (i.e., self-guided). At least three types of facilitation styles have been identified in the literature regarding museum exhibitions, where facilitation is mediated through computer technologies. The three styles are pedagogy and learning, interactive exhibits, and mediation through games and play. Pedagogy and learning focus on visitor studies and educational philosophy and report on how to implement educational experiences in exhibitions mediated by technology (Hein, 1995, 1998, 2007; Jonassen, 2004; Kadoyama, 2007; Marsick & Watkins, 2001; Spector et al., 2008). Interactive exhibits emphasize design interventions that avoid didactic forms where visitors passively receive information by designing interactive exhibition environments that encourage visitors to explore, question, and reflect on the exhibition content, reporting positive outcomes (Bannon et al., 2005; Hornecker & Stifter, 2006; Spector et al., 2014) and mediation through games that explore the dynamic of transformational play where visitors can assume roles within a game setting, such as an archeologist in an excavation searching for clues to extinct species (Barab et al., 2009, 2010; Beale, 2011), and other types of games and play, such as scavenger hunts and quizzes. Many of the studies mentioned above report on designing digital experiences to promote learning in exhibitions, and the consensus in the literature is that exhibitions are regarded as informal learning spaces with the potential for facilitation and mediation through interactive technologies (Csikszentmihalyi & Hermanson, 1995; Falk & Dierking, 2013; Pendit & Zaibon, 2014).

After the first iteration of reviewing the literature, a second iteration was completed with a focus on the learning aspect in exhibitions, as this aspect was not included in the first inquiry but will be presented in 0 as part of the unpacking of the central discourse in the study regarding enlightenment and experience in 1.4.1.

Overall, it can be argued that the applications and systems studied in the literature review combine all of the exhibition ecology components (i.e., liminality, sociality, and engagement). In this context, games, in particular, display potential for the area of concern. They can be designed to integrate education, entertainment, guidance, social interactions, and linking digital spaces with physical places (Bekele et al., 2018; Ioannides et al., 2017; Jegers, 2009; Jensen et al., 2010; Kan et al., 2013; Miyashita et al., 2008; Montola, 2011; Montola et al., 2009 & Mueller et al., 2018). It remains unclear, however, how these types of games or systems can support users in automated exhibition sites. The studies reviewed in the literature contain a few studies based on outdated technologies or analog solutions, such as manuals and maps for self-guidance (Bitgood & Davis, 1991), but none target the area concerning automation through digitally mediated games articulated in this study. After establishing the current state of research, the exhibition site, HMR was studied through mapping of the site, observation studies of the users, and interviews with the host [D2; E4].

1.3.3.2 Exhibition Ecology

A reconnaissance of HMR was executed, where the primary objective was to observe and talk to visitors and the host in addition to mapping the physical setting of the museum (the latter was presented in 1.3.1), found in appendix [E4]. The site was visited multiple times between June and November, in 2016. One formal visit to get acquainted with the museum host, and several subsequent visits to examine the site and observe its visitors. The interview data was collected as part of a graduate student project collaboration, found in appendices [D2; E2].

"Skansen sucks! [The redoubt sucks!]" ~ kid playing hide/seek

For a small house museum far removed from large cities, it was well visited by various visitors regarding age, gender, and social constellations with families, friends, and partners across generations. The outdoor area of the redoubt was lively. Visitors sat on the cannons scattered around the ramparts and took pictures, played hide and seek, walked their dogs, and simply sat for a quiet spell in the shadow of the trees. In their way, they interacted with the nature surrounding the armory that contains the exhibits. What was remarkable was that many people spent time there and engaged in a multitude of activities, yet only a fraction went inside the exhibitions, and even fewer paid entrance fees to access it. The site was attracting people but failed to invite them inside. Why was that? The opening quote was from a young boy who was playing hide and seek on the redoubt with a group of friends (Figure 4). When they were approached and asked what they thought about the place, they explained that it was fun to play there but that the exhibition inside was boring and "sucked".

Figure 4: A group of young kids playing hide/seek on the redoubt, summer of 2016.

Inside the armory, which contains exhibits, visitors would wander around with their hands behind their backs and make their way through the exhibition, looking, reading, conversing with each other, and discussing the artefacts. It was striking how the visitors behaved outside, where they were touching, playing, sensing, and interacting with the physical space and each other, while inside, they went mute and changed their behavior radically. The powder chamber, which is located outside next to the armory house, also contains part of the exhibition, but unless the visitors were made aware and directed to it, they would miss it on their way out of the armory. For the younger audience, there was a quiz, found in appendix [E4], that encouraged them to explore the exhibition for the prize of candy upon completion. None were observed completing the quiz. The atmosphere is perhaps best captured through the following quote from an interview with the host:

> *"...this is a museum, here, you are expected to keep your hands in your pockets and keep a watchful eye, and I will answer your questions, but it is forbidden to touch anything."* [D2\HALS\DATA\interview-transcript, lines 194–196].

The way visitors were primed upon entering the exhibition influenced their behavior. However, visitors were observed to carefully orient themselves before touching some of the artifacts, such as picking up items, examining them, and playing with them in a subversive way. The redoubt is also used annually as a backdrop for open-space live performances by a local group who build their stage on the area ensconced by the star-shaped fortress (Figure 5).

Figure 5: Live performances at the redoubt with stagecraft and open-space events supported by local groups.

Another insight gained through this study is the contrast between a small and low-budget site that focuses on local history and everyday life and well-funded larger museums managed by commercial and public agencies. This means that different types of exhibition ecologies operate under different economic rules and with different aims (Macdonald, 2006), which clearly affects the potential for developing smaller sites.

1.3.3.3 Research Orientation

The contrast between the activities in the exhibition and in the redoubt became visible over time; they were clearly decoupled. While the visitors engaged with the artifacts, nature, and the physical space of the redoubt in an active, explorative, and playful way, there were no learning activities embedded there. They were exploring the exhibition site's cultural heritage and history but were unaware because there was no mediation of the artifacts of historical value that they were engaging with. In contrast, the exhibition site's inside was full of text-based facts and objects and artifacts that the visitors were not allowed to explore, merely observe passively.

In summary, the difference between the observed activities outdoors, which encouraged a more curious, exploratory, roaming user interaction, and the more passive, fragmented, and perplexing exhibition, outlines a polarity within the ecology of this particular exhibition. Revisiting the literature clarified the design and evaluation of various types of experience technologies in various exhibition contexts, but none of the studies focused on digitally mediated experiences in automated self-guided sites. Many installations and technology-driven experience layers take place in larger museums in experimental settings to evaluate a technology. Most interestingly, the literature revealed ways of combining digital technologies with learning and play, which provides an opportunity to expand the existing literature to further investigate how technologies can support users in a self-guided situation. Thus , reprogram their behavior to extend their active user state inside the exhibition, rather than defaulting back to a passive user state.

Due to the findings of the initial research inquiry, the focus of this project is on the following question concluding the initial investigation: *How can experience technologies support users to actively engage with the exhibition in an automated site?*

This question is articulated within the scope of the research program and project. The expected output of the program is a combination of theory and practice through the design, implementation, and evaluation of communication strategies that address the relation between enlightenment and experience. Due to the nature of this project, which combines computer technologies within the museum exhibition context, HCI can provide design practices, tools, methods, and methodologies that can link theory and practice through research on how to design, develop, and evaluate emerging approaches to communication in exhibitions. Hals Museum and Redoubt present an area of interest that stems from the challenges of designing digital experiences to support users in an automated site, evident in the striking disparity between the passive, peripheral experience with the indoor exhibition and the active, explorative, and playful interactions outside. The following subsections will expand upon this area of interest and position this study within a broader field of research.

1.4. Research Context: Exhibition Design Research

The research program provides an overarching frame that focuses on the interplay between enlightenment and experience, described as a dyad of expectations. This directly influences this project's objective, which is to investigate, through design, development, and evaluation, how users can be supported in *automated sites*. The previous sections set the perimeter for the area of interest between design research and exhibition design and position this project by posing the question of how computer technologies can be utilized to design exhibitions in automated sites. Through this, the aim is to examine how enlightenment and experience can be equilibrated in this particular project, ultimately contributing to the research program. The following subsections will connect the research program, project, and exhibition context within HCI and perform a calibration to position this thesis through a set of hypotheses.

Exhibition design has been studied in multiple areas over a long time, ranging from world fairs (Taylor, 1963, p. 196) to cultural contexts, such as aquariums (Nesbitt & Maldonado, 2016), galleries (Bourdeau & Chebat, 2001), museums, and zoo exhibitions (Bitgood & Patterson, 1987). As a design field, exhibition design research has been described as a combination of *design research* and *exhibition design* (MacLeod et al., 2015, p. 314), an area that is marked by multiple design fields, such as museum architecture, exhibition design, and experience or interpretive design. This area of research is populated by a growing number of museum design researchers' representatives of the multiplicity of museum design itself (Hughes, 2015). MacLeod et al. (2015) described the museum design research community as a "dynamic research community comprising a whole range of people from museums, the creative industries and academia and who span fields as diverse as architecture, various design disciplines, visitor studies, learning, theatre, animation, film, and museum studies." (p. 314). Echoing MacLeod et al.'s (2015) sentiment, Eva Hornecker and Luigina Ciolfi provided a foothold for HCI researchers by presenting the complex cluster of museum professionals, such as figures trained in archival science, archeology, and other sciences relevant to the collection (e.g., astrophysics, biology, history, etc.) or conservation, museology, pedagogy, communication, and design (Hornecker & Ciolfi, 2019) and that an HCI researcher's role may vary according to the skills, knowledge, and roles present in that particular exhibition ecology.

In *Human-Computer Interactions in Museums* (Hornecker & Ciolfi, 2019), Hornecker and Ciolfi highlighted the proliferation of technologies being utilized in exhibitions and the experiences as a result of user's interaction with exhibition content through technologies, focusing on the user- and technology-centric dimensions to exhibition design. Here, they provided a lens to view visitor-exhibition interactions through HCI by positioning exhibitions as an application context similar to other HCI contexts, where user characteristics, motivations, expectations, and physical and social contexts of use, etc., need to be considered (Hornecker & Ciolfi, 2019, p. 1). From an HCI perspective, the relationship between technology, users, and the museum context has spawned entire research agendas within HCI that connect a multitude of disciplines and practices (Hornecker & Ciolfi, 2019).

Other key entries include the anthology, *Museum Experience Design: Crowds, Ecosystems, and Novel Technologies* (Vermeeren et al., 2018), which presents studies that focus on technologies, interaction design, and storytelling in exhibition design and exhibition making by focusing on technologies that can mediate, facilitate, and augment user interactions in exhibitions to enrich the overall museum experience. Interactive museums and a focus on mediated communication are at the core of the anthologies: *The Interactive Museum* (Drotner, 2011) and *The Routledge Handbook of Museums, Media, and Communication* (Drotner et al., 2018). The latter provides a broad scope of analytical and theoretical museum studies with mediated communication. It is evident from the outlined literature that the body of research found within HCI related to exhibition design research is substantial but also that it is still being explored and expanded upon. Following this rationale, it is important to understand how core museological variables affect HCI research. Although this is not a thesis on museum studies, it is important to treat the underlying discourse that the HCI research presented here is based on. So then, how do the variables, enlightenment, and experience factor into this? The following will present and discuss the two concepts and, while doing so, include subjects relevant to the central discourse.

1.4.1. ENLIGHTENMENT AND EXPERIENCE

The International Council of Museums (ICOM)'s most recent definition of museum exhibitions' objectives states that,

> A museum is a non-profit, permanent institution in the service of society and its development, open to the public, which acquires, conserves, researches, communicates and exhibits the tangible and intangible heritage of humanity and its environment for the purposes of education, study and enjoyment. (ICOM: Museums, 2017)

More than a century ago, in his article, *Some Principles of Museum Administration* (Boas, 1907), Franz Boas stated, "Museums may serve three objects. They may be institutions designed to furnish healthy entertainment, they may be intended for instruction and they may be intended for the promotion of research" (Boas, 1907). Without entering semantic scrutiny, the two statements have overlapping sentiments, and they both actualize enlightenment and experience. The meaning that the two concepts are imbued with, however, has shifted in the 110-year timespan.

The discussion about "enlightenment" versus "experience" has played a major part in the discourse around museums and museological institutions, as they strive to entertain, educate, and maintain the interest of their users. Over time, many fields have merged with museological studies and development, with scholars from anthropology, psychology, education, and technology, contributing to a trend toward more playful and interactive experiences in museums (Beale, 2011; Drotner, 2011; Drotner et al., 2018; Hein, 1998; Hornecker & Ciolfi, 2019; Knerr, 2000; Madsen & Krishnasamy, 2020; Tallon & Walker, 2008; Vermeeren, Calvi, & Sabiescu, 2018; Witcomb, 2007). In parallel with societal changes and the most prominent ideologies of the time, museum development has also changed to meet shifting user expectations and demographics (Hooper Greenhill, 1992; Johnson et al., 2013; Sæter, 2004). The following paragraphs introduce multiple stances between enlightenment and experience through the voices of scholars from various fields related to museum studies. The aim is to understand the nature of the two concepts, how they influenced past and present museum development, and how they can influence the future development of museum exhibition development through these voices.

Kathleen McLean, an exhibition designer, advocates prioritizing users rather than the objects. She posits that users come to museums for various reasons. They interact with the museum in various ways and seek social interaction and entertainment (McLean, 1993). Therefore, museums should study entertainment industries to learn how to treat their users (McLean, 1993). However, educators are also important to ensure that exhibitions are developed with content that users can understand (McLean, 1993), underlining that museum institutions should study users to properly deliver education and entertainment. Her position advocates entertainment without eliminating education from the equation.

John Terrel, an anthropologist, emphasizes the lack of collaboration among museum professionals. In *Disneyland and the Future of Museum Anthropology*, he details a museum's struggle in the 1970s, as it competed against Disneyland and other entertainment industries (Terrell, 1991). He criticized *disneyfication* and emphasized the importance and effectiveness of museum professionals and the lack thereof. He describes three types of museum professionals: curators, educators, and exhibition designers (Terrell, 1991). He defined curators as personnel responsible for selecting content for exhibits, thus deciding what should be presented. Educators are responsible for the accessibility of information relating to the content, and finally, the exhibition designer is charged with designing an aesthetically pleasing exhibition (Terrell, 1991). Terrel noted that when museums were experiencing declining attendance, institutions decided to switch the responsibility of content design from curators to educators. This switch in museum dynamics created a rift between the different museum professionals, and he stated that if museums continued down that path, they would cease to exist and become or fall to Disneyland (Terrell, 1991).

Gjertrud Sæter, a museologist, echoed Terrel in *Between Conservation and Consumption. New Challenges for Museums* (Sæter, 2004, author's translation), in which she discussed the shift from a modern museum's values and objectives to a post-modern museum. She stated that the modern museum's objective was to be educative and enlightening, while the post-modern museum was entertainment (Sæter, 2004, pp. 70–72, author's translation). Here she also aligned the post-modern museums with the disneyfication of museums and stated that to safeguard themselves economically, museums had given in to the public's desire for entertainment. She stated that a disneyfied museum had sacrificed education and enlightenment for superficial entertainment based on illusions (Sæter, 2004, p. 68, author's translation).

The Danish museum researcher, Dorthe Skot-Hansen, argued that experience had become a part of the state's culture agenda. *"Museums are no longer institutions for enlightenment and education; they are also experience centers and attractions."* (Skot-Hansen, 2009, p. 50, author's translation). She underlined that Danish museums are facing fierce competition from commercial competitors, such as attractions, theme parks, cinema, and concerts. Pressure from politicians who demand that museums are more accessible to the public and the users' exceeding expectations of engaging and exciting experiences (Skot-Hansen, 2008). She further stated that museums in Denmark must re-evaluate their classical role as institutions of enlightenment and education and strive to develop their experience potential; through that, they can learn from the experienced economy (Skot-Hansen, 2008). The museums have to learn to navigate a whole new knowledge and experience society so that their basic tasks of collection, storage, preservation, research, and communication can be integrated with good experiences (Skot-Hansen, 2008).

The shifts in museum practices from modern to post-modern museums is perhaps best summarized by Eilean Hooper-Greenhill, stating that:

> The modernist museum collected objects and placed them on display. Visual statements, constructed through objects placed in carefully fixed relationships, presented aspects of a European world-view. The power of display as a method of communication lies in its capacity to produce visual narratives that are apparently harmonious, unified and complete. These holistic and apparently inevitable visual narratives, generally presented with anonymous authority, legitimized specific attitudes and opinions and gave them the status of truth. Display is a one-way method of mass communication – once it is completed and opened to the public it is very difficult to modify. In the modernist museum, the voice of the visitor was not heard [...] In the post-museum, the exhibition will become one among many other forms of communication. The exhibition will form part of a nucleus of events which will take place before and after the display is mounted [...] Knowledge is no longer unified and monolithic; it becomes fragmented and multivocal. There is no necessary unified perspective – rather a cacophony of voices may be heard that presents a range of views, experiences and values. (Hooper-Greenhill, 2000, pp. 152–153).

Here, she addresses some of the key challenges of adhering to the aging traditions of authoritative facilitation and mediation of museum communication and highlights the characteristics of the post-modern museum, which shows how the rules of the game have changed; audiences have switched from passive receivers of information to active participants. Visitors are engaging in performative experiences and becoming users rather than audience. This viewpoint is mirrored in contemporary researchers and practitioners, such as Genevieve Bell, anthropologist with an extensive background in HCI, noted in *Making Sense of Museums* (Bell, 2002).

According to Genevieve Bell (2002), the majority of research focusing on museums tends to fall into four categories (Bell, 2002, p. 3): commentaries about particular exhibits, analysis of museums as powerful social institutions, handbooks, and instructional guides for running museums, or analysis of museum visitors. She further points out that the same literature tends to view the visitor as a passive recipient of the vernacular *museum voice,* which transmits messages in an anonymous and authoritative way (Bell, 2002). Early proponents, such as Marshall McLuhan and Willem Sandberg as far back as the 1960s, challenged this practice by recognizing both the museum's voice and the visitor's and that they should engage in a dialogue (Tallon & Walker, 2008).

Nina Simon, an exhibition designer, is a proponent of users as active participants rather than passive observers. In *The Participatory Museum* (Simon, 2010), she stated that for cultural institutions to become relevant to the public, they need to invite users as active participants rather than passive. She pointed to digital media technologies, such as the Internet and social media, as developmental factors. She also pointed to the way in whichh users engage with museums through technologies, such as capturing and sharing experiences and immediate access to immense sources of information. The shift from modern to post-modern indicates a shift from considering the users as passive recipients to active participants, which in turn influences the design of exhibitions from transmission toward transaction between user and museum. From this perspective, the shift from modern to post-modern, as Nina Simon describes it, opens for new forms of mediating that support technology-based enlightenment.

From a chronological vantage point, Terrel's article reflects the challenges and difficulties that museums have undergone over the past decades. Traces of the struggle are echoed in Sæter's discussion of the movement from modern to post-modern museums, which resonates with a global movement of the time. McLean's article entered the debate after the exhibition design responsibilities transitioned from curators to educators and offered a view that is more user centered. From a local perspective, Skot-Hansen clarified the political agendas within the Danish museum sector, which must also be considered.

The "active" attribute discussed in the previous sections and the next sections does not imply that it is superior to "in-active" or passive. Here, the passive prefix is about mental perception and reception and not commentary on cognitive and psychological processes. The active prefix relates to active and interactive attributes that enable participation and exploration in an exhibition. There is a broad spectrum between active and passive user states, and none of these are static, as one user may switch and assume either an active or passive state during the same visit. The focus on the active user state stems from the articulation of the research inquiry, where the collaborating museum has expressed an interest in how digital technologies can facilitate and mediate an active user experience (1.3.2). This interest highlighted some of the observed user behavior on-site in the reconnaissance of Hals Museum (1.3.3.2) and established an understanding of the exhibition ecology, where active and passive user attitude and behavior were emphasized. The shift from modern to post-modern has, however, influenced the discourse, which emphasizes a focus on mediated communication in addition to the gestalt and architectural aesthetics of an exhibition. So, how is it possible to find a resolution that accommodates the users between enlightenment and experience?

In *At the museum—between enlightenment and experience* (Floris & Vasström, 1999, author's translation), Lene Floris and Annette Vasström discussed whether the objective of museums is enlightenment or experience. In a way, they bring balance to the discussion by relating to the origin of museums as a place that provides enlightenment to the visitors and specify that enlightenment core to museums and plays the primary role, where the experience aspect is regarded as merely a shell, with a secondary role (Floris & Vasström, 1999). While stating about the experience that museums in recent years have, increasingly, utilized entertaining and activating elements of communication in exhibition design (Floris & Vasström, 1999). In other words, the attitude they present is that museums should take up the challenge instead of tagging experience centers as disneyfication and disengage (Floris & Vasström, 1999). Essentially, Floris and Vasström present a third way that brings balance between the two through a synthesis by positing that it is necessary to have both enlightenment and entertaining experiences—it is not a question of either or (Floris & Vasström, 1999).

This sentiment resonates with museum researchers, John H. Falk and Lynn D. Dierking, who have asserted that a dichotomy between enlightenment and experience is problematic, and as a response, they presented and advocated a *free-choice learning* approach where "most museum visitors see learning and fun as *both-and* rather than an *either-or* proposition" (Falk & Dierking, 2013). However, from a user's perspective, both enlightenment and experience would be perceived as integrated experiences rather than differentiated ones, as Falk and Dierking stated. The polarity exists when museum professionals discuss enlightenment and experience that have a direct influence on the exhibition design and communication strategies, which ultimately impacts the user experience. The free-choice learning approach is interesting, as it advocates a shift from transmission models, as presented in previous studies, where the information in an exhibition is prepared, and the learning outcome is an evaluation of the prepared material and toward a more constructive and transactional model, in which the visitor is viewed as driving their learning and interpretation based on their experience and intentions (Macdonald, 2006, pp. 323–339).

In summary, the discourse around enlightenment and experience in exhibitions reveals more nuanced views, which is necessary to consider both (Falk & Dierking, 2013; Floris & Vasström, 1999) and not as binary. However, they are presented here as a continuum with multiple viewpoints between them, which raises the question of whether current understanding is limited by models that enforce the user experience in either-or propositions, tempered by research and museum institutionalized practices. Are the current models of user experience sufficient to capture the eclectic exhibition experiences that must prioritize both enlightenment <u>and</u> experience? It would be pretentious to aim for one final resolution to the discussions, neither was it the scope here. The aim was to present and clarify the concepts and gain an understanding of how the two concepts influence the development of exhibitions. The objective of this study is to strike a balance and inform the design of a digital experience layer. For that, the discussion has provided a deeper understanding that re-configures enlightenment and experience and outlines the implications of the user experience if the design is realized as either enlightenment or experience and turns toward the third option, as presented by Floris and Vasström (1999) and Falk and Dierking (2013), which points to didactic approaches that can provide the user options to be both educated and entertained. Thus, how is it possible to design digital experiences that embrace a free-choice learning approach?

1.4.2. ENLIGHTENMENT THROUGH EXPERIENCE

"By any definition, there can be no learning (or meaning making) if there's been no interaction."

~ Hein, 1998, p. 136

Learning outside of the classroom, informal education, and de-schooling were ideas that gained traction around the 1960s and 1970s (Lang et al., 2006, p. 10). Entering the discourse around new ways of learning and informal lifelong learning (Anderson et al., 2003; Durbin et al., 1996; Gibbs et al., 2007), museums became a context where a new kind of education could be forged (Lang et al., 2006, p. 10). The science of learning and education is an immense field that is under continuous scrutiny and development, as the *Encyclopedia of the Sciences of Learning* (Seel, 2012) demonstrates with its 4200 entries. A delimitation is necessary to navigate the expansive chart of learning sciences. This was done by examining the often cited and referenced didactic models in museum studies. In *The Responsive Museum* (Lang et al., 2006), *Digital Technologies and the Museum Experience* (Tallon & Walker, 2008), *The Museum Experience Revisited* (Falk & Dierking, 2013), *Exhibition Design* (Hughes, 2015), *The Routledge Handbook of Museums, Media, and Communication* (Drotner et al., 2018), *Human-Computer Interactions in Museums* (Hornecker & Ciolfi, 2019), and a myriad of research papers and articles, the *constructivist* approach stemming from the work of George E. Hein (Hein, 1995, 1998) is frequently cited and used as the basis for museum learning. Therefore, Hein's *Learning in the Museum* (Hein, 1998) served as the entry-point. From this, interconnected theoretical frames and approaches were investigated, such as understanding the necessary conditions to stimulate and motivate learning, linked to the concept of *flow* by Mihalyi Csikszentmihalyi (Csikszentmihalyi, 1990, 1997; Csikszentmihalyi & Hermanson, 1995) and *experiential learning theory* from David A. Kolb (1984/2015).

George E. Hein argued in *Learning in the Museum* (Hein, 1998) that humans construct their realities and meanings rather than being introduced to an external world that is accepted, and suggested a typology of pedagogical views based on preceding schools of learning sciences and theories. He summarized them as *didactic expository*, *stimulus-response*, *discovery framework*, and *constructivism* (Hein, 1998, p. 25). Didactic expository denotes transmission of pre-defined knowledge and information, which is traditional in the sense that the exhibition host is in control of what the visitors do and learn, while stimulus-response is a conditioning of the visitors through repetition of activity and reward for correct answers, which is another model that resonates with the traditional transmission model where learning is seen as a passive reception. The discovery framework enables visitors to explore with open-ended activities, and constructivism offers open-ended activities, enabling, and encouraging visitors to construct their meaning-making through reflection on the experiences that they bring (Hein, 1995, 1998, 2016; Hornecker & Ciolfi, 2019, pp. 11–12). The notion of curiosity-driven user behavior is familiar to the field of museum studies. Falk and Dierking (2013) pointed to seven user types—one being *Explorers*, described as driving learning through curiosity and exploration.

The sentiment in the constructivist approach resonates with Kolb's (1984/2015) experiential learning theory, in which learning is considered the process that creates knowledge through the transformation of experience (Kolb, 1984/2015). In his theory, Kolb described experiences as the impetus for the development of new concepts, which is elaborated in his four-stage learning cycle: concrete experience (feeling), reflective observation (watching), abstract conceptualization (thinking), and active experimentation (doing) (Kolb & Fry, 1974), which views learning as an integrated process that leads the learner from one stage to the next (Kolb, 1984/2015). Kolb's (1984/2015) Experiential Learning Cycle has inspired various research disciplines, such as education, psychology, computer, and information science, and learner's experiences with digital technologies in museums (Lai et al., 2009; Melber, 2003; Moorhouse et al., 2019, p. 20; Petrovic et al., 2014; Sung et al., 2010; Vince, 1998). Essentially, what Kolb proposed that learning is a process whereby knowledge is created through the transformation of experience. The two didactic models overlap. Hein's constructivist approach encourages exploration and meaning making through reflection on their experiences, and Kolb's experiential learning promotes a learning style that is triggered by a concrete experience, reflection, abstraction, and active experimentation. Recent research has shown that implementing digital technologies in museum-based learning can influence critical thinking and evoke curiosity, memorable moments, discussions, and explorations in exhibitions of all museum types (Andre et al., 2017).

In his proposed constructivist approach, Hein included the development of museum institutions from the 1800s while considering the discourse centered on museums as temples of enlightenment and cabinets of curiosities for amusement (Hein, 1998), which essentially taps into the previous discussion regarding enlightenment and experience. Here, he described the progression, as it goes beyond the modern museum's transmission model that positions the visitor as a receptive audience to constructivist and transactional models that enable visitors to become active participants and encourage them to drive their own learning and interpretation based on their experience and intentions, which harmonizes with the free-choice learning approach. Another way of stating this would be that the visitors can achieve enlightenment through experiences: experiences that position the visitors as active participants who engage in inquisitive and explorative ways. In the following, the exhibition itself is examined and discussed regarding understanding the optimal conditions in a free-choice, informal learning setting, such as museums.

Mihalyi Csikszentmihalyi and Kim Hermanson (1995) presented, in *Intrinsic Motivation in Museums: Why Does One Want to Learn?,* how museum exhibitions can be viewed as a *flow activity* by deconstructing the museum exhibition experience and presented a model for the development of learning through intrinsic motivation in museum settings. They presented learning as an open process of interaction with the environment, an experiential process that develops and expands the self in a learning experience that integrates the whole person, not just the intellectual but also the sensory and emotional capacities. They further stated that when complex information is presented in a way that is enjoyable, the person will be motivated to seek further learning because it is intrinsically rewarding (Csikszentmihalyi & Hermanson, 1995, p. 67). With a departure in positive psychology, they combined cognitive and affective processes and presented a four-stage model for implementing intrinsic motivation in museum settings. Thus, they draw on motivation theory (i.e., human action is motivated by a combination of intrinsic and extrinsic rewards), in which extrinsic rewards come from outside a given activity, for example, the behavioral approach is similar to stimulus-response conditioning (Skinner, 1938), while intrinsic rewards are doing the activity for its sake, with or without any external rewards (Csikszentmihalyi & Hermanson, 1995, p. 67; Ryan & Deci, 2000a, 2017) and elaborate on intrinsic motivation in the state of being in flow, the *flow experience*. The flow experience is an experiential state of mind, also referred to as being in *the zone*, that occurs when a set of conditions are met and described as the salient elements of a flow experience (Csikszentmihalyi, 1990, pp. 48–67, 2014a, pp. 137–146). Csikszentmihalyi described it as "... a state in which people are so involved in an activity that nothing else seems to matter; the experience is so enjoyable that people will continue to do it even at great cost, for the sheer sake of doing it" (Csikszentmihalyi, 1990, p. 4). Here, Csikszentmihalyi and Hermanson posited that if a flow experience can be achieved in a museum, the right conditions for learning can be met.

For this, Csikszentmihalyi and Hermanson proposed a four-stage model that can lead the user to achieve learning due to intrinsic motivation through flow in exhibitions. Here, they use curiosity as the trigger point to grab the visitor; curiosity is described as contextual stimuli, such as sounds, colors, displays, etc., so that the visitor's attention may be attracted and, thereby, be compelled to invest more psychic energy, which could lead to extensive interaction, resulting in learning (Csikszentmihalyi & Hermanson, 1995, pp. 68–69). This then leads to an initial interest, which is presented as a phenomenon that emerges from a visitor's interaction with the environment that can produce situational and individual interests, such as personal domain-specific appeal like astronomy, biology, etc. Here, learning is framed as an experience that must originate from individual interest (Csikszentmihalyi & Hermanson, 1995; Dewey, 1913, 1938a). From this, the visitor should be presented with emotional (empathy and self-reflection), intellectual (rational, scientific, and historical), and sensory (visual, aural, and kinesthetic) opportunities for involvement. The term employed here is *mindfulness* (Langer, 1993): "...a state of mind that results from drawing novel distinctions, examining information from new perspectives, and being sensitive to context" (Langer, 1993, p. 44). This directly influences the communication strategies employed in the museum. If the information is presented as absolute without an alternative perspective, the motivation to explore and learn more is discouraged, a mechanism referred to as "premature cognitive commitment" (Langer, 1993, p. 45). If the exhibition design manages to facilitate the visitor through the three stages, the end result will be a fourth and final stage, where the visitor will be absorbed in an intrinsically rewarding experience that can be sensorial, intellectual, and/or emotional. However, the visitor's desire to maintain the flow experience must be met with "increasing challenges to avoid boredom and increasing skills to avoid frustration; the consequence of this dynamic involvement is a growth in sensory, intellectual, and emotional complexity" (Csikszentmihalyi & Hermanson, 1995, p. 72).

The four-stage model for exhibition design, to encourage learning through intrinsically motivating (flow) activities, advocates using triggers that can lead to enjoyment, which in turn could lead to learning. It describes the use of novel and contextual stimuli to spark curiosity, which can ignite the visitor's interest, and the visitor should be allowed to explore the exhibits instead of being directed and instructed. If these conditions are met, the museum exhibition can induce the flow state, leading to an intrinsically rewarding experience. With the model, Csikszentmihalyi and Hermanson provided a pathway from experience to enlightenment, using experience as an engine for enlightenment through exploration. Essentially, they offer a practical way to design that can evoke a state of flow. This in turn primes the visitor for a learning experience, where the flow bridges enlightenment and experience as a dynamic involvement that could lead to a growth of sensory, intellectual, and emotional complexity.

The theory of flow has been used to make sense of why humans do the things they do when they engage themselves in an activity; it offers a lens to understand human activities and has been linked to many activities outside the small sphere presented here as exhibitions. In his work, Csikszentmihalyi (1990) presented elements of enjoyment, the prerequisite for flow and to enter the zone, by stating that those who play sports and exercise gain enjoyment from the focused attention these activities require. Flow has also been explained through neuroscience or, more specifically, neurochemical reactions, such as *dopamine,* which is linked to learning or encountering something new and rewards exploratory behavior and *endorphins,* which is a natural endogenous pain relief that triggers when the body is pushed to extreme physical exertion (Kotler, 2014). He further stated that the flow zone could be achieved by using the mind to play games and get into the flow state, which produces enjoyment (Csikszentmihalyi, 1990). This means that flow can be achieved through both physical and intellectual efforts, activating the faculties of the mind and the body. For example, art, creativity, and music (Csikszentmihalyi, 1996), physical exertion and sports (Jackson & Csikszentmihalyi, 1999), and scientific discoveries and playing games (Csikszentmihalyi, 1990, 2014a, 2014b). Since the concept of flow was introduced through Csikszentmihalyi's work in 1975 (Csikszentmihalyi, 1975), stemming from a cell in positive psychology, it has been widely adopted in other areas and disciplines as a way to explain the phenomena surrounding human activity, creativity, and exceptional performance, whether it is for learning, playing, or exercising. Since the early 2000s, flow has been used as both an analytical framework and a design tool to understand and create games and playful systems, resulting in adaptations of flow, such as the GameFlow framework (Chen, 2007; Csikszentmihalyi, 2000; Sweetser et al., 2012, 2017 & Sweetser & Wyeth, 2005).

Here, flow provides a framework for priming and maintaining the user's state of mind for learning in an exhibition. The constructivist approach positions users to be active and engage in open-ended explorative experiences. The model for intrinsic motivation enables the user to enter the zone through curiosity, exploration, and discovery while prioritizing a balance between ability and skill to maintain flow. Experiential learning theory supports these approaches by presenting experience as central to the transformation of knowledge. The link is implicit above: the didactic models encourage active experimentation through explorative experience, while flow provides cohesion with the user's motivation through a framework that attunes the flow for exhibitions to elicit exploration. Thus, it can be argued that through explorative interactions, enlightenment, and experience can be linked in informal learning environments.

The question raised in 1.3.3.3 regarding how users can be supported through experience technologies in automated exhibition sites has, in part, been answered by discussing the connection and configurations of enlightenment and experience and presenting a way to balance both in explorative exhibitions. However, if existing didactic models (Falk & Dierking, 2013; Hein, 1998; Kolb, 2015) propose that learning can be achieved through explorative experiences triggered by curiosity that ultimately leads to discovery and potentially learning and that this can be supported by the flow state of mind (Csikszentmihalyi, 1990; Csikszentmihalyi & Hermanson, 1995; Langer, 1993), then how can all of this be facilitated?

1.4.3. ENLIGHTENMENT × EXPERIENCE

> "Games are ancient. [...] playing games is part of what it means to be human. Games are perhaps the first designed interactive systems our species invented."
>
> ~ Zimmerman, 2014, p. 19

Games and play are core concepts in the subsequent discussion that introduce playing games to facilitate enlightenment and experience. In *Rules of Play* (2004), Katie Salen and Eric Zimmerman presented a way to discern between play and games, used here to understand games and play in an exhibition context. Salen and Zimmerman presented two ways to frame the relationship between games and play: games as a subset of play and play as a subset of games (Salen & Zimmerman, 2004, p. 83). In the former, play represents many kinds of playful activities. Some of them are games, but many of them are not. In this sense, games are contained within play. A distinct way of understanding play is that order and rules can be used to set the boundaries to the free will inherent in unstructured play, at which point play transitions to game (Salen & Zimmerman, 2004, pp. 71–72). In the latter, games are complex phenomena, and there are many ways to frame and understand them. Rules, play, and culture are three aspects of the phenomena that frame a game. Thus, play is contained within games (Salen & Zimmerman, 2004, pp. 72–73, 2004, p. 75, 2004, p. 83). Every game exists within a frame: a delineated time and space that communicates to players, consciously or unconsciously, that a game is being played (Salen & Zimmerman, 2004, p. 99). The imaginative place traced in time and space is often referred to as *the magic circle* (Salen & Zimmerman, 2004, p. 95), a notion that stems from Johan Huizinga's concept of *play-grounds* (Huizinga, 1949, p. 10): a play frame for games. A magic circle of a game is the space within which a game takes place. Whereas more informal forms of play do not have a distinct boundary, the formalized nature of games makes the magic circle explicit. In the circle, the game's rules create a special set of meanings for the players of the game. These meanings guide the play of the game (Salen & Zimmerman, 2004, pp. 94–99). The notion here is that exhibitions, in an informal learning setting, offer a place to demarcate time and space where both visiting exhibitions and playing games can be aligned. Additionally, a quality inherent in the activity of playing a game is that it requires a player to engage in the game and interact with the underlying system of the game. Thus, a player cannot be inactive or passive while playing games.

This view is mirrored in the anthology *Museums at Play* (Beale, 2011), which collects several practice-based examples of games and playful interactions designed specifically for museum exhibitions. The examples are presented through theoretical reflection on the use of games and play in informal learning environments by a combination of museum professionals and game theory experts. The practice-based approach provides knowledge from real-world examples in addition to the research-based ones presented in 1.3.3. Some games were designed as integral to the exhibition experience, while others were created to gamify the experience of being in the exhibition. The difference is that the latter is (often) designed to encourage first-time visitors, people apprehensive of the exhibition experience, or non-users of museums (Beale, 2011, p. 18) and to guide and facilitate visitors by harnessing game mechanics and technology, such as scanning objects with smartphones to progress and unlock access to areas and content of the exhibition (Beale, 2011, p. 22).

In the anthology, a permeating perspective presented throughout the reflections on the implementation and effect of the various games and interactive installations is that the traditional understanding of museums as a single authoritative voice needs to be challenged, a perspective that resonates with the discussion in 1.4.1. Authors of multiple entries have argued that games can do this well because games and interactive media can generally create environments that support museum–visitor interaction (Goines, 2011, p. 505). They have also argued that interactive media and games allow visitors and players to explore exhibition content through play because gameplay enables them to explore and learn (Birchall & Henson, 2011, p. 170; Goines, 2011). Museums should assume a supporting role in facilitating this (Goines, 2011, pp. 513–514). Similarly, others (Alderman, 2011; Barnes & Hayward, 2011) argued that the audience should gain more control and autonomy over their experience and that museum professionals should cede some control and let the visitors play because this enables the visitor to actively engage with the exhibition and co-author the narratives, and this can lead to a discovery that can be had through self-guided experiences (Alderman, 2011).

Games and play are linked to learning in informal settings in *The Art of Play: Exploring the Roles of Technology and Social Play in Museums* (Walker & Fróes, 2011), where play is presented as a structure to support visitor learning based on research in both museums and interaction design. The authors state that many museum researchers, such as Putnam (2009), Parry (2007), and Hooper-Greenhill (1999), consider the museum itself as the medium, following McLuhan (1964), who stated that "the medium is the message," and that media send their messages, which are distinct from the content they carry (Walker & Fróes, 2011, p. 495). This sentiment is echoed in *Digital Technologies in the Museum* (Tallon &

Walker, 2008), where the shifting role of museums from one-way dialogue to multiple avenues of understanding via the incorporation of interpretive technologies should be pursued in the museum sector (Samis, 2008). After all, exhibitions are full of other media, including interactive digital media, which by definition mediate visitor meaning making as presented previously through Drotner (2011) and Drotner et al. (2018). The authors have recognized the commercial pressure for museums to compete with leisure industries, such as theme parks and sporting events (Bradburne, 1999) and that this has resulted in a tendency to add interactive technologies in exhibitions but often "to mask serious subjects in the guise of popular culture" (Walker & Fróes, 2011, p. 488), which is part of the discussion in 1.4.1 that leads to disneyfication rather than an integrated experience. In the pursuit of a more integrated way to design game experiences for exhibitions, Walker and Fróes, proposed that by aligning "playing games" with "visiting an exhibition," the necessary conditions for designing play experiences for exhibitions can be met (Walker & Fróes, 2011, p. 495). Thus, they argued that "play can provide museums with ready-made structures and concepts, which can help plan for visitor learning" (Walker & Fróes, 2011, p. 487). In the following, Johan Huizinga's four aspects of play (Huizinga, 1949) will be juxtaposed with the exhibition design research presented and discussed in the previous sections.

The four aspects position play as a free-choice activity, distinct from real life, provide a structure similar to games, and establish social bonds (Huizinga, 1949). Play is a free choice; it cannot be forced. It is connected to freedom and free time, which implies personal commitment and engagement. This aspect is linked to museums as free-choice learning environments, as established in section 1.4.1 (Falk & Dierking, 2000). They were further supported by didactic models that encourage an explorative, experiential learning style that must be triggered through curiosity to enable the intrinsic motivation necessary for learning (Csikszentmihalyi & Hermanson, 1995; Hein, 1998; Kolb, 2015). Play is distinct from real life. The cultural manifestations surrounding the play (e.g., playground or micro-worlds constructed from imagination) provide a "spatial separation from ordinary life" (Huizinga, 1949, p. 19) referred to as a "magic circle" that denotes the idea of a special place in time and space created by a game (Salen & Zimmerman, 2004, p. 95). The notion of framing activities through play as playgrounds or imaginative "magical" constructs that provide a spatial separation in place and time resonates with the concept of exhibitions as liminal settings (Bell, 2002) or "social laboratories" (Fritsch, 2007), where exhibitions are regarded as artificial constructs similar to, e.g., digitally mediated virtual realities (Thomas & Mintz, 1998, p. 50; Walker & Fróes, 2011, p. 490). In this setting, play frames the activity and games provide the structure.

Exhibitions collect and display artifacts from times, locations, and contexts that are de-synced from real life and the world outside the exhibition. Furthermore, exhibitions provide a confined setting for play, and games provide a rule-based structure. Visitors generally do not have predetermined ideas of what they are going to do or learn upon entering an exhibition (Hood, 1983, p. 50; Walker & Fróes, 2011, p. 492), thereby the visitors allow the museum to structure their visit to a certain extent (Smith & Tinio, 2008). Play connects communities and establishes social bonds; co-experience is a characteristic of play in which players unite toward common objectives, whether as part of a team or as opponents. In other words, play can be an aggregation tool that brings people together to share in an activity in which they mutually withdraw from the rest of the world (Huizinga, 1949, p. 12). Furthermore, exhibitions act as a *space of emulation* (Bennett, 1995, p. 98) where visitors go for social and educational experiences (Hood, 1983, p. 50), with a majority of visitors going to museums in groups (Griffiths & King, 2008), which could be harnessed to design playful social interactions. In this regard, it is also important to consider visitors' motivations for visiting, as it can be for learning, relaxing, socializing, or aesthetic experiences (Walker & Fróes, 2011, p. 492). The activity of playing games in museums can link entertaining elements with learning functions and, in a more practical sense, transform exhibition sites into *knowledge playgrounds*, where it can be argued that the activity is a way to *experience enlightenment*. An activity that combines both enlightenment and experience and where all outcomes, whether for learning or entertainment, or both, can be achieved.

The elements repeated in the didactic models specific to exhibitions, such as active experimentation, curiosity, exploration, discovery, flow, and motivation, are trace elements found in games. Games (and play) can unite elements, such as autonomy, control, curiosity, challenge, choice, discovery, interactivity, etc., depending on the genre and setting of the game. Games played in exhibitions contain elements of investigation, exploration, and puzzles in the form of scavenger hunts and quizzes—a game genre known as *adventure games*. Adventure games emphasize exploration, collection, and puzzle-solving (Bates, 2004; Fullerton, 2019) as core game features. This form of gameplay originated in the 1970s with the game *Adventure* (Crowther & Woods, 1976), which was based in part on the layout of real-world cave structures. The game was a partial exploration of a real place, but with elements of fantasy (Barton & Stacks, 2018), which has since evolved into other genres. Adventure games could provide a frame for the type of games played in exhibitions because this type of game resonates with the didactic models discussed previously: active experimentation through explorative experiences in exhibitions enable exploration through curiosity and strike a balance between skill and challenge to maintain and sustain the user's interest and motivation. The following quote from Tom Chatfield's (2011) musings on the analogies between players' encounters with games and visitors' encounters with exhibitions sums it up in:

> The potential analogies between entering a museum and entering a video game should be clear enough: each is a self-directed process of discovery within an environment carefully shaped to provide both emotional experiences and new skills and ideas. There is something inherently playful to each experience in the freedom and serendipities it can offer, and the fact that a visit is as much its own reward as the means to end – something that can be moving, delightful, enthralling, revelatory, beautiful, informative, or simply a transporting escape from the quotidian. The differences between museums and games are equally obvious: from tone and topics to simple matter of virtual reality versus actuality. Nevertheless, the video

games industry has much to offer those interested both in understanding the experience of visiting a museum in new ways, and of translating a museum's assets into other realms. Perhaps above all, it offers a ready-made and highly-evolved expertise in the embedding of mechanics for engagement in public places. (Chatfield, 2011, pp. 481–482).

1.5. Research Perspectives

The theoretical stances and positions presented in the preceding sections discuss different perspectives on the OM program's foundational thesis regarding enlightenment and experience. They are a dyad that creates challenges for museum exhibitions. However, they are not necessarily binary, as demonstrated through the discussion in 1.4.1; they can be re-conceptualized in multiple ways, as they have, and the meaning imbued within the two can also be differentiated. Here, they are presented as a dyad that combines both as part of the exhibition ecology. Games and play are introduced as forms of mediation where symmetry between enlightenment and experience can be realized. Specifically, adventure games are emphasized because this type of game contains trace elements that connect with constructivist and experiential learning and can convey motivation and sustain flow through gameplay. Thus, the dyad, didactic models, and the combination within a game shell are reconceptualized and referred to as *explorative exhibitions* in exhibition design and *exploration systems* in designing interactive systems for explorative exhibitions.

HCI provides an approach to designing, developing, and testing systems for purposeful and playful exhibitions that integrate the learning potential, meaning-making, and entertaining experiences, as discussed in 1.4.1, 0, and 1.4.3. Furthermore, the challenge articulated by the HMNJ regarding automated exhibitions focused one research on the use of experience technologies to support self-guidance. The literature presented and discussed throughout provides a contextualization and indicates a growing interest in researching the use of computer technologies in museum exhibitions and signals an ongoing trend in a direction where HCI and game systems can be the underlying approach for designing, developing, and evaluating technology's role as an exhibition experience. In this instance, there is an interest in researching the use of computer technologies to support users through explorative interactive experiences in exhibition design practice.

At the frontier of this development, researchers and practitioners are creating and testing ways to facilitate and mediate experiences within museum exhibitions, as discussed in 1.3 and 1.4, which include instantiations of technologically mediated experiences in exhibitions. In addition, more advanced applications and systems are emerging based on new computing and interacting paradigms, and as technology advances, the boundaries for what is possible and feasible are expanding rapidly.

The objective of researching this subject is not to assert having discovered computer technologies and interactive experiences as an approach to design and develop museum exhibitions but rather to break new grounds and expand an existing field of research. The area of concern outlined here is not to ask if it is possible to design digital experience layers mediated through computer technologies that can integrate enlightenment and experience within the exhibition ecology in a balanced way. Instead, it seeks to expand the existing research by exploring how interactive digital media and experience design can create self-guidance in an automated site through the transference of game design principles and processes. Thus, the aim of this project is to contribute to exhibition design research and praxis by applying experience technologies to design and develop systems to support users in automated sites. Therefore, this work employs HCI methodologies in the design process and research regarding the use of both games and interactive systems in museum exhibitions to design and develop systems for exhibition sites in an integrative way.

Shneiderman et al. (2018, 2016) suggested that HCI as a field needs to establish "grand challenges" to steer the direction of future research, design, and commercial development (Mueller et al., 2020; Shneiderman, 2018; Shneiderman et al., 2016). Hence, the work in this thesis is established in such a challenge. While the concept of facilitation and mediation through integration between user and computer is not a recent endeavor, it echoes the initial trailblazers from both research and praxis. It is the most recent articulation of the automation of exhibitions and self-guidance mediated through interactive digital media that provides a segue to establish this project as a grand challenge that investigates how the dyad between enlightenment and experience can be reconfigured in a way that brings balance while setting the scope to facilitate self-guidance mediated through experience technologies.

The stratification of the research project can be summed up as the facilitation of automated exhibitions through systems designed to integrate trace elements into didactic models and adventure games mediated by computer technologies. Thus, exhibition design research and HCI are the underlying and overshadowing approaches for design, implementation, and evaluation.

1.5.1. HYPOTHESIS

The presented theoretical background aligns with the motivations for this work, the OM program, and the research project in collaboration with the HMNJ. In addition, the theoretical, practical, and methodological approaches derived from HCI and exhibition design research provide an approach to frame this study and design, implement, and evaluate experience-based computer systems.

The research program, project, and prescribed challenges are investigated and examined through different resolutions throughout this section. A high-resolution investigation of enlightenment and experience led to an understanding of the two as phenomena with a complex past and various ways of interpreting them within the discourse. The initial research inquiry was articulated around striking a balance between the two, which resulted in a low-resolution study where enlightenment is delineated to learning through exploration, and experience is delineated to the activity of playing games in exhibitions.

Zooming further reveals the core components of this project: experience technologies denote the utilization of technologies to mediate evocative experiences, playing games to reframe exhibitions as knowledge playgrounds and facilitate self-guidance in automated sites, and exploration as a central term that links everything together. Finally, HCI provides an approach to design, implement, and evaluate systems that integrate the components for further study.

This established the foundation for the hypothesis **[H]** investigated in this thesis:

Experience technologies can be utilized to mediate the dynamics of enlightenment and experience by integrating both into the design of explorative systems for exhibitions.

The assumption inherent in the hypothesis is that enlightenment and experience can be integrated into the design of an interactive system, where exploration becomes a central design criterion, and that this system can support users in automated sites. Furthermore, playing games becomes an implicit part of "explorative systems for exhibitions," as the system's design can be either a game or a system that uses game elements. Therefore, the aim of this study is to investigate new ways to support users on automated sites through experience technologies. The objective is to understand how systems can be designed for explorative exhibitions in self-guided situations; thus, further knowledge of how to design these systems to be more useful, usable, and desirable.

1.6. Research Questions

Based on the hypothesis that reframes the research project from the initial research inquiries, this project is guided by the following overriding research question **[RQ]**:

How can experience technologies mediate explorative exhibitions in automated sites?

The research question is examined through explorative study's, where state-of-the-art technologies were used in different experimental setups and configurations that integrate games or game elements and interactive digital systems into the design processes concerned with explorative exhibitions. To further support the research question's examination of the hypothesis, the question is divided into three sub-questions. The sequence of these subquestions are based on the research question's theoretical and practice orientations.

First, the initial research inquiry and investigation formed the hypothesis, which informed and constrained the targets of this study concerning the use of experience technologies for explorative exhibitions. This leads to the following sub-question **[SQ_01]**:

What principles and criteria can be identified to design systems that mediate exploration in exhibitions?

To design explorative systems for automated exhibitions, principles from HCI, exhibitions and game design will be examined. The first sub-question sets out to define the system's scope and aim and filter out the necessary theoretical frameworks and principles that can be applied to develop explorative user interaction in exhibitions. Principles and design criteria will then be transferred to the implementation of the design, which is the basis for articulating a practical and technical-oriented second sub-question **[SQ_02]**:

How can experience technologies mediate exploration in exhibitions?

The most suitable platforms and technologies will be surveyed to understand their possibilities and limitations. Therefore, state-of-the-art technologies will be examined to specify a platform for mediation. However, mediation also implies that form and content must be examined to qualify for a suitable technological platform. Developing and implementing systems for automated exhibitions will inherently impose both technical and practical implications and challenges and determine how to shape the content that mediates exploration. To resolve these, co-design processes are involved as part of the design process in a collaborative multi-and inter-disciplinary team. The result is an iterative design process that details prototyping and testing based on the clarification of concepts and principles transferred from the previous sub-question, which leads to the evaluation of two systems designed, developed, and subsequently studied in the wild in the third and final sub-question **[SQ_03]**:

How can experience technologies facilitate automated exhibitions?

The focus of the project is on the technical implementation and execution of exploration systems that necessitate a reality check, which is achieved through user research. User studies based on both high- and low-fidelity prototypes are conducted to unveil the potential of using exploration in the design of systems for automated exhibitions. The resulting evaluation of systems for explorative interactions in exhibition sites will inform and extend the current understanding of designing, developing, and evaluating explorative systems for automated sites.

In the project, the focus is on extending the theoretical discourse for utilizing technologies to facilitate and mediate user experiences in self-guided situations and experimenting with the approach in different configurations in an intertwined relation.

SECTION 02

When you want to know how things really work, study them when they're coming apart.

William Ford Gibson

2. SETUP

The research design and methodology are presented in this section to describe how the research question was addressed. This means explaining the selected strategies for inquiry, the research logic at play, and the philosophical worldview that determines how the researcher approaches phenomena and the meta-theories that determine how the phenomena are studied. To structure and present the setup of the studies and research methodology of this study, Creswell and Creswell's (2018) framework was used as a point of origin to frame the setup of this project's design. Their framework describes, on a meta-level, the components that are part of a research design: *philosophical worldviews*, *research methods, methodologies* (which is termed *design* in their framework), and approaches that are determined by the type or combination of methods applied in the research (i.e., *qualitative*, *quantitative*, and *mixed methods)*.

The following presentation of this project's setup uses parts of the meta-level components derived from Creswell and Creswell's framework presented in *Research Design* (Creswell & Creswell, 2018) but will go beyond to explain the very specific research design of this project that requires additional components not covered in their framework.

Three methodical approaches are advanced in Creswell and Creswell's (2018) framing to research that can generally apply to any research project: *qualitative*, *quantitative,* and *mixed methods*. In research, qualitative and quantitative approaches are not presented as discrete approaches that are distinct or opposite. They represent different ends on a continuum (Creswell, 2015; Newman & Benz, 1998). Mixed methods is positioned in the middle of this continuum because it integrates both qualitative and quantitative approaches. Qualitative research is an approach for exploring and understanding the research context. It is an approach that involves emerging questions and procedures with data collected in the participant's setting, data analyzed from particulars to general themes, and the researcher interpreting the data (Creswell & Creswell, 2018, p. 41). Quantitative research is an approach for testing objective theories by examining the relationship among variables that can be measured, typically on instruments that produce numbered data that can be analyzed using statistical inference to test theories and assumptions, building in protections against bias, and being able to generalize and replicate the findings (Creswell & Creswell, 2018, p. 41). Mixed methods as an approach to inquiry involves capturing qualitative and quantitative data, integrating the two forms of data, and analyzing it using theoretical frameworks and assumptions based on the researcher's worldview. The core notion of this form of inquiry is that the integration of qualitative and quantitative data can generate additional insight compared to the information provided by either qualitative or quantitative methods (Creswell & Creswell, 2018). This project uses mixed methods throughout the different studies detailed in 2.3, as different methods obtain information regarding different issues or across different time frames. Different methods and types of data can complement or reinforce each other, i.e., *triangulation*. Methodically, triangulation is a combination of multiple methods for the same research question to corroborate evidence from several perspectives (Hanington & Martin, 2019). More specifically, four types of triangulation were used throughout the combined studies of this research project: *data triangulation* (i.e., data collected over different time frames, situations, and people), *investigator triangulation* (i.e., multiple researchers collecting, analyzing, and interpreting data), *theoretical triangulation* (i.e., applying multiple theoretical positions to analyze and understand data), and *methodical triangulation* (i.e., using different methods to collect data) (Webb et al., 1966).

The selection of methods is related to the research question and the context for inquiry, such as laboratory settings or museum exhibitions. Additionally, the methodical approach was based on existing studies with roots in HCIs and the museum context, as discussed in subsection 1.3, where a common setup is to use a combination of interviews, questionnaires, observation, and tracking studies, interaction logs, capture audios, and video recordings (Hornecker & Ciolfi, 2019). User studies reveal insights about the user, the context, their interaction with technologies in that context, and the user's attitude and behavior, which can inform the design process regarding demographics, psychographics, and technography (Button & Dourish, 1996; Dourish & Button, 1998; Hornecker & Ciolfi, 2019; Mulder & Yaar, 2007; Sharp et al., 2019).

As presented in the first part of section 1, this research project is positioned within HCI. The worldview presented in this study is based on orientation within the HCI discipline, with design research being the metatheory for the research design. An important distinction here is between research design and design research: The former refers to the structure and setup of the research project, while the latter describes a metatheoretical field in which the project is grounded. The design and development process fundamental to the research design in this thesis is shaped by the traditions of HCI as a field of research and praxis. The methods and methodology employed have roots in *interaction design research*, which is the overlap between design research and HCI elaborated on in the following subsections.

The worldview represented in this project, *pragmatism*, stems from the logical structure for the research design of being explorative and seeking to expand the existing domain knowledge that has its roots in design research. The *serial* and *expansive* research logics that were used as experimentation strategies for inquiry to expand domain knowledge will be discussed before presenting *interaction design research*, which is a form of design research that has been integrated into HCI and become part of the practice, studies, and process of conducting explorative HCI research. Hence, *constructive design research*, a methodology derived from interaction design research, will be presented to explain the overarching frame for the methods applied in this study. Finally, the research methods and techniques derived from the interconnected worldview and research design, ranging from field studies, observation, and interviews, will be described and discussed in the papers presented in 4, which report on the studies conducted throughout the Ph.D. period along with each paper contribution.

The research questions presented in 1.6 cover different levels of abstraction to explore digital systems designed to encourage exploratory behavior and thereby facilitate self-guidance in automated sites, ranging from the conceptual to the technical and practical. Answering these questions entails conducting user studies, conceptualizing prototype designs, implementing them, and experimenting with a framework for designing and studying exploration systems in the field. Based on Creswell and Creswell's (2018) framework, the different levels will be explained and how they are interconnected and continuously inform each other.

The remainder of this section will focus on explaining the research design. The objective is not to contribute methodically or methodologically to design research or interaction design research; rather, it describes the process and reflects on parts that were not clear at the beginning of the research project. Thus, the following subsections connect the research question and sub-questions to the construction of the project's research design. The first part will explain the philosophical worldview *pragmatism,* which stems from the research design; the second part will cover design research in HCI, such as *interaction design research,* along with the derived methodology, such as *constructive design research*; the third and final part will present the studies in this thesis, a chronological view of the activities throughout the Ph.D. period, the developed prototype systems, along with methods and techniques used to collect and analyze data.

2.1. Frame of Mind

> "Technology is neither good nor bad; nor is it neutral."
>
> ~ Kranzberg, 1986, p. 545

The philosophical worldview, also referred to as *paradigms* (Lincoln et al., 2018; Mertens, 2015), *epistemologies,* and *ontologies* (Crotty, 1998), or *broadly conceived as research methodologies* (Neuman, 2014), explains the general philosophical orientation about the world and the nature of research that a researcher brings to a study (Creswell & Creswell, 2018). From the researcher's vantage point, this can also be stated as the ontological question of "what is true?".

Pragmatism is a position derived from the work of Charles Sanders Peirce, William James, and later John Dewey and George Herbert Mead (Cherryholmes, 1992; Rylander, 2012) and is a worldview that is concerned with applications and a "solutions to problems" way of thinking (Patton, 2014). Instead of focusing on methods, attention is on the research question and emphasis is placed on using all approaches available to understand the problem (Rossman & Wilson, 1985). The focus on the research problem is unpacked by using pluralistic approaches to derive knowledge about the problem (Creswell & Creswell, 2018).

Other worldviews, such as constructivism, various forms of phenomenology, and neo-positivism, have strongly influenced design education and practice (Buchanan, 1992; Cross, 1999, p. 19; Fallman, 2003), which could serve as philosophical lenses for design research. Design theory has frequently gravitated toward neo-positivism, whereas design practice has gravitated toward pragmatism and pluralism, with phenomenologists in both areas (Buchanan, 1992). Pragmatism's emphasis on the constructive aspects of research design practice resonates with the research design and its selected strategies for inquiry in this research project. Because in pragmatism, the question that is addressed is not "what is" in the world (Goldkuhl, 2012), rather what "might be". This frame of mind resonates with the thinking embedded in interaction design research, where knowledge is created through intervening to build a "better world" or explore possible worlds through the construction of design artifacts (Löwgren, 2016; Shneiderman, 2018). That is, both in pragmatism and design research, the search for a possible and desirable world is not only a question of conjectures; it is not only guessing or proposing what might be but also installing it through action. It is a process of "knowing through making" (Goldkuhl, 2012, p. 88; Löwgren, 2016; Shneiderman, 2018).

Recent contributions have pointed to *design research* as grounded in pragmatism (Dalsgaard, 2014; Kolko, 2011; Rylander, 2012; Stolterman, 2008). Koskinen et al. (2011) echoed this sentiment in their description of how a theory or hypothesis can be crystalized through the construction of prototypes that can be subjected to tests. Treating prototypes as hypotheses does involve some complexities, as the design process can integrate many types of information into a prototype, in which theory is a component (Stappers, 2007, p. 87). The creation, function, and role of prototypes in this research project will be discussed in 2.3.4.1. Pragmatism has been argued as a foundation for conducting *constructive design research* (Bang et al., 2012; Fallman, 2008; Gaver, 2012; Kolko, 2010; Koskinen et al., 2011; Shneiderman et al., 2016; Stolterman, 2008 & Zimmerman et al., 2007), with references to Dewey (1938b). The pragmatic lens provides a rationale for addressing the research question through the construction of design artifacts as a strategy for inquiry that fits the type of design research widely applied within HCI. With references to Pierce, James, Mead, and Dewey, Peter Dalsgaard presented a pragmatic maxim for design thinking as "... a foundational proposition stating that the meaning of our conceptualizations of the world–ideas, theories, assumptions etc.–should be evaluated on the basis of their consequences and implications in practice." (Dalsgaard, 2014, p. 146), which reflects Dewey's "learning by doing" principle (Dewey, 1938a). This reflects the underlying conditions for *constructive design research*.

Constructive design research is a continuation of a tradition that merges research and design, where researchers create prototypes and models to codify their understanding of a particular situation and to provide a framing of the problem and a description of a preferred state (Zimmerman et al., 2007). This frame of mind enables the researcher to construct possible futures through disciplined imagination: *"... Design researchers can explore new materials and actively participate in intentionally constructing the future, in the form of disciplined imagination, instead of limiting their research to an analysis of the present and the past."* (Zimmerman & Forlizzi, 2008, p. 4).

2.1.1. RESEARCH LOGICS

This research project is categorized as an *exploratory* research project (Shields & Rangarajan, 2013). The objective of exploratory research is to explore the topic with varying depths rather than provide conclusive answers. This type of research explores new problems with few or no previous research contributions, or in other words, explores uncharted territories (Brown, 2006). Exploratory research identifies issues with the variables in the area of interest, which contrasts *descriptive* and *explanatory* research efforts in which more variables are known (Brown, 2006, p. 46). The degree of problem definition describes the type of research: exploratory does not have key variables defined, descriptive has key variables defined, and explanatory has both key variables and relationships defined (Brown, 2006).

In this study, the aim is to explore how experience technologies can be utilized to mediate explorative exhibitions in automated sites and to seek to expand the area of interest. To achieve this, *serial* and *expansive* modes of inquiry were selected from the typology developed by Krogh et al. (2015), which describes different research logics through five methods of experimentation in design research. The five methods are categorized in the typology table (Figure 6) as *accumulative*, *comparative*, *serial*, *expansive,* and *probing* (Krogh et al., 2015).

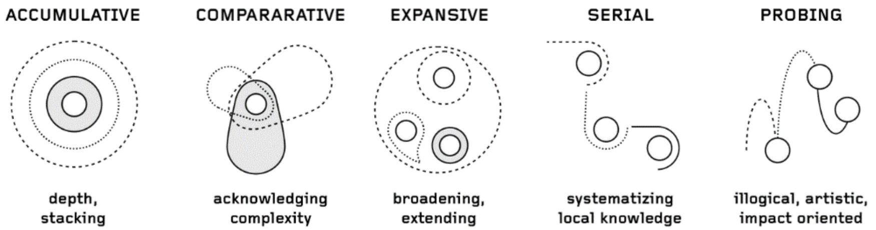


Figure 6: Table of typology with the five methods adapted from Krogh and Koskinen (2020, p. 62).

The five methods of knowledge production through design experimentation are described as *ways of drifting*, that is, how research is done through design can drift when experimenting and how these drifts can yield insights that were not originally planned but valuable knowledge nevertheless (Krogh et al., 2015). With this categorization, Krogh et al. (2015) described how opportunities emerge from design research, which might set the research adrift and, in turn, create new experiments or extend existing experiments. These drifts can provide valuable insights for the project, or they could diverge outside the scope of this project. Traditionally, in the scientific literature, drifting is regarded as random, uncontrolled, illogical, and inconsistent; in design research and practice, drifting is an embedded way of arriving at relevant knowledge (Krogh et al., 2015).

The methods presented in the table of typology allow for drifting but to a varying degree. For example, accumulative is the least forgiving, and probing allows for the largest degree of drifting (Krogh & Koskinen, 2020). Also, the methods are not mutually exclusive; it is possible in one design research project to change between different experimental modes of operation (Krogh et al., 2015, p. 47). Thus, the typology acknowledges that research projects will inherit a multiplicity of methods and may switch between different research logics. The underlying research logic of the five methods stems from design experiments as a core means of inquiry in the research tradition of *research-through-design* and *constructive design research*, which will be elaborated on in the following subsections.

The overall research design of this project is categorized as a project that explores its hypothesis and research questions through *expansive* and *serial* modes of inquiry. The expansive mode of inquiry identifies unknown aspects of a research area (i.e., undefined variables), while the serial mode offers a stricter sequential logic between research activities in a project. In HCI research, iterative development frameworks are frequently used to systematically explore a problem, as derived from the *spiral model* (Boehm, 1988; Sharp et al., 2019). Hypotheses are developed, and design experiments are created while exploring the area of concern, while there is no strict compliance with where the research begins, the type of activities, and how they are linked. An expansive inquiry defines a way of expanding the scope of the area of interest, rather than extending the knowledge of the domain. However, although the primary logic of this study is expansive, the studies that are part of this project also operate locally from serial logic.

As mentioned in section 1.4, using experience technologies to support users in automated sites has been scarcely addressed in previous contributions. Automated exhibition sites are a narrow field of research that could benefit from exploratory studies with an expansive logic. Previous studies have drawn a point of reference for this project, which now seeks to extend and explore experience technologies' capacity to support users in self-guided situations by encouraging explorative user behavior.

The studies conducted through this research project can be described as a continuous exploration of the variables pertinent to designing digitally mediated ways to support users on an automated site. The coherence between the studies becomes apparent when the individual studies are viewed as a whole, which maps out previously uncharted territories through an expansion of the existing body of knowledge. This does not imply a complete mapping; rather, it is mapping relevant knowledge using experience technologies in automated sites to draw a more precise map with new insights and lessons learned to support further exploration. The serial and expansive research logics will be revisited in subsection 2.3.

2.2. Design Research Axioms

"Invention is the mother of necessity."

~ Kranzberg, 1986, p. 548

Design research is the guiding meta-theory for the research design of this project. In retrospect, compared to classic research fields, such as the natural sciences, liberal arts, and social sciences, design research is a newer discipline. In academia, the creation of *artificial things* was largely overlooked as a subject of research, except that designs played a role in investigating natural sciences (Buchanan, 2001). In this framing, the design of artificial things was reduced to a craft, not a science. However, as industry interest in optimizing human factors in product development and systems design increased, design methods emerged (Forlizzi et al., 2009). Originating in the early 1960s, with Christopher Alexander's *Notes in the Synthesis of Form* (1964), the notion of design as a field of research within architecture and industrial design began to proliferate. This way of thinking was amplified by rationalists, such as Herbert A. Simon, who argued for merging science and technology in design. Herbert A. Simon positions the concept of design in *The Sciences of the Artificial* as envisioning "... courses of action aimed at changing existing situations into the preferred ones" (Simon, 1969, p. 111), which echoes the pragmatic frame of mind that operates within the field of HCI research. Simon defines design as "the science of the artificial" (Simon, 1969, pp. 111–113), where "artificial" refers to human-made artifacts.

Nigel Cross (1999) argued that design research must be concerned with the development, articulation, and communication of design knowledge by extending Bruce Archer's (1981) general definition of research as systematic inquiry, the goal of which is knowledge. Cross developed a taxonomy based on Archer's (1981) taxonomy for design knowledge, which falls into three main categories: *design epistemology* (study of designerly[5] ways of knowing), *design praxeology* (study of the practices and processes of design), and *design phenomenology* (study of the form and configuration of artifacts) (Cross, 1999, p. 6). Cross (1982) defined design as "the third culture" in opposition to the more recognized arts or humanities and sciences disciplines. As presented above, Simon argued for a rationalistic way of thinking as the foundation for studying and teaching design based on scientific knowledge and rational practice. Both Simon and Cross defined design as the creation of material artifacts, and both described design as a discipline of its right, different from other sciences. Simon's definition positions design as an activity that tries to turn existing situations into preferred ones, as he points out that a crucial feature of design is that it is future oriented. This way of thinking aligns with constructive design research, which is about imagining new realities and building them to see whether they work. It is a "... science of the imaginary" (Koskinen et al., 2011, p. 42).

Interaction design research is about design, and it is about *research through design*; inventing the future is part of the research process and, accordingly, part of the research method (Stolterman & Wiberg, 2010; Wiberg, 2014). Pragmatism offers a way to understand the present through empirical data and relocates the future through the design of artifacts that expand the domain knowledge through the development of theories for making accurate predictions about the future (Stolterman & Wiberg, 2010; Wiberg, 2014).

Before discussing design research in HCI, such as *interaction design research*, and elaborating on *constructive design research* as the applied methodological framework for this project, it is important to first discuss the different types of design research, such as *research through design,* which became a research approach that employs methods and processes from design practice as a legitimate method of inquiry in HCI

[5] The term *designerly way* refers to a way of thinking and acting in design practice where designers overcome complex design situations (Buxton, 2011; Cross, 2001; Moggridge, 2007; Stolterman, 2008).

research. By inspecting the origins of integrating design into HCI research, a better understanding can be derived about the types of design research before considering how to apply it in praxis.

In 1993, Christopher Frayling suggested that *design research* can be distinguished into three perspectives on research in art and design: *into*, *for,* and *through* art and design (Frayling, 1993). In later mentions, these perspectives have also been termed *on/about*, *for,* and *through* a review of design research particular to HCI in more recent years (Forlizzi et al., 2009). Here, the point of origin examined will be Frayling's three perspectives, summarized below.

Research *into* design is the most widely applied of Frayling's perspectives (Forlizzi et al., 2009), which originated from the design research ambitions of the 1960s and arguably the most traditional field of design. The ambition of research into design is to develop a detailed understanding of the human activity of design, e.g., creativity and art. One of the most influential examples of this type of design research is Donald Schön's work on reflective practice (Schön, 1983). Nigel Cross contributed with analyses of *design thinking*, practice, and research, which are prime examples of this type of research into the epistemology and ontology of design (Cross, 1999, 2006). Design thinking is defined as a methodology that imbues innovation activities with a human-centered design ethos (Brown & Katz, 2009).

Research *for* design is described by Frayling as the "thorny one" in that its ambition is to contribute to the use of designs as unique examples, which is also referred to as "ultimate particulars" (Stolterman, 2008). In this perspective, knowledge and research are embodied in an ultimate particular of the artifact that articulates a future state of the world, i.e., a design solution. The aim is not to solve a problem in practice but to extract archetypes of principles or frameworks applicable in design practice (Forlizzi et al., 2009). Thus, this perspective seeks to develop frameworks and methods of design while extracting knowledge to guide their application. It is not concerned with how the artifact solves the problem in practice but how the design practice evolves by the specific way of creating it.

Research *through* design is a perspective that has gained traction, with a growing interest in research conducted through design. Thus, research through design uses the design process as a method of academic inquiry (Forlizzi et al., 2009). The constructive element of designing ultimate particulars carries over from research *for* design but with greater emphasis on design as a solution to a specific problem. Research-through-design has also been used synonymously with constructive design research in some literature (Bang et al., 2012). Cross (1999), suggesting that design knowledge resides in the artifact, as presented earlier, and not from theories used in the process. By following this frame of mind, the researcher can engage with the wicked problems of design (Buchanan, 1992; Rittel & Webber, 1973) and become actively involved in the design process by attempting to make "the right thing" (Zimmerman et al., 2007). Rittel and Webber (1973) suggested that *wicked problems* are a characteristic of most design problems that are so complex that no correct solutions exist based on theoretical deduction alone. This instigated a shift in the discourse around design research that emphasizes the interrelation between problem and solution in design. Opposing the rationalistic tradition in design research, the concept of design as a *reflective practice,* in which the designers reflect in and back on the actions taken in the "design moves," was proposed by Donald Schön (1983). Schön's contributions formed the basis for re-introducing design as a craft with the inquiry into designing the preferable states. Wicked problems stems from the real world; they are unclear and require a complex analysis process to be understood and eventually solved. Additionally, due to their underconstrained nature, wicked problems are unlikely to be solved in optimal ways. Therefore, as Simon (1969) argued, the researcher must be satisfied with providing partial and imperfect solutions. Research thereby integrates *true* knowledge as understood from classic behavioral science with the *how* knowledge of engineering and through this process proposes an *ideal* truth of the problem. In *The Design Way* (Nelson & Stolterman, 2012), interaction design and design practice are framed as a broad culture of inquiry and action. They argued that rather than focusing on problem solving to avoid undesirable states, designers work to frame problems regarding intentional actions that lead to a desirable and appropriate state of reality (Nelson & Stolterman, 2012; Zimmerman et al., 2007). Thus, design is a unique way to examine the human condition and understand it through intellectual apperception, intentional choice, and reflective practice. Design research is framed as research on a condition that arises from many phenomena in combination, rather than a single phenomenon studied in isolation (Zimmerman et al., 2007).

The three perspectives offer ways to integrate design in research where *into* focus on constructing a theory that describes the process of design, *for* focus on the outcome of different design activities to form theories that may inform design practice, and *through* focus on employing the design process as a method of inquiry about getting the "right design" of preferred future states.

As previously mentioned, the aim of this project is to explore a relatively uncovered area of how to support users in automated sites through experience technologies. The studies that have investigated this problem were arranged around multiple inquiries into both users and technologies to explore how digital solutions can indeed support users in exhibitions. Following the HCI tradition, these studies were concerned with designing, developing, and evaluating systems, i.e., ultimate particulars. Therefore, the studies took on the nature of research through design, employing theories. As hypothesized in 1.5.1, explorative user behavior facilitated and mediated through digital experience layers can support users in automated sites. In other words, these studies methodically inquired about obtaining the "right design" of a preferred future state. However, throughout the process of creating, implementing, and evaluating prototype systems, valuable insights emerged about how experience technologies supported explorative experiences in automated sites that could not be ignored. From this perspective, research *through* design generates empirical data for designing, implementing, and evaluating experience technologies to support users. As research *for* design contribution, the knowledge gained can be parsed as design principles (Lidwell et al., 2010) or design patterns (Alexander et al., 1977) that can inform future design practices for developing digitally mediated solutions to support users in automated sites.

Krogh et al. (2015) argued that there is a predisposition in design research to focus on the final artifact, which aligns with Cross' notion of how knowledge resides in the artifact (Cross, 1999). More recent contributions (Gaver, 2012; Krogh et al., 2015 & Zimmerman et al., 2007) have argued that design studies drift through and gain insights unintended by the initial objective, which can be an equal, if not greater contribution, to the design research discourse. This project drifted from constructing instantiations to testing the hypothesis guided by the research question and the sub-questions. By evaluating these prototypes, knowledge was generated about design outcomes, such as the user experience and qualities of explorative experiences, as considerations related to the usability engineering of digital systems. As research for design, this project seeks to extract principles and lessons learned about the supportive qualities of experience technologies in automated sites. Generating data to abstract knowledge directs this project toward active experimentation using the approach in various settings where prototype systems are constructed and tested regarding interaction and user experience with systems designed for exploration and explorative user behavior. These activities align with research *through* design that provides insights into utilizing experience technologies to support users in automated sites. Thus, the research-through-design activities created insights about current understanding of abstract principles from research-for-design, which caused the research design to drift toward unexpected activities.

Forlizzi et al. (2009) argued that research *through* design could lead to the creation of theories in research *for* design. This aligns with how the knowledge generated through prototype construction and evaluation created knowledge about designing for the particular situation of automated exhibition sites. Thus, drifting between *through* and *for* is not new; however, it occurred unintentionally throughout the research process. Gaver (2012) described the mix of the two meta-perspectives when design researchers discuss their research approach as follows: "The output of this work takes the form, primarily, of artefacts and systems, sometimes with associated accounts of how these are used in field tests, but increasingly includes a variety of methods, conceptual frameworks and theories presented separately from accounts of practice." (Gaver, 2012, p. 937).

As Gaver noted, the focus is not only on artefacts but also on the concepts of theory, frameworks, and methods, which are not ultimate particulars for the individual design case. The drift between the two perspectives is unclear, perhaps because the drifts between designing the ultimate particular and extracting frameworks and design patterns to explain how the researcher got there occur more naturally. This supports another perspective that positions all types of design research, where construction is the core method of generating knowledge. A different way to describe the drifts is that the primary contribution of constructive design research is the prototypes and the frameworks that explain them (Matthews & Wensveen, 2015). The notion of constructive design research aligns with Koskinen et al.'s (2011) notion of the term that describes all types of design research, where construction is the primary method of knowledge creation. Herein lies the argument for how this study is characterized as a constructive design research study, which drifts from research *through* design to contributing with research *for* design perspective on mediating explorative exhibition experiences through computer systems that support the ultimate particulars of design.

2.2.1. INTERACTION DESIGN RESEARCH

In retrospect, design has increasingly impacted HCI practice with the transition from usability to experience. The *design as engineering* approach that once dominated HCI shifted toward a design-oriented field of research and a field to conduct research-oriented design (Fallman, 2008) with new conceptions of the user that require more interdisciplinary conceptions of design (Fallman, 2003; Wright et al., 2006). In particular, user experience in HCI motivated a change in perspective to consider *design as a craft* (Wright et al., 2006). In the early days of HCI, the term design was used to describe usability engineering: "... the process of modeling users and systems and specifying system behavior such that it fitted the users' tasks, was efficient to use and easy to learn." (Wright et al., 2006, p. 1).

Over time, as designers and developers worked together, the skills designers contributed with were considered creative design in interaction design, in contrast to engineering design. The latter, engineering design, describes developers who create systems to meet specifications, while the former, creative design, describes designers who continually reframe the problem and question the underlying assumptions during the design process (Friedman, 2003; Zimmerman et al., 2007). Zimmerman et al. (2007) identified a challenge to integrate design into HCI research practice, which motivated them to formalize research through design as a method of research in HCI by developing a model that targets HCI researchers and practitioners with a set of criteria for evaluating the quality of interaction design research contributions. This model uses the term research-through-design, as Frayling (1993) presented, in which design is defined as an activity aimed at transforming "the world from its current state to a preferred state" (Zimmerman et al., 2007). In their model, design artifacts are central parts of the inquiry; artifacts become design exemplars that provide an appropriate conduit for research findings to be able to transfer to the HCI research and practice communities, where interaction designers can engage wicked problems (Zimmerman et al., 2007). Zimmerman et al. (2007) emphasized design-oriented inquiry, combining theories from HCI with theories from the addressed practice.

In his notion on establishing a "science of design", Herbert Simon (1969) stated that the science of design would be "analytic, partly formalizable, partyle empirical, teachable doctrine about the design process" (Simon, 1969, p. 56). Concerning creating design artifacts, which is the type of interaction design research discussed here, such as research-through-design, Fallman (2003) argued, that the design is "an attitude of making" that enables the researcher to create "something that was not previously there". Fallman was critical of Simon's notion of establishing a science of design, and argued that Simon remains attached to the natural sciences, while design has limitations in resembling other sciences (Fallman, 2003, p. 228).

The primary difference between design and science is that two designers facing the same challange are unlikely to arrive at the same solution. Additionally, the design process cannot be as transparent as an experiment, because there are limits to the way designers can adapt to predetermined behavior, and their knowledge is difficult to articulate. Fallman's notion of design research aligns with Frayling's notion of research through design; new knowledge is investigated through the making of new artifacts. The practice of making is described as a route to discovery and knowledge creation in design research (Gaver, 2012; Löwgren, 2016). This leads to how research through design is understood in HCI because there is an alignment between the many faces of design and using design in interaction design research.

Research through design is characterized as a canonical design research activity (Forlizzi et al., 2009). In addition, research through design is viewed as a designerly inquiry focused on making an artifact with the intended objective of societal change (Binder & Redström, 2006; Zimmerman et al., 2007). From this perspective, the focus on intended outcomes links research through design to Simon's (1969) design definition.

As the preceding viewpoints show, there are different views on design in research. Research through design, in particular, is viewed as design science (Binder & Redström, 2006), design thinking which contrasts scientific thinking (Overbeeke & Wensveen, 2003; Stolterman, 2008; Zimmerman et al., 2007). Also, as discussed earlier, Zimmerman et al. (2007) linked research through design with the concept of wicked problems that cannot be approached using scientific or engineering modes of inquiry (Zimmerman et al., 2010). Echoing past sentiments, the objective of solving a wicked problem is a solution that is optimal for the current situation and does not focus on the discovery of truth (Binder & Redström, 2006; Zimmerman et al., 2007, 2010). Research through design is about research *on the future* (Binder & Redström, 2006; Gaver & Martin, 2000; Koskinen et al., 2011; Zimmerman et al., 2007, 2010).

As explained previously, research through design has become the most widespread design research approach in HCI: how to employ methods and processes from design practice as a mode of inquiry. Research through design lends itself to addressing problems that are defined as wicked and cannot be reduced to usability metrics through its holistic approach to integrating knowledge and theories from across many disciplines. Also, it iterates an approach to reframing the problematic situation and the preferred state as the desired outcome of the research (Zimmerman et al., 2010). Researchers within HCI focus on research on the future rather than on the present, which provides an opportunity for the research community to engage in discourse on what the preferred state might be as an intentional outcome of the research (Zimmerman et al., 2010). This focus on the future and the focus on concretely defining a preferred state allow researchers to become more active and intentional constructors of the world they desire (Zimmerman et al., 2010). As stated by Alan Kay, as the "researchers maxim" in an interview in which he speculates on the future of electronic learning environments, "The best way to predict the future is to invent it." (Wise, 1982).

Interaction design research, in particular, the methodology described in constructive design research from *Design Research through Practice* (Koskinen et al., 2011), resonates well with the perspectives brought from the HCI discipline of research through design as a way to generate knowledge where "...researchers do not try to analyze the material world [...] nor do they see design as an exercise in rational problem solving. Rather, they imagine new realities and build them to see whether they work." (Koskinen et al., 2011, p. 42). This statement also aligns with the many views on design as research presented throughout the subsection. The core of this viewpoint for researching HCI lies in the term *construction* or making of artifacts that can be used to gather data that can be interpreted as knowledge.

In *Thoughtful Interaction Design, A Design Perspective on Information Technology,* Erik Stolterman and Jonas Löwgren (2004) articulated the notion of constructing knowledge through design. Whereas many design disciplines have emphasized the produced artifacts. While the professional knowledge of design has been considered tacit, Stolterman and Löwgren (2004) introduce a complementary perspective where the artifact is not the primary contribution but knowledge (Löwgren & Stolterman, 2004). Design knowledge is primarily intended for other members of the knowledge construction culture to share, debate, challenge, extend, reject, and use. They refer to this as *articulation* "not necessarily in the form of written or spoken words, but in forms that can be appropriated and assessed by others" (Löwgren & Stolterman, 2004, p. 2). This perspective frames how the research was conducted through design in this study. Construction and making played a significant role in generating knowledge to inform design patterns and principles for design and knowledge about specific instantiations of experience technologies to support users in exhibitions through making.

On the significance of *making* in interaction design research, Löwgren suggested that making is required for the explorative design of non-idiomatic interaction[6] (Löwgren, 2016; Vistisen, 2016). Also, in extramural collaboration, as with the NHMJ in this project and the OM research program, making is a co-production nexus that yields artifactual knowledge (Löwgren, 2016). This resonates with Shneiderman's (2018) "twin-win model", an approach that "... favors a problem-oriented approach to research, which encourages formation of teams between academics and professionals to pursue dual goals of breakthrough theories

[6] Designing the finer points of interaction is arguably the dynamic experience of user-system interplay unfolding over time. Interaction design idioms are experiential knowledge about ways of interacting, while non-idiomatic refers to when there are no known idioms, which is often the case with exploring interaction possibilities outside the established idioms. This is often the case with new and novel technologies, where there is no experiential knowledge to fill in the blanks of the technology. This is further discussed in [P01].

in published papers and validated solutions that are ready for widespread dissemination" (Shneiderman, 2018, p. 12590). These roughly translate to Fallman's (2008) practical model aimed at Ph.D. students that describes three external interfaces: industry collaborations, academic research communities, and society as a place where interaction design research has a voice in exploring and shaping possible futures (Fallman, 2008). These three interfaces are design practice, design studies, and design exploration (Fallman, 2008). Fallman's (2008) model contributed to this project by offering a way to distinguish between industry collaboration with the museum (HMNJ). This project, as a Ph.D. study and the OM research program, explores the potential societal impact of museums by addressing a real-world problem related to automated exhibition sites.

Making or constructing is at the center of Koskinen et al.'s (2011) methodological framework for interaction design research, *design research through practice* (Koskinen et al., 2011). The following section will present and explain constructive design research as a methodology that this research project applies.

2.2.2. CONSTRUCTIVE DESIGN RESEARCH

The methodology described in constructive design research was the substrate for setting up studies that continuously facilitates and reframes the hypothesis. Therefore, this subsection will reflect upon how the data was gathered in the four phases. Koskinen et al.'s (2011) notion of conducting experiments is not limited to prototype construction but also to the evaluation of the prototype by exposing it to the context in which it was meant to operate.

Constructive design research is defined as "Design research in which construction – be it product, system, space or media – takes center place and becomes key means in constructing knowledge" (Koskinen et al., 2011, p. 5). This approach is a continuation of the early days of research through design. However, according to Koskinen et al. (2011), this approach was unclear and under-researched in Frayling's (1993) first definition of research through design.

Constructive design research is a practice-led approach described as "research that imagines and builds new things and describes and explains these constructions" (Koskinen et al., 2011, p. 6). This is not an exclusive approach to HCI design research. For example, Paul Dourish (2001) presented a phenomenological strategy of inquiry to decode embodied interactions in HCI, and Zimmerman et al. (2007) presented a formalized model for evaluating interaction design research. Construction and evaluation of prototype systems, and, as mentioned earlier, the balance between subjectivity and objectivity in epistemological and ontological views found in pragmatism is at the core of this project. Koskinen et al. (2011) further described constructive design research as the practice of creating knowledge through the construction of design artifacts; a constructive design researcher imagines new realities and builds them to see whether they work (Koskinen et al., 2011, p. 42).

Constructive design research can be initiated by articulating a research question based on existing theory or philosophy, which is then investigated through a process of making and designing artifacts, or it can be grounded by focusing on "real world problems by making things that force both a concrete framing of the problem and an articulation of a specific, preferred state that uses the intended outcome of situating the solution in a context of use" (Zimmerman & Forlizzi, 2008, p. 5). In this project, a pre-defined research question was presented from the OM research program, which originated from a real-world problem, and the problem was investigated using existing theory and field studies to decode the context and problem, resulting in a hypothesis and the formulation of research question and sub-questions. The construction of a hypothesis and qualification of an experimental process of abductive reasoning in this project means that knowledge, empirical findings, concepts, and ideas are combined as a form of abstract prototypes to be tested and debated according to their relevance to the practice, academia, and viability of the experiment (Bang et al., 2012). Stappers (2007) described how prototypes are the core means that the designer connects theory with the real world. According to him, "Prototypes serve to instantiate hypotheses from contributing disciplines and to communicate principles, facts, and considerations between disciplines. [...] The designing act of creating prototypes is in itself a potential generator of knowledge..." (Stappers, 2007, p. 87).

To explore how experience technologies can support users on automated sites, the sub-questions unpack the research question to combine theory and practice *for* and *through* design. This entails a theoretical inquiry to understand the museum context and field of research that links HCI with exhibitions, designing, developing, and implementing instantiations of theory to be tested and evaluated in an automated site to generate knowledge about explorative user experiences to support users in automated sites. Engaging in constructive design research to investigate the research question made it possible to imagine the new realities of automated exhibition sites and build them to see whether they worked. The construction of prototypes, the resolution, and fidelity will be discussed in 2.3.4.1, along with the presentation of the constructed prototype systems that serve as both proof-of-concepts and instantiations of hypotheses for inquiry.

The methodology of constructive design research is shaped primarily by three different contexts: the *lab*, the *field,* and the *showroom*. These contexts are characterized by research cultures adapted from other research traditions, such as the natural sciences, social sciences, and art (Bang et al., 2012; Koskinen et al., 2011). The three contexts are presented below.

Lab decontextualizes design and focuses on studying designs in laboratory settings where the design element is taken out of its natural environment and experimented with independently, such as when the null hypothesis predicting no change is rejected. After establishing the basic relationship, other explanations are studied to see whether they somehow modify the results. In the lab setting, control is at the core but at the cost of studying the design in its entirety since design has many aspects and only some are appropriate for lab study. The lab is ideal for conducting tests to decontextualize a phenomenon to focus on isolated variables with less interference. This type of study is often theoretically inspired by using quantitative data and statistics to generate design knowledge, framework, and theory through controlled experiments (Koskinen et al., 2011).

Field contextualizes design and focuses on studying design in natural settings. In contrast to lab setups, the field is a context-dependent method that seeks to research and understand design, as it plays out in a specific context. This entails documenting how it was used and by whom. The field draws on methods and tools from social sciences and focuses on how design affects the social context and how the design entity can be researched in its intended context. This method implies ethnographical studies that prioritize understanding how people create meaning with designs over rigorous fact-finding constructed in lab settings. Thus, data generated from the field often take on a more descriptive account rather than a more theoretically informed interpretation as in the lab (Koskinen et al., 2011).

Showroom is a context that focuses on studying and understanding the aesthetics of art and design. This approach builds on the tradition of arts and crafts rather than science. The showroom is described as either more abstract or broader than both the lab and field contexts. Artifacts constructed for design experiments often have ambiguous agendas and ask more questions than they can answer. Contrasting the natural science for the lab and the social science for the field, the showroom is often related to the domain of critical design, exploring how design can be used as a critical medium for reflecting on the cultural, social, and ethical impact of technology. This "design for debate" approach seeks to instigate critical thinking and is an arena where research meets design and art (Koskinen et al., 2011).

In this project, studies were conducted in all three design research contexts, following serial and expansive logics. The showroom in this project was not directly applied in the same way as described above. Instead, it was applied to present the designed prototype systems to peers at research conferences, and as an ongoing part of the research program, different designs in various stages of development were presented to internal museum partners who were part of the OM program and external museum professionals who were interested in the research programs' work and findings. Thus, the showroom context will not be covered in depth, as this project did not seek to isolate, reflect, and understand the aesthetics of art and design, only to the extent that it affects the user experience. This project's contribution redux in section 4 will detail the context for each study.

It is worth mentioning that knowledge production in research design can be characterized as fallibilism (Gaver, 2012; Koskinen et al., 2011), meaning that attaining absolute empirical knowledge is impossible because the statements constituting it cannot be ultimately and completely verified. Therefore, conducting design research becomes a question of exploring parts of a hypothesis for abductive reasoning through design experiments. Bang et al. (2012) elaborated on using hypotheses in constructive design research as an ongoing process in which the motivation of the research project is framed to continuously develop through constructing and qualifying hypotheses through experimentation. Abduction can contrast or stand in relation to deduction and induction. Deduction begins with existing theory or theories that lead to a tentative understanding or presumption, enabling the researcher to hypothesize. Data collection is designed to test the hypotheses/hypothesis to approve or disprove and potentially revise the theory (Bryman & Bell, 2019; Rylander, 2012). In other words, the process here is to deduce from universal to particular. Induction begins with empirical knowledge or data, and the researcher searches for connections and patterns in the data and hypothesizes or theorizes based on the information that emerges from the data (Rylander, 2012). In other words, the researcher induces from the particular to the universal (Rylander, 2012). Deductive reasoning is characterized as a quantitative approach, while inductive reasoning is characterized as a qualitative approach, methodically speaking (Kolko, 2010; Mitchell, 2018).

Abductive reasoning is similar to deductive and inductive approaches; it is applied to make logical inferences and construct theories (Mitchell, 2018). It is typically triggered by surprise or curiosity over an observation, phenomenon, or problem. For example, a researcher may encounter an empirical phenomenon that cannot be explained by the existing range of theories, which makes the researcher seek and choose the "best" answer to explain the phenomenon identified at the start of the research process (Mitchell, 2018; Rylander, 2012). However, abduction differs from deductive and inductive reasoning because abductive reasoning is an iterative sense-making process, while the other two are not defined as such (Kolko, 2010). Thus, "[a]bductive reasoning, follows a pragmatist perspective, taking incomplete (or 'messy') observations from experience and reality that may then lead to a best prediction of the truth, and perhaps even to a new theory" (Mitchell, 2018, p. 105). Abductive reasoning in this project stems from the notion of using hypotheses as an ongoing process that frames the motivation of the research project and continuously develops through experimentation (Bang et al., 2012). Jon Kolko (2010) offered a way to approach design problems via abductive sense-making, described as *design synthesis*. This aligns with Bang et al.'s (2012) way of adding the hypothesis dimension to constructive design research by articulating an assumption as a hypothesis. Researching to either validate or falsify the hypothesis will ultimately lead to knowledge creation about the field of research or design problems. This, as Gaver argued, shows that "the goal of conceptual work in research through design is not to develop theories that are never wrong, it is to create theories that are sometimes right" Gaver, 2012, pp. 940–941).

Abductive reasoning integrates deduction and induction in an iterative process. This process is embedded in interaction design and development processes or *lifecycles* that operationalize design synthesis throughout the research, which will be explained in the following section. The overall methodological framework derived from constructive design research and the rationale for following this approach as part of the research design for this project have now been explained. The framework was used throughout this project to distinguish between the types of studies conducted. The final prototypes reflect serial research logic, as experiments were first conducted in the lab context and subsequently moved into the field. The research context, as explained above in lab, field, and showroom, determines the selection of participants and methods applied in the study or studies. They are added to the overview of each study presented in section 4.1 and in the following, where the research project is described in four primary phases of the entire Ph.D. project period.

2.3. Research Design Praxis

"Technology comes in packages, big and small."

~ Kranzberg, 1986, p. 549

The research design describes the underlying frame of mind, logics, types of design research, and a methodological setup that frames interaction design research as design research through practice—a way to put the design research axioms into research design praxis.

There are many lifecycle models or process models that guide research activities in praxis through systematic, structured, sequential, and iterative design and development processes. Likewise, there are many fields of design, and each discipline has its own approach; this is also true for interaction design in HCI. For example, the *design sprint* (Knapp, 2016): a practice-oriented model that emphasizes rapid ideation and testing of potential solutions to a design challenge to complete an iteration of design and development in five days, or the *spiral model for software development*: a cyclic approach that was created to guide multi-stakeholder concurrent engineering of software-intensive systems (Boehm, 2000; 1988), and the *double diamond of design* (Ball, 2019; Banathy, 1996) that describes the design lifecycle in four phases termed *discover*, *define*, *develop,* and *deliver* in divergence, convergence cycles, and iterative structures.

In HCI, the four phases described in the double diamond are also followed, supported by the philosophy of user-centered design (Sharp et al., 2019). These four phases describe the basic activities of interaction design: *discovering requirements*, *designing alternatives*, *prototyping,* and *evaluating*. The presentation of the four phases are based on Sharp et al. (2019):

Discovering requirements focuses on discovering something new about the world and defining what will be developed. In interaction design, this phase emphasizes and integrates user research and the support an interactive system offers. In this project, the first phase aims to investigate how digital technologies, physical exhibitions, and playing games can be integrated into an explorative experience in automated sites and, through this investigation, inform the design of the prototypes that will be used to study the efficacy of using experience technologies for automated exhibitions. This leads to the next phase: design.

Designing alternatives is the core activity of designing. This entails proposing design ideas for meeting the requirements. In interaction design, this activity can be divided into two sub-activities: conceptual design and concrete design. The former involves constructing a conceptual model for the system that describes an abstraction outlining what users can do with the system and what concepts are needed to understand how to interact with it. The latter, concrete design, considers the product's detail, including the colors, sounds, and images, to use menu design and icon design. Alternatives are considered at every point. This is also where design concepts are turned into proof-of-concepts and prototypes.

Prototyping, as mentioned earlier, is an important aspect of constructive design research. This involves designing the system's behavior in addition to aesthetics, graphical user interface design, or look and feel. Prototyping focuses on enabling users to evaluate designs by interacting with them. Prototyping techniques, however, vary greatly, which will be discussed regarding the fidelity and resolution of prototypes in 2.3.4.1. But evaluation is inextricably linked to developing prototypes.

Evaluating is the process of determining the design or system, measured regarding various usability and user experience criteria. Evaluation of prototypes can be used to iterate and refine a design from its inception to final release but also as proof-of-concepts to test and verify whether a concept is viable or not.

Throughout the process of discovering requirements, designing alternatives, building prototypes, and evaluating them are interlinked; design alternatives are evaluated through prototypes, and the results are reloaded into further design or to identify alternative requirements or qualify the current exploration of a design space.

The four phases were also the substrates for systematically structuring the research process. However, as mentioned, other models describe processes; the one described here is a generic form of a lifecycle. This approach was chosen for this project because it is a more generic approach and has the freedom to follow an approach that does not have prescribed sets of activities or is more suitable for a specific context. It is possible to specialize in the activities and progression of the lifecycle to fit this specific context and this specific project. Thus, in this project, the phases are named *investigate*, *design*, *develop,* and *evaluate* for the sake of brevity and were used in two ways: first, the phases provide a systematic approach to segment the entire research project; second, experiments executed throughout this project period that informed the final prototypes and evaluation were also planned and executed using the same lifecycle. In other words, multiple lifecycles within this project linked the experiments, regardless of scale, through a serial research logic, while each study generated knowledge through an expansive logic, which is a methodological approach that broadens and expands knowledge through experiments (Krogh et al., 2015). In this project, expansive elements become visible through exploration and defining the theoretical criteria for creating explorative user experiences in exhibitions. The serial studies were informed and initiated by expansive studies to explore design ideas. Thus, some experiments were conducted serially to explore and expand; expansive experiments inspired more serial experiments. Expansive experiments were executed in both the lab and field, with the final evaluations stemming from field tests.

2.3.1. CHRONOLOGIC OVERVIEW

The research project as presented in a chronological overview (Figure 7) to provide a visual reference of the timeline for research activities. The four phases and the planned timeline for the project runtime, along with a rough timeline for the implementation and subsequent user tests of the two prototype systems and the boardgame developed throughout the research project period, are included. These will be elaborated further shortly.

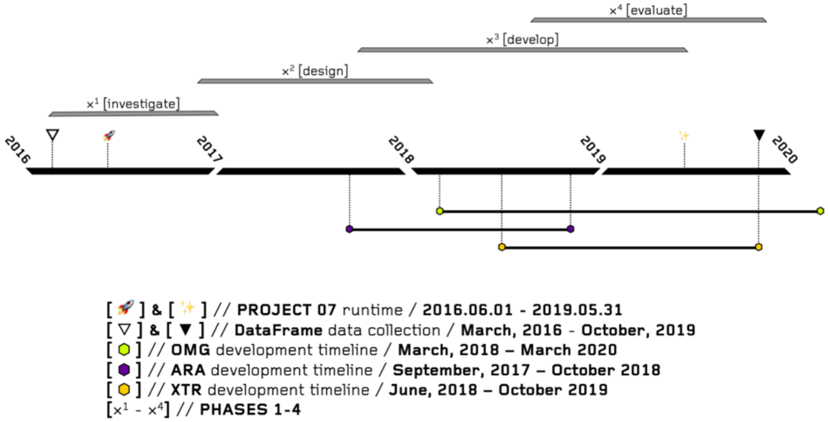


Figure 7: Chronological overview that details the phases and progression of the research project .

In the following subsections, the four phases will be explained to present the methodical approaches. The methods and techniques applied throughout the individual studies conducted in the research project will be presented on a meta-level. Also, each paper's contribution will be discussed, and the limitations of the applied methods and techniques will be described individually. The four-phase structure used in the remainder of this subsection will be reutilized in section 4 to cluster the paper's contributions into four studies. Phase 01 is primarily a theoretical and explorative study of automated sites and the museum exhibition context, while phases 02, 03, and 04 are constructive design research inquiries in which the phenomena were examined and explored through design, implementation, and evaluation.

The following four phases that describe how the research progressed throughout the project's time frame include introductions to the study contributions, such as the two prototype systems (**Explore the Redoubt** [XTR] and **ARATAG** [ARA]), and the boardgame (**Our Museum Game** [OMG]) that were developed. These contributions will be reintroduced later as part of the study's contributions summary in section 4. The details of why and how they were constructed as part of this study will be elaborated upon.

2.3.2. PHASE 01: INVESTIGATE

The first phase commenced before the research project's original inception date as part of the application for the Ph.D. candidature. Literature was reviewed to understand the area of research. This is documented in appendix [C1_TAB1], which was presented in 1.3.3.1 as the scientometric review. That review addressed the unknown variables that emerged in the first phase of the research, where the museum context and the discourses central to this study—enlightenment and experience, the users of museum exhibitions, and technologies' roles in this context—could be studied. As explained in 1.3.3.1, the review strategy used a systematic approach that was based on a combination of the PRISMA and snowball methods (Moher et al., 2010; Wohlin, 2014). This later inspired a systematic method to capture and code data from field studies and state-of-the-art investigations into a table, presented in the following subsection, viz. the *DataFrame.xlsx* in appendix [C1].

Through a narrative synthesis and thematic analysis of the scientometric review, hypotheses emerged that prompted the initial research inquiry to be reframed and articulated more precisely to reflect the knowledge that had emerged. The first studies conducted were a combination of the following trails of past research ventures that also took place in exhibition sites or similar contexts, as reported in [P01; P02; P05]. During this phase, automated exhibition sites gained the focus of attention and were defined to be able to position it as a term that could be discussed and examined for the implication of automation in museum exhibitions. Hence, the digitally mediated technologies were studied to understand how they could contribute to the user experience and qualify game design elements, specifically the mapping of curiosity and exploration as features from adventure games to support users in automated sites. During this period, a systematic approach to collecting, organizing, and analyzing data from ethnographical studies (Bryman & Bell, 2019) started taking shape, found in the table in appendix [C1_TAB2]. Digital technologies and game design were examined to understand how they have been used and can be used to support users on automated sites, as reported in [P02]. It explores how game design elements can be used to both entice and support the first use of systems designed to assist users in self-guided situations. This will be explained as *idiomatic* and *non-idiomatic* interactions, which was part of the first paper contribution [P01] and will be explained further later.

In extension to the literature reviews, the exhibition sites planned to transition into automated sites as part of this research project were studied as part of ethnographical field studies. In praxis, field studies comprise multiple methods, a mixed-methods approach where different methods and types of data can complement or reinforce each other, viz. triangulation. This methodical approach is recommended across the literature from HCI in museums (Hornecker & Ciolfi, 2019). The methods applied ranged from naturalistic and in-person observations, video observations, audio recordings, tracking, timing and logging studies, semi-structured interviews, ethnographic and auto-ethnographic studies, surveys, and questionnaires. The selection of specific methods was based on considerations, such as museum layout, available resources, and the research question being investigated. These studies established a baseline understanding of the museum context, technologies' role in the hands of visitors visiting exhibitions, and the personnel who work at the site. These insights were critical to understanding a context unknown and new to the researcher. In addition, the qualitative methods were central to understanding the context and underlying reasons and motivations that would later inform design decisions and determine the content for prototype systems. The most used methods will be described in more detail, with an experiential reflection from applying those methods.

In the early stages, interviews, video and photo documentaries, note-taking, observations (shadowing visitors who had volunteered), tracking and timing, and studying user behavior were used for data collection and analysis. The vast amounts of data collected in phase 01 was not meant to be analyzed in-depth or at a micro-level but were reviewed. The most relevant findings concerning the research question were extracted and used for future studies. As mentioned, this project was explorative because there were many unknown variables at the beginning. To study a field of research in an explorative way, it is necessary to collect many types of data to discover things that were not within the scope but could still be interesting and relevant to study the research question. All captured data can be accessed in the appendix [E] for review.

The reviewed observation data yielded insight into user behavior and attitude in exhibitions and timing and tracking information to understand the user's pattern, such as movement through the exhibition, points of interest, interactions, both the exhibition and each other in social groups. Different patterns of how users explore museums emerged, which were directly used in the design process of the prototypes. Other ways of tracking have been used with the advent of mobile and ubiquitous technologies through Bluetooth beacons. User movement through exhibitions was logged and analyzed, as reported in [P04], which investigates the feasibility of this type of technology in exhibitions. Three methods are used predominantly throughout the investigative phase, which will be elaborated on subsequently. They are questionnaires, interviews, and observations.

Questionnaires constructed to investigate psychographic profiles were used to collect user demographics, motivation, and experience information. In addition, they were used to collect technographic information, such as attitudes toward digital technologies for self-guidance and the tech literacy of users investigated. However, questionnaires are a limited way of harvesting data, as they are meant to be filled by users on their own without assistance within a relatively short time frame. There are other ways to implement questionnaires, such as post-visit surveys and online forms, but other studies have shown that it is increasingly difficult to recruit users, and they are rarely filled out (Diamond et al., 2016; Nelson & Cohn, 2015). Therefore, using questionnaires must be planned, and if possible, the users must be incentivized. Despite these limitations, questionnaires are a useful way to obtain research data, and they are established in the museum world (Bryman & Bell, 2019; Hornecker & Ciolfi, 2019). The approach that had the best hit rate in this project was to approach users and hand them a tablet preloaded with the questionnaire ready to be filled out immediately.

Interviews were used to gain insight into user motivation and to evaluate the entire exhibition experience from the user's perspective. Interview techniques included structured, semi-structured, and open-ended interviews (Brinkmann & Tanggaard, 2020; Bryman & Bell, 2019). Some were coded directly into surveys to analyze the answers quantitatively, while others were recorded, transcribed, coded, and subjected to thematic analysis. Some of the interview questions stemmed from prior observations.

Observations are the third method applied, which was conducted both qualitatively and quantitatively. These methods were essential for investigatIng the actual conduct of users, which can differ from what they report in surveys or interviews. Observations followed a structured coding and tracking approach and a naturalistic, open-ended approach that captures emergent insights. As described earlier, part of the investigative phase was ethnographic studies, a specific type of observational approach that usually combines interviews for deep immersion into the research context (Brinkmann & Tanggaard, 2020; Bryman & Bell, 2019).

As a part of the baseline investigation at the beginning of the study, a large-scale survey was conducted across all research projects in the OM program, which were conducted at all three sites that were originally part of this study, which can be accessed in appendix [E4], but due to inconsistencies, and other external factors, the data was not used in this study. A new baseline investigation, specifically of the Hals Museum and Redoubt, was executed in 2018 after the museum had transitioned to an automated site, which can be accessed in appendix [E4]. This data was used in the design process of the prototype system (XTR).

An initial part of the investigation into the research context during phase 01, aside from studying the literature, examined existing solutions and conducted a state-of-the-art technological survey to identify emerging technologies[7]. The state-of-the-art technology stems from HCI research targeting museum exhibitions, market reports, and analysis (Ericsson, 2018; frog, 2021; Gartner, 2021).

Context-aware computing platforms, sensors enabling devices to "sense" information related to the user and use this information in applications, such as augmented reality (AR), virtual reality (VR), mixed reality (MR), and extended reality (XR), and mobile devices, such as smartphones, tablets, and wearables, were featured significantly in current and emerging tech trends.

This survey established a technological baseline for this project, which informed research activities that leaped into preliminary design experiments with graduate students from Aalborg University. The exhibition sites that were initially part of this project, described in section 1.3.1,

[7] In this study, the term *emerging technologies* is defined as a hypernym that contains a wide spectrum of developing technology types that are relatively fast growing and radically novel, characterized by a certain degree of coherence persisting over time and with the potential to exert a considerable impact on the socio-economic domain(s). There are five core attributes of emerging technologies, as defined by Rotolo et al., (2015), that are used as lenses to survey state-of-the-art and emerging technologies. They are (1) radical novelty, (2) relatively fast growth, (3) coherence, (4) prominent impact, and (5) uncertainty and ambiguity (Rotolo et al., 2015).

were investigated, and designs were conceptualized around the challenge of automation. The data comprises interviews, photographs, and video material, accessed in the appendix [D]. These initial student co-design collaborations proved fruitful in that data was collected from multiple perspectives and did provide valuable insights that would have been challenging otherwise. In particular, designs could be conceptualized to explore different paths for supporting users in automated sites. Also, on a conceptual level, they receive feedback from museum collaborators and present it to potential users in small-scale setups. The evaluations were reality checks on user interaction, technology focus, and economic viability, which informed further concept designs. These collaborations with students led to a larger workshop collaboration, detailed in the next phase. As part of the co-design activities, the students were introduced to the *Multiverse* (explained below) and asked to conduct their state-of-the-art technology investigations that explored each *realm* of the framework.

To map and examine different types of technologies, Pine II and Korn's (2011) 2 × 2 × 2 matrix, the *Multiverse* framework (Figure 8), was a valuable tool. The Multiverse matrix is a framework that maps the known or, as they describe it, the *cosmos cognito,* the known universe in which all reality exists. This mapping comprises three elements: time, matter, and space. From this, they map the unknown or *cosmos incogniti*, the parts of the universe that are less known (Pine II & Korn, 2011), that is, no-time, no-matter, and no-space.

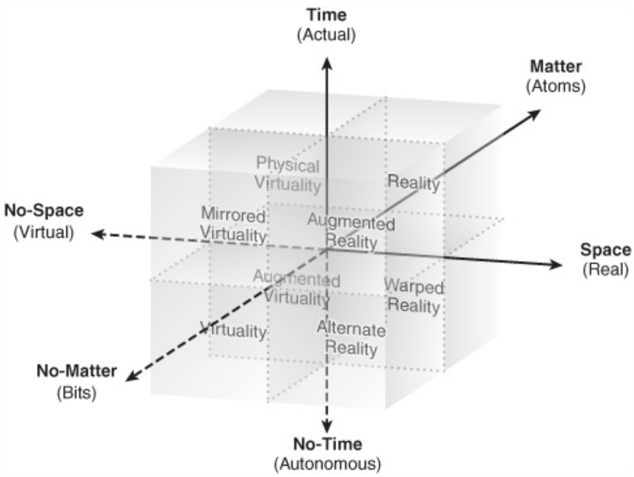


Figure 8: The eight realms of the Multiverse, along with the variables, time, space, matter, no-time, no-space, and no-matter. Source: Pine II and Korn (2011, p. 41).

This produces the 2 x 2 x 2 Multiverse matrix with its eight realms that offer a tool to explore the cosmos incogniti of imagination that helps to make sense of explorations of the digital frontier (Pine II & Korn, 2011). Furthermore, the framework was used as a practical tool to map out the multiple ways for <u>when</u> experiences happen (time/no-time), <u>where</u> they occur (space/no-space), and what they act on (matter/no-matter) (Pine II & Korn, 2011).

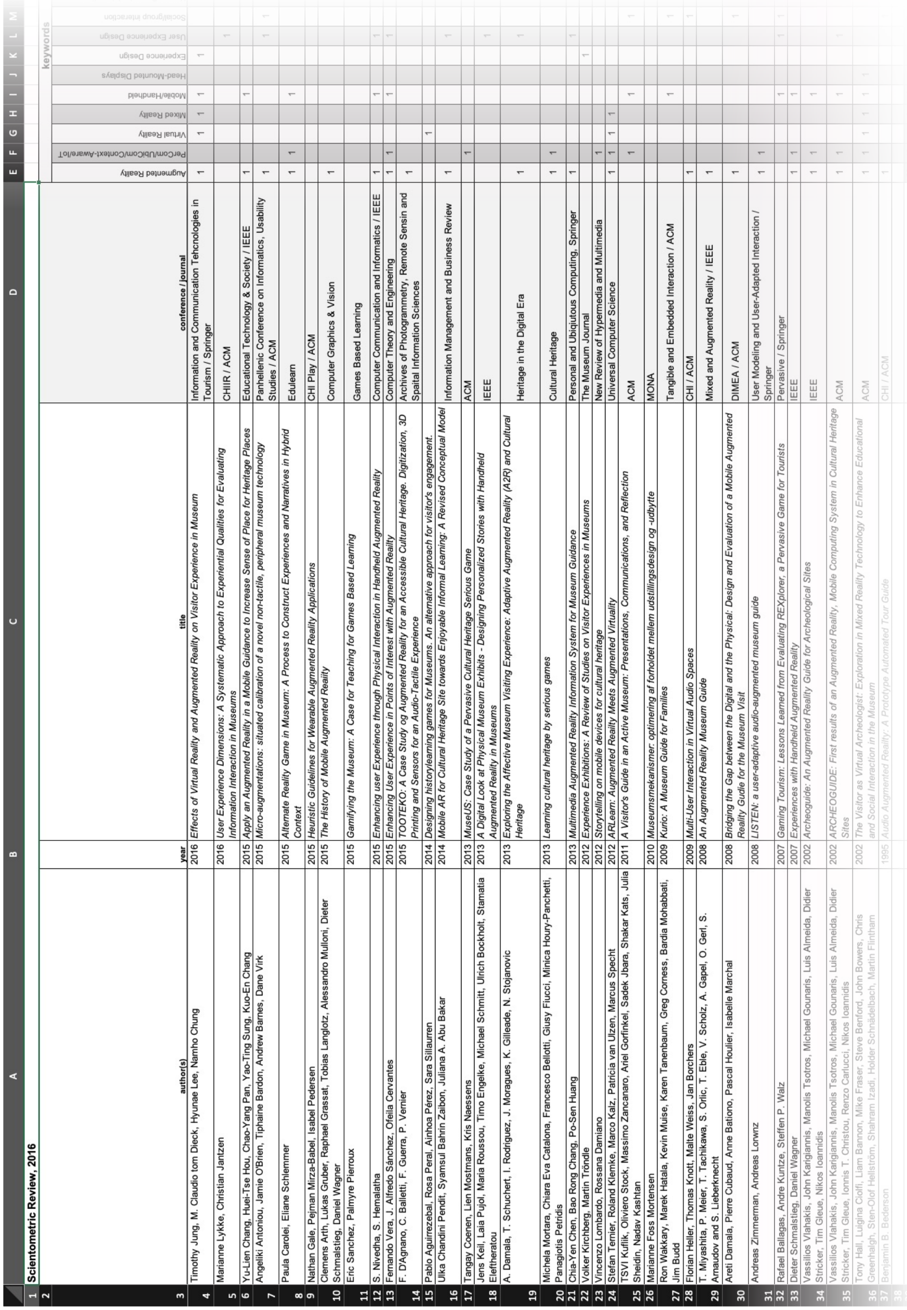
These experimental setups and studies from the initial investigation led to the identification and framing of the design of exploration systems, leading to studies of different technologies that could qualify for experience technologies suitable for self-guidance in automated sites. Mobile phones rapidly gained momentum in the investigative phase as the dominating platform in situations that required self-guidance, as presented in 1.3.3.1 and will be elaborated on in 3.1.2, where interaction frames in museum exhibitions will be presented.

This initiated data collection and analysis in appendix [C1_TAB3], which focused on studying variants of mobile applications from different exhibitions and applications independent of the museum context, captured knowledge from commercially available systems. A particularly interesting aspect here is the inclusion of known technologies and interaction patterns or idioms. The first studies revealed considerable challenges in introducing new interaction modalities or types, discussed in [P01], as *non-idiomatic technologies*. This can cause breakdowns in the first use and onboarding process in the user journey of using new and novel technologies. Irrevocably, as this project investigated how experience technologies can support users, new and novel ways were explored through emerging technological trends.

2.3.2.1 DataFrame

This section comprises data collected from a field study of 56 exhibitions sites worldwide from 2016–2019. The field study began as an investigation into the museum exhibition domain to map out the different types of exhibition ecologies discussed in section 1. Following a systematic approach, they were coded into a table similar to the scientometric review [C1_TAB1] explained and referenced in 1.3.3. The cells were coded using a binary setup, where 1 indicates that data was collected to substantiate a verification and 0 indicates that data was collected to substantiate a nullification; the absence of either 1 or 0 indicates that insufficient data was collected to neither verify nor nullify. This also meant that if a new entry was added to the row of elements in a category, the data was rehashed and traversed throughout all entries and updated with either 1 or 0. The field study began as an ethnographical study to collect data on current museum practices, state-of-the-art implementations of digital technologies, and the current state of design interventions and interaction types in exhibitions. The latter will be covered in depth in section 3.1. The ethnographical study also generated insight into the museum context that, combined with the data collected, was used to clarify and qualify a selection of computer technologies suitable as experience technologies to support users in automated sites through exploration. Through the field study, multiple user and museum personnel interactions were observed, some of which were recorded and included in the appendix [E].

The table, *DataFrame.xlsx* in appendix [C1], contains three tabs: TAB1 (Figure 9) contains the scientometric review presented in 1.3.3, TAB2 (Figure 10) contains the reconnaissance of 56 exhibition sites, and TAB3 (Figure 11) contains a state-of-the-art mapping of mobile applications.



Scientometric Review, 2016

	author(s)	year	title	conference / journal	Augmented Reality	PerCom/UbiCom/Context-Aware/IoT	Virtual Reality	Mixed Reality	Mobile/Handheld	Head-Mounted Displays	Experience Design	User Experience Design	Social/group interaction
4	Timothy Jung, M. Claudio tom Dieck, Hyunae Lee, Namho Chung	2016	*Effects of Virtual Reality and Augmented Reality on Visitor Experience in Museum*	Information and Communication Tehcnologies in Tourism / Springer	1		1	1	1		1		
5	Marianne Lykke, Christian Jantzen	2016	*User Experience Dimensions: A Systematic Approach to Experiential Qualities for Evaluating Information Interaction in Museums*	CHIIR / ACM								1	
6	Yu-Lien Chang, Huei-Tse Hou, Chao-Yang Pan, Yao-Ting Sung, Kuo-En Chang	2015	*Apply an Augmented Reality in a Mobile Guidance to Increase Sense of Place for Heritage Places*	Educational Technology & Society / IEEE	1				1				
7	Angeliki Antoniou, Jamie O'Brien, Tiphaine Bardon, Andrew Barnes, Dane Virk	2015	*Micro-augmentations: situated calibration of a novel non-tactile, peripheral museum technology*	Panhellenic Conference on Informatics, Usability Studies / ACM	1							1	1
8	Paula Carolei, Eliane Schlemmer	2015	*Alternate Reality Game in Museum: A Process to Construct Experiences and Narratives in Hybrid Context*	Edulearn	1	1			1				
9	Nathan Gale, Pejman Mirza-Babel, Isabel Pedersen	2015	*Heuristic Guidelines for Wearable Augmented Reality Applications*	CHI Play / ACM									
10	Clemens Arth, Lukas Gruber, Raphael Grassat, Tobias Langlotz, Alessandro Mulloni, Dieter Schmalstieg, Daniel Wagner	2015	*The History of Mobile Augmented Reality*	Computer Graphics & Vision	1								
11	Eric Sanchez, Palmyre Pierroux	2015	*Gamifying the Museum: A Case for Teaching for Games Based Learning*	Games Based Learning									
12	S. Nivedha, S. Hemalatha	2015	*Enhancing user Experience through Physical Interaction in Handheld Augmented Reality*	Computer Communication and Informatics / IEEE	1				1			1	
13	Fernando Vera, J. Alfredo Sánchez, Ofeila Cervantes	2015	*Enhancing User Experience in Points of Interest with Augmented Reality*	Computer Theory and Engineering	1	1			1			1	
14	F. D'Agnano, C. Balletti, F. Guerra, P. Vernier	2015	*TOOTEKO: A Case Study og Augmented Reality for an Accessible Cultural Heritage. Digitization, 3D Printing and Sensors for an Audio-Tactile Experience*	Archives of Photogrammetry, Remote Sensin and Spaital Information Sciences	1								
15	Pablo Aguirrezebal, Rosa Peral, Ainhoa Pérez, Sara Sillaurren	2014	*Designing historylearning games for Museums. An alternative approach for visitor's engagement.*				1						
16	Ulka Chandini Pendit, Syamsul Bahrin Zaibon, Juliana A. Abu Bakar	2014	*Mobile AR for Cultural Heritage Site towards Enjoyable Informal Learning: A Revised Conceptual Model*	Information Management and Business Review	1							1	
17	Tangay Coenen, Lien Mostmans, Kris Naessens	2013	*MuseUS: Case Study of a Pervasive Cultural Heritage Serious Game*	ACM		1							
18	Jens Keil, Laia Pujol, Maria Roussou, Timo Engelke, Michael Schmitt, Ulrich Bockholt, Stamatia Eleftheratou	2013	*A Digital Look at Physical Museum Exhibits - Designing Personalized Stories with Handheld Augmented Reality in Museums*	IEEE								1	
19	A. Damala, T. Schuchert, I. Rodriguez, J. Moragues, K. Gilleade, N. Stojanovic	2013	*Exploring the Affective Museum Visiting Experience: Adaptive Augmented Reality (A2R) and Cultural Heritage*	Heritage in the Digital Era	1							1	
20	Michela Mortara, Chiara Eva Catalona, Francesco Bellotti, Giusy Fiucci, Minica Houry-Panchetti, Panagiotis Petridis	2013	*Learning cultural heritage by serious games*	Cultural Heritage	1	1							
21	Chia-Yen Chen, Bao Rong Chang, Po-Sen Huang	2013	*Multimedia Augmented Reality Information System for Museum Guidance*	Personal and Ubiqiutous Computing, Springer	1							1	
22	Volker Kirchberg, Martin Tröndle	2012	*Experience Exhibitions: A Review of Studies on Visitor Experiences in Museums*	The Museum Journal							1		
23	Vincenzo Lombardo, Rossana Damiano	2012	*Storytelling on mobile devices for cultural heritage*	New Review of Hypermedia and Multimedia		1							
24	Stefan Ternier, Roland Klemke, Marco Kalz, Patricia van Ulzen, Marcus Specht	2012	*ARLearn: Augmented Reailty Meets Augmented Virtuality*	Universal Computer Science	1	1	1	1					
25	TSVI Kuflik, Oliviero Stock, Massimo Zancanaro, Ariel Gorfinkel, Sadek Jbara, Shakar Kats, Julia Sheidin, Nadav Kashtan	2011	*A Visitor's Guide in an Active Museum: Presentations, Communications, and Reflection*	ACM		1			1				1
26	Marianne Foss Mortensen	2010	*Museumsmekanismer: optimering af forholdet mellem udstillingsdesign og -udbytte*	MONA									
27	Ron Wakkary, Marek Hatala, Kevin Muise, Karen Tanenbaum, Greg Corness, Bardia Mohabbati, Jim Budd	2009	*Kurio: A Museum Guide for Families*	Tangible and Embedded Interaction / ACM					1				1
28	Florian Heller, Thomas Knott, Malte Weiss, Jan Borchers	2009	*Multi-User Interaction in Virtual Audio Spaces*	CHI / ACM	1								1
29	T. Miyashita, P. Meier, T. Tachikawa, S. Orlic, T. Eble, V. Scholz, A. Gapel, O. Gerl, S. Arnaudov and S. Lieberknecht	2008	*An Augmented Reality Museum Guide*	Mixed and Augmented Reality / IEEE	1								
30	Areti Damala, Pierre Cubaud, Anne Bationo, Pascal Houlier, Isabelle Marchal	2008	*Bridging the Gap between the Digital and the Physical: Design and Evaluation of a Mobile Augmented Reality Gudie for the Museum Visit*	DIMEA / ACM	1								1
31	Andreas Zimmerman, Andreas Lorwnz	2008	*LISTEN: a user-adaptive audio-augmented museum guide*	User Modeling and User-Adapted Interaction / Springer	1	1							
32	Rafael Ballagas, Andre Kuntze, Steffen P. Walz	2007	*Gaming Tourism: Lessons Learned from Evaluating REXplorer, a Pervasive Game for Tourists*	Pervasive / Springer					1			1	1
33	Dieter Schmalstieg, Daniel Wagner	2007	*Experiences with Handheld Augmented Reality*	IEEE	1	1			1				
34	Vassilios Vlahakis, John Karigiannis, Manolis Tsotros, Michael Gounaris, Luis Almeida, Didier Stricker, Tim Gleue, Nikos Ioannidis	2002	*Archeoguide: An Augmented Reality Guide for Archeological Sites*	IEEE	1	1			1				
35	Vassilios Vlahakis, John Karigiannis, Manolis Tsotros, Michael Gounaris, Luis Almeida, Didier Stricker, Tim Gleue, Ionnis T. Christou, Renzo Carlucci, Nikos Ioannidis	2002	*ARCHEOGUIDE: First results of an Augmented Reality, Mobile Computing System in Cultural Heritage Sites*	ACM	1	1			1			1	
36	Tony Hall, Luigina Ciolfi, Liam Bannon, Mike Fraser, Steve Benford, John Bowers, Chris Greenhalgh, Sten-Olof Hellström, Shahram Izadi, Holder Schnädelbach, Martin Flintham	2002	*The Visitor as Virtual Archeologist: Exploration in Mixed Reality Technology to Enhance Educational and Social Interaction in the Museum*	ACM	1	1	1	1	1	1			
37	Benjamin B. Bederson	1995	*Audio Augmented Reailty: A Prototype Automated Tour Guide*	CHI / ACM	1								

Figure 9: The scientometric review in [C1_TAB1].

TAB-2: ***RECON SITES***

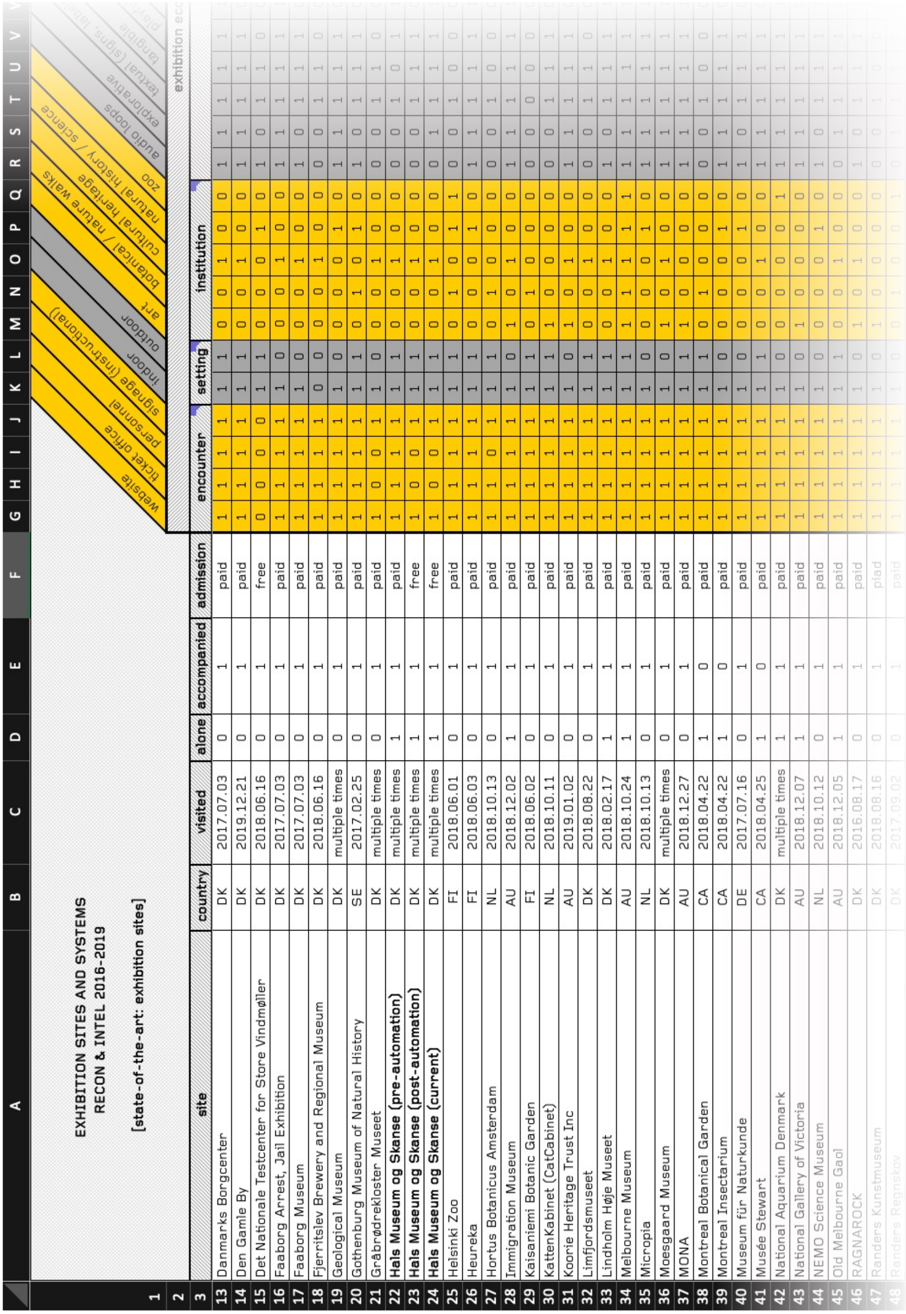
This tab contains data from 56 sites. Apart from when the site was visited for geographic and practical information, there are two primary indexes: *exhibition ecology* and *interaction frames*. The former stems from museum studies, while the latter originates from HCI research and interaction design. The elements for each index and its respective categorization should be self-explanatory. However, the categories' *integration, modalities,* and *types* require more explanation. These will be explained in section 3.1.

Exhibition ecology denotes information about the exhibition, as explained below:

× *encounter* stems from user journey and checks for interaction points with personnel/staff or information communicated by the museum, such as a website for pre-visit information, ticket office/instructions during the visit by either personnel or signage;
× *setting* checks whether the museum exhibition's physical setting was indoor, outdoor, or both;
× *institution* checks for the type of museum institution/context;
× *communication* checks for implemented communication grips; and
× *facilitation* notes which options for guidance in the exhibition are available, including enforced guidance, optional, and enforced self-guidance.

Interaction frames denote information about the types of digital experiences available in exhibitions, as described below:

× *mediation* refers to the spectrum of digital interactive technologies implemented in the exhibition;
× *integration* checks for implementation and integration into the physical setting of the exhibition, whether the interactive installations are stationary, mobile, and/or interlinked;
× *socialization* examines the shared social experience of the interactive technologies;
× *modalities* inspect employed interaction modalities; and
× *types* classify interaction types available in interactive technologies.



	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V
1	EXHIBITION SITES AND SYSTEMS RECON & INTEL 2016-2019 [state-of-the-art: exhibition sites]						website	ticket office	personnel	signage (instructional)	indoor	outdoor	art	botanical / nature walks	cultural heritage	natural history / science	zoo	audio loops	explorative	textual (signs, labe	tangible	play
2																				exhibition ec		
3	site	country	visited	alone	accompanied	admission	encounter				setting		institution									
13	Danmarks Borgcenter	DK	2017.07.03	0	1	paid	1	1	1	1	1	1	0	0	1	0	0	1	1	1	1	1
14	Den Gamle By	DK	2019.12.21	0	1	paid	1	1	1	1	1	1	0	0	1	0	0	1	1	1	1	1
15	Det Nationale Testcenter for Store Vindmøller	DK	2018.06.16	0	1	free	0	0	0	0	1	1	0	0	0	1	0	1	0	1	1	0
16	Faaborg Arrest, Jail Exhibition	DK	2017.07.03	0	1	paid	1	1	1	1	1	0	0	0	1	0	0	1	1	1	1	1
17	Faaborg Museum	DK	2017.07.03	0	1	paid	1	1	1	1	1	0	0	0	1	0	0	1	0	1	1	1
18	Fjerritslev Brewery and Regional Museum	DK	2018.06.16	0	1	paid	1	1	1	1	0	0	0	0	1	0	0	0	0	1	1	0
19	Geological Museum	DK	multiple times	0	1	paid	1	1	1	1	1	0	0	0	0	1	0	1	1	1	1	1
20	Gothenburg Museum of Natural History	SE	2017.02.25	0	1	paid	1	1	1	1	1	1	0	1	0	1	0	1	0	1	1	1
21	Gråbrødrekloster Museet	DK	multiple times	0	1	paid	1	0	0	1	1	0	0	0	1	0	0	0	0	1	1	0
22	**Hals Museum og Skanse (pre-automation)**	DK	multiple times	1	1	paid	1	1	1	1	1	1	0	0	1	0	0	0	0	1	0	1
23	**Hals Museum og Skanse (post-automation)**	DK	multiple times	1	1	free	1	0	0	1	1	1	0	0	1	0	0	0	0	1	1	1
24	**Hals Museum og Skanse (current)**	DK	multiple times	1	1	free	1	0	0	1	1	1	0	0	1	0	0	0	1	1	1	1
25	Helsinki Zoo	FI	2018.06.01	0	1	paid	1	1	1	1	1	1	0	1	0	1	1	0	0	1	0	0
26	Heureka	FI	2018.06.03	0	1	paid	1	1	1	1	1	1	0	0	0	1	0	1	1	1	1	1
27	Hortus Botanicus Amsterdam	NL	2018.10.13	0	1	paid	1	1	0	1	1	1	0	1	0	0	0	0	0	1	0	0
28	Immigration Museum	AU	2018.12.02	1	1	paid	1	1	1	1	1	0	1	0	1	0	0	1	1	1	1	1
29	Kaisaniemi Botanic Garden	FI	2018.06.02	0	1	paid	1	1	1	1	1	1	0	1	0	0	0	0	0	0	0	0
30	KattenKabinet (CatCabinet)	NL	2018.10.11	0	1	paid	1	1	1	1	1	1	1	0	0	0	0	0	0	1	1	1
31	Koorie Heritage Trust Inc	AU	2019.01.02	0	1	paid	1	1	1	1	1	0	1	0	1	0	0	1	1	1	1	1
32	Limfjordsmuseet	DK	2018.08.22	0	1	paid	1	1	1	1	1	1	0	0	1	0	0	0	0	1	1	0
33	Lindholm Høje Museet	DK	2018.02.17	1	1	paid	1	1	1	1	1	1	0	0	1	0	0	1	0	1	1	1
34	Melbourne Museum	AU	2018.10.24	1	1	paid	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
35	Micropia	NL	2018.10.13	0	1	paid	1	1	1	1	1	0	0	0	0	1	0	1	1	1	1	1
36	Moesgaard Museum	DK	multiple times	0	1	paid	1	1	1	1	1	0	1	0	1	0	0	1	1	1	1	1
37	MONA	AU	2018.12.27	0	1	paid	1	1	1	1	1	1	1	0	0	0	0	1	1	1	1	1
38	Montreal Botanical Garden	CA	2018.04.22	1	0	paid	1	1	1	1	1	1	0	1	0	0	0	0	0	1	0	0
39	Montreal Insectarium	CA	2018.04.22	1	0	paid	1	1	1	1	1	0	0	0	0	1	0	1	1	1	1	1
40	Museum für Naturkunde	DE	2017.07.16	0	1	paid	1	1	1	1	1	0	0	0	0	1	0	1	0	1	1	1
41	Musée Stewart	CA	2018.04.25	1	0	paid	1	1	1	1	1	1	0	0	1	0	0	1	1	1	1	1
42	National Aquarium Denmark	DK	multiple times	1	1	paid	1	1	1	1	1	0	0	0	0	0	1	1	1	1	1	1
43	National Gallery of Victoria	AU	2018.12.07	1	1	paid	1	1	1	1	1	0	1	0	0	0	0	1	1	1	1	1
44	NEMO Science Museum	NL	2018.10.12	0	1	paid	1	1	1	1	1	0	0	0	0	1	0	1	0	1	1	1
45	Old Melbourne Gaol	AU	2018.12.05	1	1	paid	1	1	1	1	1	1	0	0	1	0	0	0	1	1	1	1
46	RAGNAROCK	DK	2016.08.17	0	1	paid	1	1	1	1	1	0	1	0	1	0	0	1	0	1	1	1
47	Randers Kunstmuseum	DK	2018.08.16	0	1	piad	1	1	1	1	1	0	1	0	0	0	0	0	0	1	0	0
48	Randers Regnskov	DK	2017.09.02	0	1	paid	1	1	1	1	1	0	0	1	0	0	1	0	1	1	1	1

Figure 10: The reconnaissance from 56 different exhibition sites across three continents in [C1_TAB2].

TAB3: ***RECON SYSTEMS***

This tab contains state-of-the-art mobile applications. The types of mobile applications were sorted into four variants: 1. platform variants are types of applications that are not exclusively designed for exhibitions, but can be used, and that offer a content management system style platform, where a (super)user can create the content for other users; 2. variants that are independent of the exhibition context; 3. variants that are used *in the wild* (i.e., not inside a museum exhibition building) that require traversing multiple points or large areas; and 4. variants that are offered by and used on an exhibition site.

The applications were examined for the following features: technical (hardware) and technological (how it is used); game play; exhibition; social. Additionally, the interaction modalities and types were also inspected.

The table has been used in various ways throughout the Ph.D. period. It was used to collect and organize data from reconnaissance trips to multiple sites, which revealed how exhibitions are designed with and without the use of experience technologies. This informed design decisions to focus on types of interaction and modalities that are prevalent, and known to the users, as well as new and novel approaches that could be taken.

EXHIBITION SITES AND SYSTEMS
RECON & INTEL 2016-2019

[state-of-the-art: mobile applications]

	A	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	AB
1						Augmented Reality	Mixed Reality	Virtual Reality	Context Aware	GPS	WiFi	Bluetooth	RFID/NFC	Browser-based	Authoring Tool / CMS	Image Processing / Recognition	+	puzzle	objectives (goals/missions/quests)	narrative (story/setting/theme)	exploration	scavenger hunt	role playing (RPG)	emergence	dialogue	quiz
2	application	released	tested	country	pricing	tech features												game features								
3	platform variants																									
4	ActionBound	2012	2018	worldwide	free	0	1	0	1	1	1	0	0	0	1	0	#	1	1	1	1	1	0	0	1	1
5	Google Expeditions	2015	2015	worldwide	free	1	0	1	0	0	0	0	0	0	1	0	#	0	0	1	1	0	0	0	0	0
6	Kahoot!	2013	2018	worldwide	free/paid	0	0	0	0	0	0	0	0	0	1	0	#	0	1	0	0	0	0	0	1	1
7	+					1	1	1	1	1	1	0	0	0	3	0		1	2	2	2	1	0	0	2	2
8	independent variants																									
9	Ingress	2012	2012	worldwide	free	1	1	0	1	1	1	0	0	0	0	0	#	1	1	1	1	1	1	0	0	0
10	Pokemon GO	2016	2016	worldwide	free/paid	1	1	0	1	1	0	0	0	0	0	0	#	0	1	1	1	1	1	0	0	0
11	Zombies, Run!	2012	2013	worldwide	free demo/paid	1	1	0	0	1	0	0	0	0	0	0	#	0	1	1	0	0	1	0	0	0
12	+					3	3	0	2	3	1	0	0	0	0	0		1	3	3	2	2	3	0	0	0
13	in the wild variants																									
14	Field Trip	2012	2012	worldwide	free	1	1	0	1	1	1	0	0	0	0	0	#	0	0	0	1	0	0	0	0	0
15	PlantNet	2014	2019	worldwide	free	1	0	0	1	0	0	0	0	1	0	1	#	0	0	0	0	0	0	0	0	0
16	Sky Guide	2014	2018	worldwide	paid	1	1	0	1	1	0	0	0	0	0	1	#	0	0	0	0	0	0	0	0	0
17	Sherpa Tours	2019	2019	worldwide	free demo/paid	1	0	0	1	1	0	0	0	0	0	0	#	0	0	0	0	0	0	0	0	0
18	Big Bus Tours	n/a	2019	worldwide	free	0	0	0	0	1	0	0	0	0	0	0	#	0	0	0	0	0	0	0	0	0
19	HopOn HopOff	n/a	2019	worldwide	free	1	1	0	1	1	0	0	0	0	0	0	#	0	1	1	1	1	0	0	0	1
20	Lyden af Danmark	2019	2019	DK	free	0	0	0	1	1	0	0	0	1	0	0	#	0	0	0	1	0	0	0	0	0
21	+					5	3	0	6	6	1	0	0	2	0	2		0	1	1	3	1	0	0	0	1
22	exhibition variants																									
23	Den Blå Planet	2011	2016	DK	free	1	1	0	1	0	1	1	0	0	0	0	#	0	1	0	1	1	0	0	0	1
24	Google Arts & Culture	2011	2018	worldwide	free	0	0	1	0	0	0	0	0	0	0	0	#	0	0	0	0	0	0	0	0	0
25	Montreal Cité Mémoire	2017	2018	CA	free	1	0	0	1	1	0	0	0	0	0	0	#	0	0	0	1	0	0	0	0	0
26	Nordsøen (Nordsøen Movie Maker)	2014	2015	DK	free	1	1	0	1	0	0	0	0	0	0	0	#	1	0	1	0	0	0	0	0	0
27	Street Art	n/a	2019	worldwide	free	0	0	0	1	1	0	0	0	0	0	0	#	0	0	0	0	1	0	0	0	0
28	Australian Museum (TrailBlazers)	2016	2018	AU	free	0	1	0	1	0	1	1	0	0	0	0	#	1	1	1	1	1	1	0	0	0
29	MONA (The O)	2017	2018	AU	free	0	0	0	1	0	1	0	0	0	0	0	#	0	0	0	1	0	0	0	0	0
30	Uist	2018	2018	worldwide	free	1	1	0	1	1	0	0	0	0	0	1	#	0	0	0	1	0	0	0	0	0
31	Vizgu	2018	2017	DK	free	1	0	0	1	0	0	0	0	0	0	1	#	0	0	0	0	0	0	0	0	0
32	Natural History Museum	2016	2019	UK	free/paid	0	0	0	0	0	0	0	0	0	0	0	#	0	0	0	0	0	0	0	0	0
33	British Museum	n/a	2019	UK	free/paid	0	0	0	0	0	0	0	0	0	0	0	#	0	0	0	0	0	0	0	0	0
34	Useeum	2018	2018	DK	free	1	1	0	1	1	0	0	0	0	1	0	#	1	1	1	1	1	1	0	0	1
35	National Gallery Victoria (NGV)	2017	2018	AU	free	0	0	0	1	0	0	0	0	0	0	0	#	0	0	0	0	0	0	0	0	0
36	Kulturpunkt	2019	2019	NO	free	0	0	0	1	1	1	0	0	1	0	1	#	0	0	0	0	0	0	0	0	0
37	National Museets Chatbot	2019	2019	DK	free	0	0	0	0	0	0	0	0	1	0	0	#	0	0	0	0	0	0	0	0	0
38	+					6	5	1	11	5	4	2	0	2	1	3		3	3	3	6	4	2	0	0	2
39						15	12	2	20	15	7	2	0	4	4	5		5	9	9	13	8	5	0	2	5

Figure 11: The state-of-the-art mobile applications table in [C1_TAB3].

2.3.3. PHASE 02: *DESIGN*

The design phase primarily comprised co-design and collaborative design activities. The co-design activities took the shape of workshops and multiple conversations and collaborated investigations of concepts and technologies with the museum collaborators, the OM program members, and graduate students from Aalborg University.

In retrospect, technologies have been viewed as prisms from which future developments and applications can be explored. These views can be utopian and dystopian, depending on the forces that steer technological advancements in future directions. In fiction, undesired futures are often presented as dystopic worlds where either the technology itself has become uncontrollable by humans, or humans have shaped technology in undesirable ways for humankind (Jensen, 1991). The technologies themselves are seldom the cause of media-induced panic (Drotner, 1999) but are often caused by cultural mechanisms (Drotner, 1992; Jensen, 1991). To explore prospective future scenarios, a practice termed *design fiction* has emerged over the past decades as an approach to merge science fiction with design research to push the frontiers from what is possible to what could be possible and to examine future applications of technologies (Bell & Dourish, 2007; Dourish & Bell, 2014; Jensen, 1991; Sterling, 2009). Essentially, this method offers a way to envision a possible world and let a design artifact play out its intended or envisioned purpose. This can lead to unplanned discoveries and use beyond the original intent. Echoing the sentiments from pragmatism and constructive design research is about imagining new realities and building them to see if they work and extending this frame of mind by asking if it is a viable idea by presenting the vision to its intended users. With design fiction techniques, the step to realizing a vision, which can be a resource-intensive activity, can be simulated through techniques in which the concept can be presented in visions, typically visual media, where a constructed artifact is presented as a finished product in the hands of the intended user who performs the planned or imagined activities. This can also be flipped around, where potential negative effects of technology can be explored through a dystopic depiction. Design fiction played a pivotal part in the co-design activities with students, where many ways of supporting users through technology were explored through design fiction scenarios and turned into concepts. These concepts were presented to the museum collaborators as specific instantiations of technologies for users in self-guided situations particular to Hals Museum and Redoubt.

Thus, in September 2017, three teams of graduate students comprising six members per team produced concepts for Hals Museum and Redoubt in a cross-and interdisciplinary workshop. The workshop period lasted three weeks and was set up as a lab study. The objective of the workshop was to establish designerly collaboration among participating stakeholders, students, and researchers through user-oriented laboratories. Thus, the students, researchers, and museum stakeholders engaged in a triple helix formation as equal partners. The workshop format is divided into three phases: *fieldwork*, *ideation,* and *concept development*. The teams produced three concepts that were based on ethnographical studies (Bryman & Bell, 2019), interview (Brinkmann & Tanggaard, 2020) with the host, and video observations (Brinkmann & Tanggaard, 2020) that fed into three design iterations that were discussed with potential users and heritage stakeholders, and finally turned into a final concept that was presented as a vision video prototype. All three concepts that were delivered as part of this workshop were used to spark debates and discourse for future directions at the HMNJ, as they presented concepts supported by real-world data turned to knowledge in a visual format that could be presented to museum professionals without the technical jargon or technological complexity of the systems being presented. The design process and produced material can be accessed in appendix [D3]. The three concepts demonstrated mixed and XR applications using both stationary and mobile solutions, with inspiration from game design using a mix of quiz and scavenger hunt elements.

The concepts and the ensuing discussion looped into a collaborative design process with the HMNJ and an external technology provider who was insourced to develop a system. At the beginning of this process, only a few variables were known, such as the technological platform, and there would be some form of a context-aware layer. But the content and form of the context-aware layer were unknown. Based on previous design insights, two games were discussed: One utilized Bluetooth beacons as nodes, while the other used marker-based augmented/mixed reality. This led to two expansive studies that were developed simultaneously. One was based on existing assets that the technology provider, ARURA, had developed for a marker-based mixed reality, which was redesigned and changed to a game-guided experience in exhibitions that use Bluetooth beacons. This was developed through two separate co-design workshops with a schoolteacher, museum host, museum director, curator, custodian, and an external technology provider, ARURA, comprising developers, game designers, and artists (Figure 12). The result was a prototype application for mobile devices where the user could unlock and populate a virtual world with items to make. The unlock mechanic was central to this concept to motivate users to explore and collect items for the virtual world by traversing physical locations. The second prototype is a mixed reality game guide, in which users can summon virtual creatures using physical markers and collect virtual items to engage with the creatures.

Figure 12: Top-left and top-right: Design workshops at HMNJ to develop concepts for Hals Museum and Redoubt with curators, teachers, application developers, museum hosts, historians, and custodians. Bottom: Output from a prioritization workshop to specify requirements of content and features for XTR.

This game had elements from *Tamagotchi*[8] and *Pokemon Go* merged with an unlock feature that encouraged players to explore physical locations to track and collect items and food for the creatures. Both games were developed with a focus on the explorative features of adventure games but into two distinctly different versions. One was a mixed reality game, while the other was an augmented reality game.

These two more specific concepts were developed and tested in lab contexts with graduate students who acted as lead-users to perform usability tests, critique sessions with concept and feature improvements, and design iterations related to aesthetics and content, such as textual information. The lab study can be accessed in appendix [D4].

The AR game prototype utilized physical markers to augment physical spaces with virtual creatures that the user can interact with. In this study, a combination of usability tests, system usability scales, usability severity ratings, observations, interaction logs, and analytics collected on the device were used in a lab context (Figure 13: left).

[8] *Tamagotchi* is toy with a virtual pet that exists as handheld devices, as well as mobile applications.

Figure 13: Left: Students performing playtests and usability tests of the augmented reality virtual pet game. Right: Students serendipitously discovered a way to play the game socially by stacking their devices and combining the virtual creatures into a single screen. This informed later design decisions where emergent systems were examined as part of the game design.

An interesting finding that led to a change in gameplay design was a discovery made by students. The technical implementation of marker-based augmented reality could be tricked to group multiple users' virtual creatures into a single shared space (Figure 13: right). They found that by stacking their phones, they could gather multiple creatures on the final screen, which was not intended by design. This discovery triggered an investigation of emergent systems (Holland, 1997; Johnson, 2012) and how to design games that integrate and allow for emerging gameplay into its mechanics (Salen & Zimmerman, 2004) and inform future studies to be open for emerging game mechanics and ways users construct their game play goals. These co-design and collaborative design activities also brought narrative framing into perspective. The user tests revealed that the applications lacked a narrative drive and that they should tell a story. However, it is not about telling a story in an arbitrary environment or location but framing the experience of being guided in the exhibition through a narrative setting that taps into unique features of locational storytelling and the shared experience that users or players can have with it. This is elaborated in [P10], where the narrative perspective and locational storytelling with mobile devices are unpacked.

The lab study led to significant findings through the design and implementation of the AR game but had to be dropped due to resource constraints. The type of game system that was acclaimed as the lead users appreciated the novelty of using an augmented reality game for guidance in exhibitions, but the technology and its implementation would require resources beyond the limits of this project. The Bluetooth beacons were focused on developing a mixed reality game, detailed in [P05; P06], which will be presented in the next phase.

2.3.3.1 Our Museum Game → [OMG]

To address some of the challenges of gathering a team of multidisciplinary members in exhibition design activities, a boardgame, the *Our Museum Game* (Figure 14), was developed through multiple iterations by museum collaborators and the OM program members and with another Ph.D. student from the OM program, Kristina Maria Madsen. The background of the game and the applied game mechanics are reported in [P08]. The main challenges the game seeks to address are the lack of communication and cross-disciplinary understanding, which often lead to unclear design goals. The construction of the game was inspired by facilitating user-centerd design activities, as described in the preceding subsection and reported in [P06; P07], through the museum institutions, stakeholders, technology providers, teachers, and hosts. Insights from the design study, elaborated in 4.2, show the importance of having a shared language between multiple disciplines and professions to engage in user-centered design activities and support collaborative design processes. These insights were transformed into a tool for others to use, a physical contribution from the OM program, focusing on understanding, designing, and evaluating the *user* dimension, which is one of the three main dimensions of the research program, the other dimensions being *institution* and *representation* [A1; A4].

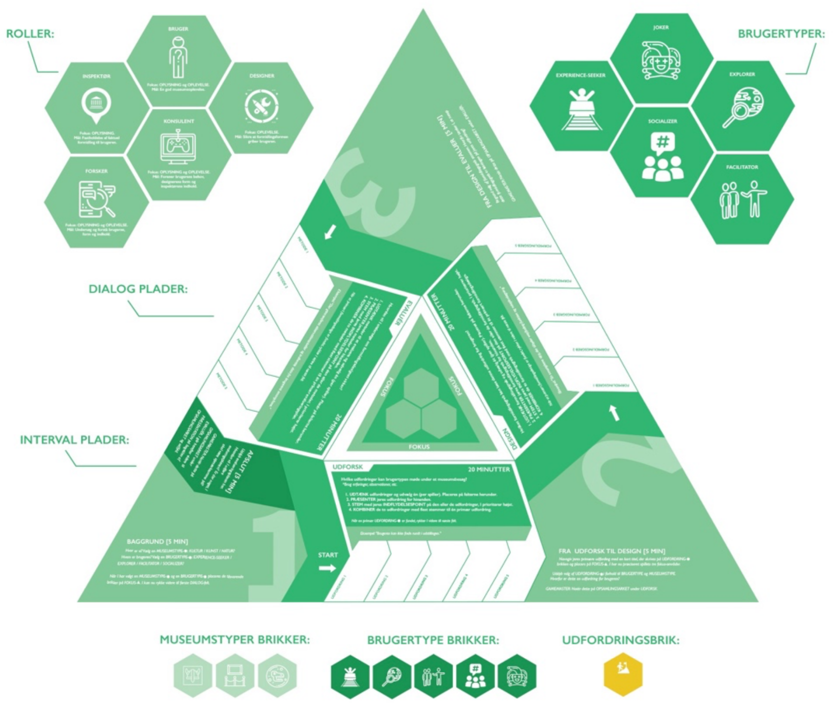


Figure 14: The layout of the game board, along with its tiles, tokens, and pieces. A larger resolution version can be viewed in appendix [F3].

The following quote sums up the philosophy behind the construction of the game:

> The prime purpose of gaming/simulation is to establish dialogue to increase communication among a group about a topic which is complex, future-oriented, of a systems nature, and which requires a vocabulary or vernacular which is not commonly shared by the group at the outset of the discussion. (Duke, 1974, p. 78)

The game's core objective is to establish a shared vocabulary so that by playing the game, the players (i.e., museum professionals, researchers, technology providers, exhibition designers, etc.) can agree on definitions and work toward an exhibition design that integrates experience technologies. The game has three intervals: *exploring*, *designing*, and *evaluating* the exhibition design, based on the iterative lifecycles presented in 2.3.

Through the three intervals that represent aspects of designing a user-centered exhibition experience, the gameplay forces players to agree on the type of museum context and the type of user that is targeted and place the user at the center of designing exhibitions rather than focusing on what type of institution or how the communication design should be represented in the exhibition, and then detect what the actual challenge is with the current exhibition design before addressing how they want to solve it. The solution entails agreeing on the communication grip, the type of interactions, and how the proposed solution can be evaluated after it has been implemented. Players are compelled to position themselves as users rather than researchers, designers, technology providers, museum hosts, or directors.

Figure 15: The first play session with the program members in version 1 of the OMG in 2018.

The game was developed due to the necessity identified during the Ph.D. program and evolved into a valuable workshop tool for practitioners when initiating a new museum exhibition. The game has, since its conception, gone through multiple iterations, described in [P08], and has become a toolbox for museums to sustain a design-in-use practice when designing future exhibitions. The game was used during the Ph.D. time frame with the OM members (Figure 15) and after the Ph.D. program in public sessions with practitioners (Figure 16).

Figure 16: Left: The second public play session at the cultural meeting in Mors 2019. Right: The third public play session in 2020 at the annual Association of Danish Museums gathering, which is a coalition of 170 museums, visitor centers, and conservation centers from the museum sector in Denmark.

By harnessing the utility of the constraints and mechanics found in game design, along with the liminal setting that "playing a game" provides, offering role-playing attributes to a game designed specifically for the museum sector, the boardgame proved useful as a tool for collaborative user-centered design.

2.3.4. PHASE 03: *DEVELOP*

The design insights from the investigations and explorations of the museum context, the users, and the technologies from the preceding phases led to the development of two prototype systems. Both systems were based on Bluetooth beacons to deliver context-aware digital experiences on mobile devices, such as phones and tablets.

From the design phase, the concepts of the systems underwent several iterations, which derived two context-aware mixed reality concepts: *Explore the Redoubt* and *ARATAG*. Both systems used the same technical setup, Bluetooth beacons for proximity sensing, and mobiles as user-operated devices to access and run the applications. The main difference is that XTR is designed to be a game that guides users, while ARA uses elements from game design, such as nodes that the user can track down and explore but is otherwise designed as a wayfinding application with information about the exhibits. The latter was also developed with a content management system (CMS) in mind to be used by personnel who are nontechnical so that they can focus their attention on the content layers, such as video, pictures, and text, instead of having to learn the technical setup first, which is often seen as a barrier to implementation. ARA was developed externally and will be presented in the following subsection, while XTR was developed in close collaboration with the application developers, ARURA, and the researcher.

Multiple designs and implementation iterations throughout 2018 led to the development of the two final prototypes. These iterations comprised tests in both lab and field contexts, with observation and questionnaire data from play tests and usability tests. The data analysis and user feedback led to hardware stability and compatibility optimizations, range from tweaks for users to interact with beacons, and significant changes to the content regarding how the text was articulated and splitting XTR into two separate gameplay modes: quiz and a scavenger hunt.

On May 4th, 2018, a new baseline survey of Hals Museum and Redoubt was conducted due to the exhibition site transitioning ahead of schedule to become automated. This survey was based on the original OM baseline survey, which collected 21 respondents. However, after reviewing the survey responses, which were done while the survey was still live, it became clear that many of the questions the OM program had articulated were too abstract and rejected by the respondents. Therefore, a new survey was created from scratch Sto target visitors at the Hals Museum and Redoubt with the intent of gathering information that could inform the design and development of XTR. Meanwhile, a pilot study was executed in situ before the re-opening of Hals Museum and Redoubt as an automated site with XTR. The test setup allowed visitors to spend as much time as they wanted in the exhibition and around the site and subsequently recruited to play XTR. After they ended the play session, the visitors completed a questionnaire. All the data can be found in appendix [F1].

From the evaluation of the test, findings were used to refine and optimize the game, for example, how long a play session should last to support a visit, how the game should be played (i.e., singleplayer/multiplayer, cooperative/competitive), type of game mechanics that encourage exploration of the exhibition site, placement of Bluetooth beacons, etc., into a release-ready version of XTR, which was released on both iOS and Android.

Based on the rejection of the baseline survey in May, a new baseline survey was conducted. This baseline survey, which had a runtime from June 27th to August 6th, had 49 respondents (28 male and 21 female), with a diverse age span, ranging from 16 to 78, and in different social constellations, such as family, couples, and groups of friends found in appendix [F1]. The survey was designed to gather demographic information and metrics, such as average visiting time, 35 visitors reported in 30 minutes or less, while 14 visitors reported between 30 and 60 minutes, and social constellations, only three visitors were there, the rest were in groups of 2–3 or larger. The survey also offered insight into visitor motivation. Visitors reported that the primary reasons were "to experience something new", "to learn something new," and "to relax". And finally, the survey asked visitors to input what they felt was missing to gain insight into how the transition to automation had changed the visiting experience. Surprisingly, none of the visitors asked for museum personnel's presence, but the visitors asked for more information on certain exhibits, more interactive experiences, and coherence between the different exhibits, as presented in 1.3.1. The primary exhibition inside the armory contained five different exhibition zones, each with its topic or theme, but there were many out of place elements found sporadically around the exhibition, which added to a fragmented experience overall. Finally, the one thing that was requested as missing from the exhibition after the transition to the automated site was restrooms. The one that had been closed for public use due to maintenance constraints. One final lab test was executed to optimize Bluetooth beacons for XTR on Android and iOS and then released as the final version on September 7th, 2018. This version was used for the final evaluation detailed in the next and final phase.

2.3.4.1 Prototype Systems

The many forms of design research presented in section 2.2 entail the design and deployment of prototypes. Thus, in design research, the role of and focus on designed things as components of the research process is central (Matthews & Wensveen, 2015).

The spectrum of roles prototypes play in design research is varied. The role of prototypes as a means of inquiry for design has been documented in previous research. In *What do Prototypes Prototype?* (Houde & Hill, 1997), prototypes are defined as "any representation of a design idea, regardless of medium to answer a design question" (Houde & Hill, 1997, p. 3). Houde and Hill (1997) distinguished three dimensions of the design space of questions that prototypes explore in design practice: the "role" of a product, its "look and feel," and its "implementation." Within these three dimensions, prototypes provide a means of examining design problems. Thus, prototypes are conceptualized as tools for traversing a design space where design alternatives and their rationales can be explored (Goel & Pirolli, 1992; Moran & Carroll, 1996), leading to the creation of meaningful information about the final design as envisioned in the process of design and purposefully form manifestations of design ideas (Lim et al., 2008).

In *The Anatomy of Prototypes* (Lim et al., 2008), a similar approach to that of Houde and Hill (1997) is described, but with a more extensive discussion of prototypes in design, defining prototypes as "filters intended to sift through and traverse a design space" and as "manifestations of design ideas that concretize and externalize conceptual ideas" (Lim et al., 2008, pp. 4–5). Following both Houde and Hill (1997) and Lim et al. (2008), the focus of this study is on the roles of prototypes as vehicles for research about, for, and through design, as proposed in *Prototypes and Prototyping in Design Research* (Matthews & Wensveen, 2015). Prototyping within research processes that necessitate design activities, as it does in constructive design research, is presented as a rough typology of the four roles that prototypes or designed things appear in design research. These prototypes are *an experimental component*, *a means of inquiry*, *a research archetype*, and *the process of prototyping as a vehicle for inquiry* (Matthews & Wensveen, 2015).

The purpose and role of prototypes as an *experimental component* positions the prototype itself as an object by which design knowledge is sought through experimental setup. In this role, prototypes can also be treated as physical hypotheses to test specific hypotheses. Thus, the prototype can be developed as systematic variations, or the context of use can be varied. In this research project, multiple small-scale tests were conducted to test early hypotheses that would eventually lead to the design of the XTR and ARA prototypes. Variables, such as specific instantiations of technologies, content layers related to museum exhibitions, and game design elements were systematically examined throughout the course of this project.

As a *means of inquiry*, prototypes are deployed as instruments to collect, record, and measure phenomena, or as *provotypes* (Mogensen, 1992), which are prototypes that are used to provoke reactions and insights that can expose aspects of users' values and practices that are taken for granted. Anything that treats design as an intervention in the world and studies its consequences or work that deploys prototypes in the field and studies them are considered open-ended explorations of a hybrid and undetermined design space, where prototypes assume the role of a means of inquiry (Matthews & Wensveen, 2015). In this project, the two final prototypes, XTR and ARA, were used as instruments to investigate the prowess, utility, and usefulness of mobile applications designed to support users through explorative experiences in automated sites. Provocatively, they were also used to spark a debate within the OM program and museum institutions to elicit responses on using digital layers to replace the human host.

As a *research archetype*, prototypes are the physical embodiment of concepts, understandings, or design spaces that can be argued to constitute contributions to the discipline. An archetype can embody research concepts and perspectives that have broad application and require specific examples to demonstrate their potential (Matthews & Wensveen, 2015). The prototype systems XTR and ARA are not developed as archetypes, although they strive to be exemplary in demonstrating how explorative experiences can be used to support users in automated exhibitions. Their roles are confined to the other three.

The role that prototypes play in the research process falls between design research and design practice. In design, the primary focus of prototypes is on their role as vehicles for furthering design agendas by generating and testing new forms, functions, systems, etc., of design (Matthews & Wensveen, 2015), but when used as vehicles for research, they can provide answers to research questions and make knowledge contributions. In this study, the final prototypes XTR and ARA, which resulted from antecedent prototype design and evaluations, also assumed different roles throughout the different tests. First, they have been experimental components, as they manifest the hypothesis of this thesis, that experience technologies can be utilized to mediate the dynamics of enlightenment and experience by integrating both in the design of explorative systems for exhibitions. Second, they are also used as means of inquiry; they have been deployed in both lab and field settings and discussed in academic forums, which generated knowledge that would further revamp the design and technical layout of the two systems. Finally, they have also been drivers for the research direction, which positions the two systems as vehicles for inquiry and yields insights into research *for* design of exploration systems.

Creating a prototype enables a design researcher to communicate the rationale behind design decisions through prototypes. Prototypes can stimulate reflections that design researchers can use to frame, refine, and explore a design space (Lim et al., 2008). Thus, conducting design research systematically and rigorously to perform a design inquiry enables the researcher to arrive at a relevant research contribution. Notably, in this study, the empirical knowledge gained from the final evaluation of the prototypes cannot be generalized to other sites conducted in different contexts and involving different individuals without adequate recontextualization. Rittel and Webber (1973) and Simon (1969) emphasized that it must be accepted that the results derived from design interventions are not universal truths but depend on the different factors and variables involved in the problem and the context investigated.

The data acquired through the evaluation of prototype systems can produce different and unpredictable outcomes if they are evaluated using different methodologies or are conducted by different researchers and with different subjects. Therefore, the systems created in this project are not meant to provide undisputable data but design insights and a framework that can be applied to future studies. An equally important aspect of the role of prototypes, and proofs-of-concept, is that novel technologies and interaction frames are often explored, as they are in this project. It can be challenging for heritage stakeholders to envision the application and development of novel technologies and user experiences that these can provide (Ciolfi et al., 2019; Halloran et al., 2006; Hornecker & Ciolfi, 2019, p. 93). Nevertheless, by constructing and implementing prototype systems, it is possible to have an experimental component, a means of inquiry, and a way to demonstrate and possibly provoke a debate, which can lead to critical perspectives and insights or serendipitous findings that can be crucial for future work.

However, whereas the design process creates complexity through multiple generated diverging design ideas, prototypes can reduce that complexity by focusing on parts of that complexity or particulars (Vistisen, 2016). Ths process is also described as "a way of organizing complexity or finding clarity in chaos" (Kolko, 2010, p. 15). This is the case with the prototype systems designed and implemented in this study. Subsequently, the two systems developed and used for the final evaluation will be described to concretize the prototypes referenced conceptually.

2.3.4.2 Explore the Redoubt → [XTR]

Explore the Redoubt (DA: *Opdag Skansen*) is a mobile application designed and developed specifically for the Hals Museum and Redoubt to integrate curiosity and exploration as core gameplay features for self-guided exhibitions. The game uses the exhibition site as the grid, where a total of 15 Bluetooth beacons, simply referred to as nodes, are embedded and hidden. The game is played inside the armory (the house containing the exhibits), in the powder chamber next to the armory, and outside on the star-shaped redoubt. The game is split into two game modes: quiz and a scavenger hunt. Both modes utilize nodes for proximity, which the user can track down using a distance indicator (Figure 17: : bottom-right). When the user is within a set proximity limit, the node switches from red to green and can be unlocked. However, it is only possible to unlock and complete the game or reset it and start over. There are no other gameplay mechanics to track progression. Also, features such as character death or similar consequences were not part of the design philosophy behind this game because the core gameplay focuses on exploration. The nodes were placed in locations that users would overlook or not notice as part of the exhibition, such as the powder chamber, as revealed by the initial investigations. The game can be played in 20–30 minutes, on average, if playing the game is the primary activity. Playing the game when visiting the exhibits would increase the total visiting time to approximately 1 hour.

Figure 17: Top-left: An overview of Hals Museum and Redoubt's physical setting. Top-right: Hals Museum and Redoubt's digital contemporary representation while playing the quiz game. Bottom-left and bottom-right: Screenshots showing the scavenger hunt game mode played outside where the redoubt is re-built as it was originally constructed in the 1600s.

There are 10 nodes inside the armory. Each of the 10 nodes will present a quiz upon activation by the user that can be answered by orienting in the vicinity where the node was activated. Unfortunately, a function where the user could answer the quiz within the application was not re-alized at the time of release and was therefore implemented differently. The correct answers for the 10 quizzes were implemented on a physical board (Figure 18), where the user can check whether the answer was correct or not.

Figure 17: From left to right: The first picture shows the physical implementation of the correct answers; the second photo shows users checking answers to see how many were correct; the third and fourth pictures show users exploring the site to discover nodes in-side the armory and outside on the redoubt.

The scavenger hunt is played outside on the star-shaped site, with five nodes hidden in total. When the player starts the game in scavenger hunt mode, they are presented with an empty construction site for the redoubt (Figure 17: : bottom-left). For each node the user tracks down, part of the redoubt is fully reconstructed (Figure 17: : bottom-right). The five parts are the four houses, canons, powder chamber, palisades, and the ravelin. The nodes are placed in locations that link the location itself to its digital representation, so the users must traverse the site to unlock and construct that part of the original redoubt.

As mentioned earlier, the game was not intentionally built around cooperative or competitive play, nor were any points, scoreboards, or penalties implemented into the game design. Instead, this was a part of the open-world exploration game philosophy, designed to include as many types of users as possible and let them determine their goals with the game. Therefore, some players cooperate on finding the nodes, unlocking them, and solving the quizzes together, while others compete on who finished re-construction of the redoubt first or had the correct answers at the board with the right answers.

2.3.4.3 *ARATAG* → [ARA]

ARATAG was developed in collaboration with a privately owned construction company, Pangea Rocks, specializing in artificial aquatic and land features for aquariums, museum exhibitions, theme parks, and zoos. Pangea Rocks approached the research project for knowledge and innovative features for designing and developing a digital location-aware system for exhibition navigation in 2017. This led to the construction of a mobile application that utilizes Bluetooth beacons integrated into the physical environment that provides contextual clues for users in different exhibitions. From the start, the system was being developed as a content management system (CMS) backend for exhibitions of different types, which was the primary reason why ARA became a part of this project. The explorative features were embedded as nodes that the user could track down and interact with to gain additional information about the exhibition. The CMS aspect was of particular interest to this study because creating toolkits can allow non-technical users to realize advanced interactive experiences rather than separating conceptual design from technical design (Hornecker & Ciolfi, 2019; Petrelli et al., 2016). During the design process, non-technical staff members from extant exhibition sites were included to accommodate and consider that this system is intended to be used by them and not technical experts and developers.

The application (Figure 18) contains an overview of exhibitions that are part of ARA with a home screen. From there, the user selects a specific site and can view information, such as events on the day of the visit, nodes in proximity, an explore tab that presents an overview for users to select and save specific exhibits they want to visit, and a map with location tracking.

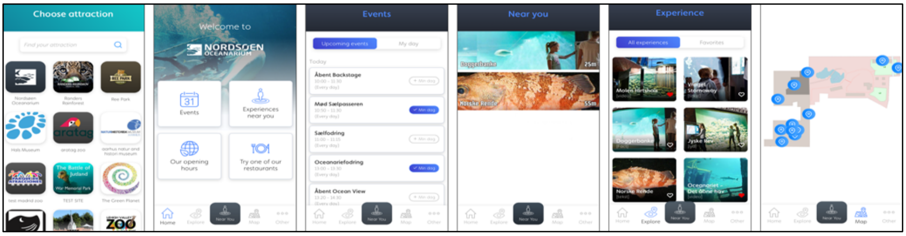


Figure 18: Overview of the application screens, elaborated on in [P09].

The content layers in any given exhibition can be customized to fit the exhibition type. For example, as seen in Figure 19, different types of content are demonstrated, where the information can be the same but mediated differently so that the user can select the type of mediation preferred.

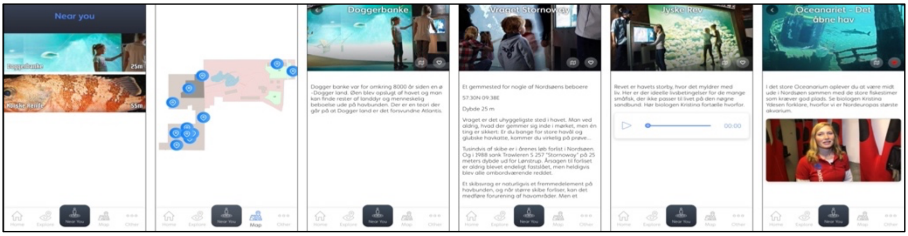


Figure 19: Examples of types of content at a node: text, audio, and video. The information is the same, but the depth is different. The features are detailed in [P09].

The focus of this study is on using exploration for wayfinding and navigation with traces of game elements and the challenge of having users rely on technology in the absence of human guides or personnel.

Figure 20: Concept development and clustering of activities in the pre-visit, visit, and post-visit stages. Requirements for the alpha version of the application were determined using this mapping.

Through a series of co-design workshops and prioritization activities (Figure 20), with five external exhibition site stakeholders, the application was developed between 2017 and 2018, with a final implementation and test of the prototype system, reported in [P09], in October 2018, at the North Sea Oceanarium. The application, design, implementation, and test are detailed in [P09] as part of the evaluative study [D].

2.3.5. PHASE 04: *EVALUATE*

The final test and evaluation of XTR was a mixed-methods experiment design in which qualitative data from interviews, observation, and quantitative data from application analytics and questionnaires, along with a subset of expert heuristic evaluations, were the combined source of empirical data. The test runtime was October 14th–24th, 2019. The retrieved data was analyzed and reported in [P10] and presented in 4.4.

While ARA's final implementation and test were planned to also use mixed methods, with qualitative data from focus group interviews, observations, and field notes, combined with quantitative data from analytics, the analytics feature was unavailable on the day of testing and had to be omitted. Thus, a strictly qualitative approach was adhered to during this test. The data was coded subsequently: audio recordings from the focus group interviews were transcribed and later thematically analyzed and coded. The test with ARA was executed in the North Sea Oceanarium in October 2018. This test addressed two specific challenges: self-guidance with digital technologies and user preferences for the content type. The methodology for the final evaluation of ARA and the findings are reported in [P09] and presented in section 4.1.4.

The test and evaluation of XTR and ARA are the final parts for addressing this research project's questions and are the foundations for generating knowledge that can be transferred as patterns or principles for designing, developing, and implementing self-guided systems that elicit exploration and game design as core features. The last subsection elaborates on the criteria for evaluating the findings and argues for the validity of the insights generated.

2.3.5.1 Criteria for Evaluation

This subsection explains the validity of the insights and the lessons learned from this study by presenting the evaluation criteria that argue for validity. The source for discussing validity stems from Zimmerman et al.'s (2007) four lenses for evaluating an interaction design research contribution: *process*, *invention*, *relevance,* and *extensibility* (Zimmerman et al., 2007, pp. 499–500). The first lens, *process*, explains that the reliability of the work examines the rigor applied to the methods and the rationale for selecting specific methods. By documenting these contributions, interaction design researchers must provide enough detail to reproduce the process employed (Zimmerman et al., 2007). In this study, this process is documented both in the preceding four phases of this section and reported in the paper contributions in section 4.

Since most interaction design research is conducted by constructing artifacts, a criterion for evaluation should be its novelty. The concept or prototype created is a new contribution to the existing body of knowledge within the field of research. As presented in phase 01, novelty was a criterion for surveying digital technologies before qualifying them as experience technologies suitable for exploration systems. This criterion resonates with general scientific practice, which searches for new insights rather than reproducing old ones. In interaction design research, novelty can be explained more precisely through Zimmerman et al.'s (2007) notion of *invention*, i.e., the design researcher has created novel insight, approach, or artifact to address a specific situation. This compels the researcher to frame results within the current state of the world and the preferred state that the design experiments propose and to argue for why others should consider this state as the preferred one.

An important part of the invention entails performing an extensive literature review to situate the work and detail the aspects that demonstrate how the project's contribution advances the current state of the art in the research community. It is also important to detail how technological advances could result in significant advancement by articulating novelty as integrating various subject matters to address a specific situation as an invention. The articulation of the invention communicates the details of technical opportunities to engineers in the HCI research community and guides what to build (Zimmerman et al., 2007).

The inventiveness of the research must also be considered relevant to the scientific community of design research. The *relevance* lens is described as the primary evaluative factor in design research. In other sciences, for the work to be considered valid, it must be documented so that peers can reproduce the results. This requirement does not make sense in a research through design approach. As explained earlier, there are no expectations that two design researchers will arrive at identical or similar artifacts given the same problem or problem framing. Therefore, relevance should be the criterion instead of validity. By following a research through design approach, this project also arrived at multiple ways to solve the same problem. For example, in this project, game elements, viz. curiosity and exploration, became the core to designing supportive systems in automated sites. But by choosing this path, many others were left unchecked, which may have been chosen by other researchers with different frames of mind.

In this interaction design study, the design process was detailed at the beginning of subsection 2.3, and throughout section 1, the current situation (museum exhibitions that are transitioning to automated sites) and the preferred state (using experience technologies to support users by encouraging explorative behavior through adventure game elements) has been explained. This also, in one part, holds the motivation for the work, while the research program holds the other part by seeking contributions about the dynamics of enlightenment and experience in the museum context. Thus, the relevance of this research project is argued for.

The final criterion for successful interaction design research is *extensibility*. Extensibility is defined as the ability to build on the resulting outcomes of interaction design research. This can be done either by employing the process in a future design problem or by understanding and leveraging the knowledge created by the resulting artifacts (Zimmerman et al., 2007). Thus, extensibility means that the design research has been described and documented so that the community can leverage the knowledge derived from the work, which this project's contributions [P01–P10], prototype systems XTR and ARA, and the dialogical design tool OMG, aim to achieve. Both the project's contributions and prototypes will be presented in section 4.

2.4. Setup Summary

Section 2 presents and discusses the research design by tapping into Creswell and Creswell's (2018) framework, which integrates philosophical worldviews and research methods into an interconnected research approach.

The pragmatic worldview proposes a lens through which a theory can be transferred to a designed artifact as a specific instantiation of that theory, connecting the current state of the world with a possible world. It is worth noting that pragmatic philosophy is not a unified worldview. In it, there exist, to some extent, incongruent assumptions between its contributors. However, pragmatism in this project has been argued as the primary philosophical paradigm concerning design research and the overall research design, particularly as an inquiry into the effects of using experience technologies to support users through explorative behavior. In this, pragmatism ultimately proposes a foundation for epistemology and ontology in the research design (Creswell & Creswell, 2018, p. 21). In research design, epistemology and ontology exist in an interplay to describe the underlying conditions of the research. Pragmatism presents a way to study a phenomenon through a subjective epistemological view and an objective ontological position in this project. This worldview frames the research logic and research design that this project follows axiomatically, such as research *through* and *for* design in interaction design research. Finally, the research strategy for inquiry, constructive design research with roots in interaction design research, was chosen as the methodological approach. More specifically, this methodology was used as research-through-design to contribute with research-for-design characteristics. The research design had serial and expansive logic toward advancing knowledge through studies on using experience technologies to support users in automated sites. The studies were organized as pragmatic inquiries primarily situated in either the lab or field context.

This project is described as explorative research, which generates knowledge through established design processes from HCI that inspire expansion through insights. The discoveries made through expansion further informed serial experiments in the design process toward the design of explorative experience to support self-guidance in exhibitions. Finally, by applying methodologies and methods from HCI in museum exhibitions, the drifts that the research activities have taken are based on their openness to exploring insights and ideas emerging from serial studies. Drifts were hard to document and structurally evaluate, but ways of drifting related to lifecycle processes provided a way to maintain an overview and to re-evaluate and reflect on the progression and structure of studies through analytical perspectives by clustering the many activities into studies. With these final reflections on the research design and methods, the next section will elaborate on the frames for this study before presenting each study and its contributions.

A final philosophical remark to conclude this section stems from the three quotes that are inserted at the beginning of subsections 0, 2.2 and 2.3. They are the first three of the six laws articulated by Melvin Kranzberg (1986). In this project, they serve as a recall to understand technology's role in society and avoid the philosophical doctrine of technological determinism, that is, technology is the prime factor in shaping lives, values, institutions, and other elements of society.

Technology is indeed a core component of this research project. Therefore, it is also important to remember political and social forces: technology's history, and, perhaps more importantly, that the function of technology is its use by human beings. The three laws quoted remind us that technology's interaction with social ecology is such that technical developments frequently have environmental, social, and human consequences that go beyond the immediate purpose of the technical devices and practices themselves, and the same technology can have quite different results when introduced into different contexts or under different circumstances (Kranzberg, 1986, p. 547).

The hardware, the technology itself, is of no use without the human element, but it would not be possible to make systems without the technology. Thus, technology is a very human activity in which the role of technology can best be determined by the humans that use, abuse, or misuse it.

SECTION 03

THE MATRIX HAS its roots in primitive arcade games [...] in early graphics programs and military experimentation with cranial jacks. [...] Cyberspace. A consensual hallucination experienced daily by billions of legitimate operators, in every nation, by children being taught mathematical concepts . . . A graphic representation of data abstracted from the banks of every computer in the human system. Unthinkable complexity. Lines of light ranged in the nonspace of the mind, clusters and constellations of data. Like city lights, receding. . . .

William Ford Gibson

3. FRAMES

This section presents and discusses existing frames of user interaction with experience technologies in exhibitions, theoretical frameworks related to user experiences, and frames of reference for the concepts and terms used in the studies presented in section 4. It will cover different levels of theoretical, technical, and practical abstractions. The aim is to identify and qualify technologies suitable for mediating explorative experiences on an automated site. This is done through a combination of field studies and theory that explain current theoretical and practical considerations concerning exhibition design that involves digital mediation, thereby addressing [SQ_02] and [SQ_03], which is related to identifying suitable experience technologies and investigating these technologies' capacity to facilitate user's visiting automated exhibition sites.

Due to paper limitations, the theoretical exposition has been compressed to focus on each paper's primary contribution: developing new theory and design principles. While the papers elaborate on applying and evaluating theories and frameworks, the underlying theoretical foundation is not explicated there, nor are all concepts clarified. Thus, this section serves as an introduction to the assembly of theories applied throughout the studies and presents the framing of the studies, along with an explication of the frames of references used in the studies. Multiple scientometric reviews are part of this section that could have appeared in papers but were left out due to either the focus of academic journals or size limitations. The first subsection, *Exhibition Experience*, provides an overview of different frames of interaction with digital technologies in museums and interaction modalities. Interaction frames were used to organize data from field studies presented in appendix [C1_TAB2]. As such, this subsection will include a few real-world state-of-the-art examples from field studies of 57 sites across nine countries worldwide. To make sense of the data regarding types of digitally mediated interactions in exhibitions, Eva Hornecker and Luigina Ciolfi's *HCIs in Museums* (2019) provided a set of reference frames and terminology that clusters types of digitally mediated interactions into three overarching clusters: *standalone interactions*, *mobile interactions,* and *assemblies*. Their book *Human-Computer Interactions in Museums* (2019) will therefore be used extensively in subsection 3.1 to present the real-world examples from [C1_TAB2] that influenced the final designs of XTR and ARA. The subsequent subsection, *Experience Entanglement*, clarifies concepts and definitions of terms related to the fusion of user experiences from users' interactions with digital technologies, visitors' journeys in a museum exhibition, and players' ventures through a game. The primary reason for visiting these themes is to understand the design rationale that has resulted in XTR, ARA, and OMG through the link established between motivation, flow, curiosity, exploration, and exhibitions. A secondary reason is the terms used interchangeably throughout the studies: both users, visitors, and players are used in the different studies; although consistent in the studies, the terms are not addressed, nor are there any clear distinctions among them. Additionally, some studies evaluate the user experience of a system [P09; P10], while others evaluate the player experience of a game [P06; P07]. Here, the differences and alignments are explained, along with a mention of inventories that were part of the evaluation of XTR, where they are elaborated. The final subsection, *Exploration Systems*, defines and establishes experience technologies designed to facilitate exhibition visits through explorative features.

3.1. Exhibition Experiences

As discussed in the previous section, constellations of computer technologies implemented in exhibitions can mediate user experiences between the museum and its content. They can also facilitate the visit or alleviate practical challenges, such as guidance and wayfinding, and they can link the physical-digital interaction through different technological setups. The various configurations afford different types of interaction within the exhibition. They can even augment physical labels and guidance and extend the content with language choices, for example. Increasingly, as discussed in section 1, experience technologies enable a range of activities, from playful engagement with exhibitions to forms of personalization, such as customized content delivery or carefully selected curation of exhibits. But exactly what do experience technologies entail in an exhibition context? This section expands on using digital technologies in exhibitions to investigate how experience technologies can mediate explorative experiences in exhibitions, which will be unpacked by examining the interaction frames present in exhibitions today and discussing the main characteristics and issues relating to the user experience. An interaction frame refers to how the interactive experience is expressed regarding the type(s) of the device, input/output mechanisms, and the physical context of the museum, along with other contextual factors, such as social constellation and the presence of others (Hornecker & Ciolfi, 2019, p. 17). The data presented in [C1_TAB2] were categorized and coded using frames referred to as *integration* in [C1_TAB2]. Therefore, they will be presented here, along with a few real-world examples. In addition to interaction frames, the various modes of interaction identified and coded in the appendices [C1_TAB2] and [C1_TAB3] are also classified into *modalities* to understand how users interact within a given frame of interaction. Modalities here are used to classify and describe interaction (i.e., input and output) modalities, methods, technologies, and devices. Although there are taxonomies within HCI that offer rich and complex classifications, the taxonomy applied in this thesis is limited to *audition*, *exertion*, *haptic,* and *vision* (Augstein & Neumayr, 2019), as these were considered the most prevalent in interactive museum exhibitions. Concerning modalities, the term *types,* used in both [C1_TAB2] and [C1_TAB3], refers to conceptualizing the design environment regarding how a person will interact with a system or application underlying the user experience (Sharp et al., 2019, p. 81). There are five primary types of interaction (Lueg et al., 2019; Sharp et al., 2019), which were used to code the table, as presented below:

× Instructing: Users issue instructions to a system, e.g., typing commands and selecting options from a menu.
× Conversing: Users dialog with the system, e.g., speak or type in question to which the system replies via text or speech output.
× Manipulating: Users interact with objects in a virtual or physical space by manipulating them.

- Exploring: Users move through a virtual environment or a physical space, e.g., 3D worlds, augmented, virtual, and mixed reality systems.
- Responding: System initiates the interaction, and the user chooses whether to respond, e.g., proactive mobile location-based technology that can alert the user to the point of interest.

In *Human-Computer Interactions in Museums* (Hornecker & Ciolfi, 2019) Hornecker and Ciolfi distinguished between three frames of interaction in three low-resolution definitions: *standalone installations*, *mobile interactions,* and *assemblies* (Hornecker & Ciolfi, 2019, p. 18), with additional high-resolution, detailed descriptions of implementation of digital technologies: *embedded and embodied interactions*, *extended reality* and *multisensory experiences* (Hornecker & Ciolfi, 2019, p. 34). The frames will be presented in the following, as they provide a vocabulary to make sense of the data collected in [C1_TAB2]. As such, these terms retrogressively substitute for the terms initially used in [C1_TAB2]: *stationary*, *mobile,* and *interlinked,* as the terms in [C1_TAB2] were conceived and used from 2016 and forth. Subsequently, the frames were used to steer the direction of the design of early low-fidelity prototypes and the final high-fidelity prototypes of XTR and ARA. Finally, the higher-resolution descriptions will be presented in brief, as they are detail oriented regarding implementation strategies.

3.1.1. FRAME: STANDALONE

Standalone installations refer to self-contained interactions unrelated to other interactive elements. Mobile interactions refer to users roaming with devices that they use to interact within the exhibition, and assemblies are interactive installations comprising multiple components linked to each other and distributed across an exhibition in an interconnected way (Hornecker & Ciolfi, 2019, p. 18). There can be overlap and mergers between the frames depending on the platform, interaction type, content, context, and integration. As Hornecker and Ciolfi (2019) remarked, the layering of digital and physical interactions across analog and digital content makes the separation of interaction frames complex and not as clearly partitioned as presented here. For example, mobile guides can operate across multiple instances of thematically varied exhibits or function as a cohesive element that brings together many different topics, and self-contained installations can be linked to form a narrative structure throughout an exhibition. A different approach to link exhibits can be achieved with *transmedia*, which can be used to interpret and connect multiple narratives, platforms, and delivery models (Freeman & Gambarato, 2019; Kidd, 2014). This approach resembles the third interaction frames and assemblies. This approach, however, is covered extensively in an affiliated project within the OM research program (Selvadurai, 2019) with collaborative contributions in [P02; P08] and will not be explored further in this project. The examples presented throughout are based on state-of-the-art, informed by the empirical field studies conducted as part of study [A] presented in [C1_TAB2].

Standalone installations are deployed to create specific areas of an exhibition or specific standalone exhibits, where digital interactions are a core feature, such as kiosks set up for digital information delivery, information screens displaying illustrative content, and isolated topical areas within exhibitions. The formats of these implementations exist today, although with increasingly sophisticated interaction types, such as gesture and movement recognition systems, for example, a wall with interactive posters that allow users to look up era, geographic-specific information (Figure 21: left), and an interactive sandbox with a projected topographic map that changes based on user interaction with the sand (Figure 21: right).

Figure 21: Standalone, self-contained installations creating isolated areas of interactivity within an exhibition or attached as information about a specific artifact or topic. Left: From the memorial in Melbourne, Australia. Right: From the Faaborg Museum in Faaborg, Denmark.

Standalone points often offer browsing/searching for information, playing media such as audio, video, animations, or problem-solving activities such as playing games, simulations, and quizzes aimed at engaging visitors with the exhibition (Hornecker & Ciolfi, 2019, p. 19).

The implementation of standalone installations can differ from single-user to multi-user experiences. Some are designed to engage onlookers and encourage social interaction and co-experiences, while others engage users individually. For example, there are many standalone installations set within one large arena in the Gladiator exhibition in Moesgaard Museum (Moesgaard Museum, 2016), where users engage with standalone points of interaction, often individually or together in small groups, but as a timed event, the whole exhibition turns into an arena with a show in the middle that transforms users into the arena spectators (Figure 22).

Figure 22: An exhibition about gladiators, where the exhibition invites users into the arena to witness a gladiator fight at the Moesgaard Museum, Aarhus, Denmark. Source: Moesgaard Museum.

Another example capturing both a single-user and multi-user experience is the self-portrait creator in National Gallery Victoria in Melbourne, Australia. Here one user may create a self-portrait in the same art style as Julian Opie and part of the Julian Opie exhibition in 2018, at the National Gallery of Victoria, Melbourne (National Gallery of Victoria, 2018), but although the installation provides no hints, it can be used collaboratively, such as couples who created each other's portraits and some cramming up to sit on each other and create portraits with both faces (Figure 23).

Figure 23: The three-step process behind the user-generated Opie-style self-portraits at NVG, Melbourne, Australia. A conversation with the developers of the interactive installation revealed that they had intentionally designed them to encourage multi-user interaction to trigger social interactions without explicitly instructing users.

Integration and placement in the environment are important to consider, as they affect the physical flow of users. For example, users in groups split up to take turns using the installation, which can lead to transient fluctuations in the flow of crowded exhibitions, referred to as *hyper congestion* (Yoshimura et al., 2014), and reports show that this could contribute to a phenomenon described as "the museum fatigue" or "museumitis" in the literature (Falk & Dierking, 2013a; Gilman, 1916; Graburn, 1977; Schwan et al., 2014). Of course, this is also disruptive to the shared experience. Some newer installations are designed to accommodate single, multiple, and shared social experiences or, to some extent, engage onlookers, which might also entice some to try the installations themselves, such as the example above.

In Museum für Naturkunde, an integrated research and natural science museum in Berlin, the central atrium of the museum exhibits "Oskar," a 13.27-meter-tall *brachiosaurus brancai* (later *giraffatitan brancai*) is displayed in the center. *Jurascopes* surround the many fossils in the atrium. These are stationary augmented reality binoculars that transition from a live view of the fossil to slowly building on layers of muscle and skin, with a final transition where the dinosaurs are animated into a re-created Jurassic environment where it moves around (Figure 24).

Figure 24: The Jurascope by which users can observe dinosaur fossils brought to life with the magic of augmented reality animations in digital displays embedded in the observation style binocular scopes. There are monitors displayed next to the Jurascopes so that others can view along. Source: Museum für Naturkunde.

Micropia, an exhibition about microscopic organisms, has a central exhibition that involves two people kissing. The people are recorded and broadcasted with information about the transference of bacteria through a single kiss (Figure 25); this type transforms users to engage in performative experiences, which are shared with everybody in proximity. Onlookers reacted with cheers, laughter, and even disgust (both at the kissing and the facts displayed afterwards).

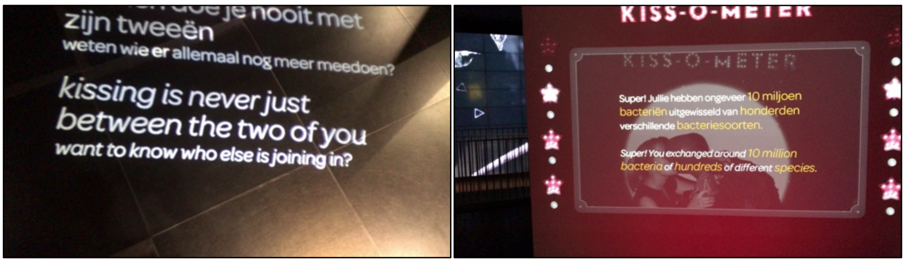


Figure 25: The "kissing-booth" that encourages visitors to kiss in front of a wall display and camera and subsequently displays information regarding the transference of germs between two people kissing—Micropia, Amsterdam, Holland.

Taking the physical aspect further in standalone installations can engage through exertion, where the body is part of the performance to engage the user through bodily interactions. Examples of this type can be seen in ARoS, an art museum in Aarhus, Denmark, where digital installations are designed to engage visitors through user input, such as physical activity and eye-tracking are utilized to present art and information about art in different forms (Figure 26).

Figure 26: Left: A user is following instructions on how to pose from other participants on the other side of the see-through display; on the other side, the participants can interact with the display to create an art piece based on the person posing to become an art piece themselves for display. Right: An image is presented, which the user must observe. While observing, the user's gaze is recorded and presented regarding where the user looked the most and in what order the user analyzed the image. Source: ARoS.

Another example that engages both mind and body into the exhibition is an installation at ACMI, where users can recreate the *bullet-time* special effect from The Matrix (Figure 27: left) and the *Laser Harp* in Experimentarium (Figure 27: center and right) where users can "play music with light" by breaking the beam of light emitted by the lasers that are received by a photoelectric cell. A sound is produced upon interrupting the amount of light incident on the photocell, thus creating a light harp.

Figure 27: Left: The bullet-time studio at ACMI, Melbourne, Australia, where users can recreate scenes from The Matrix or create scenes using the bullet-time special effect. Center and right: The laser harp plays a note when the user interrupts the laser light at the Experimentarium, Copenhagen, Denmark. Source: Experimentarium

There are potentials for encouraging social interaction across standalone installations, with audience participation or engagement, but it also poses several design challenges for smaller sites, particularly sites where the exhibition is situated both inside and outside. Here a different frame offers mobility and enables the interaction to follow the user instead of requiring the user to seek specific access points.

3.1.2. FRAME: *MOBILE*

Mobile interactions have been part of the earliest forms of interactivity in exhibitions, with analog audio guides since the 1950s (Tallon & Walker, 2008), and throughout the 1980s, mobile devices offered guidance to visitors and provided narrative paths in self-guided tours as an alternative to guided group tours. Over time, technological advancements have transformed mobile devices into powerful multimedia computing machines capable of utilizing context in their applications. Modern devices allow for interactions that mix modalities, such as reading and writing, seeing, and hearing, and touching and feeling, which opens up opportunities for multisensory or multifunctional experiences, allowing users to interact through alternative input modalities, such as speech, gesture, orientation (position) (Nova et al., 2005), and gaze or full-body interaction (Hornecker & Buur, 2006). This also includes the opportunity to receive information from the system through output modalities, such as text, sound, vibration, and speech synthesis, combined with temporal and contextual constraints (Hornecker & Buur, 2006).

Mobility is not only an attribute of devices but also an attribute of activities. Therefore, the interaction is considered mobile if both the user and the device can relocate during the interaction (Gorlenko & Merrick, 2003). There are critical differences between mobile interactions and that stationary of nature (Gorlenko & Merrick, 2003) because the interaction will happen in mobile contexts (Tamminen et al., 2003). Mobility also means that the devices can be used anytime and anywhere (Perry et al., 2001) in dynamic and complex situations (Pascoe et al., 2000; Tamminen et al., 2003).

Mobile devices have played a pivotal part in museum exhibition communication strategies in recent times, with "bring your own device" (BYOD) being adopted in many museums over the past five years—particularly by smaller museums that operate with tight budget constraints and limited internal technology expertise (Sayre, 2015). By placing hardware requirements and maintenance on the users, museums can focus on developing applications and content rather than hardware and software infrastructures with higher maintenance costs (Hornecker & Ciolfi, 2019, p. 23). Modern mobile devices are packed with an arsenal of sensors and networked capabilities that enable location detection, time of date, weather conditions, and other contextual information relative to the user. The use of mobile phone tracking based on multiliterate radio signals (GSM, Wi-Fi, Bluetooth, etc.) can also be utilized for the same purpose as an alternative to GPS or as a substitute for indoor positioning. Specifically, location detection has been utilized in exhibitions through proximity sensors (e.g., Bluetooth beacons or Wi-Fi grids) or positioning systems for outdoor environments (e.g., GPS, AGPS or GLONASS). Other location detection and user interaction methods were implemented using quick response (QR) codes and near-field communication (NFC), which became widespread check-in methods at particular points. QR codes have become widespread as a cheap method that does not require a hardware infrastructure and is easy to generate and manage.

From a generic perspective, mobile interactions are similar in form: the user carries the device, and at points of interest, the digital content is presented either automatically or through active selection. However, the type of experience that mobile technologies can supports varies. Initially, mobile devices were used for guiding, such as audio guides (Tallon & Walker, 2008), but over time, mobile devices have been used to deliver various types and styles of content, such as descriptive information and more performative content (Jensen et al., 2014). More recent applications allow users to select different styles of guiding and various underlying themes for the visit, so the user can select a topic of interest or preference, such as scientific facts, narrative flow, or information related to wayfinding for self-orientation or directions, which leads the user through a predefined thematic visiting experience. Mobile technologies are also increasingly used to engage users in activities and experiences, including playful and open-ended activities, such as scavenger hunts (Den Blå Planet, 2013; Trailblazers, 2015) or creative tasks based on museum contents mentioned in 1.3 and 1.4. There exist pencil and paper versions of these activities, where the user goes on a scavenger hunt/quiz, which were retrieved and examined as part of the field study, but they are not factored in, as they are analog and not digitally mediated.

As mentioned earlier in section 1, mobile devices have presented a set of challenges. Users frequently experience social isolation while using digital guides, particularly audio guides (Economou & Meintani, 2011), which is a concern, as social interaction is an important part of the exhibition experience (Heath et al., 2005). This challenge has influenced the hardware setup to change from handheld single-user devices to audio-cones/bubbles, with which users can listen to audio bits together. This is, of course, at the cost of mobility, and a solution that requires exhibition design considerations. Other risks cited in other studies include multimedia guides distracting users from the exhibited content or surrounding environments and focusing their attention on the device's screen (Fillippini-Fantoni & Bowen, 2008; Petrelli et al., 2013; vom Lehn & Heath, 2003). Despite the challenges of mobile interactions, they bring versatility and flexibility to design exhibitions. David Walsh, the owner of MONA, the Museum of Old and New Art, stated that his reason for removing all signage and replace all information, communication, and facilitation with a mobile application, *The O*, is because it "takes all of the stuff that makes a museum look like a museum, puts it in the background, and that enables us to play." (Walsh, 2017).

A different take on mobile interactions is to move away from screen-based mobile devices and embed digital components into physical objects. Moesgaard Museum has a permanent exhibit that uses RFID-embedded objects that the user may bring along and use throughout the exhibition to activate content (audio, video, games). The user can choose between seven different characters. One is a current-day researcher/historian who narrates the events from a non-fictional perspective, providing only descriptive information, while the remaining six characters are part of a narrative flow where the user engages in a story through a specific character to unlock performative content and may revisit to gain insight from other character's perspectives (Figure 28).

Figure 28: RFID-integrated smart objects representing a character set within the narrative, or a current-day researcher who unlocks audio-dramas, games, and other content throughout the exhibition at Moesgaard Museum, Aarhus, Denmark. Source: Moesgaard Museum.

In this respect, storytelling becomes important when interweaving different technologies in exhibitions. Recent studies have compared NFC/RFID technologies embedded in cards and replicas of historical artifacts and a mobile phone application that triggers digital content by users in both indoor exhibitions and outdoor heritage sites (Not & Petrelli, 2018; Petrelli & O'Brien, 2018). The content was the same, while the form of mobile interaction varied. The study found that visitor's preferred tangible means of interaction (cards and replicas) over mobile phone application (Petrelli & O'Brien, 2018).

While tangible objects have been successful, there are many pragmatic design considerations: the lifespan of objects that users manipulate can become damaged or wear out and require additional resources to clean the artifacts and make them available to the next user. Despite the criticism against using phones for mobile interactions, they can enable guiding and supporting activities in indoors/outdoors museums; in particular, they can assist users in open-air and outdoor sites through technology-enabled support on sites where it would be impossible or impractical to implement support otherwise. Exhibition sites with outdoor exhibits require a different set of design considerations, such as handling seasonality (McGookin et al., 2017), ambient noise, and wayfinding, and the challenge of not knowing which direction the user is facing (Nova et al., 2005). With location-based systems, data can be generated by the user or harvested through sensors in the environment. The technology provides a frame for a relationship between the user and the environment, leading to an increasing role of mobility and context in using these applications (Adey, 2017). In a sense, the technology remediates the user's relationship with the environment. Location-based games that engage users to traverse physical distances and detouring between destinations offer new mediation with the physical place and digital space by transforming the perceived nearness to other people and objects in the environment, and these systems remediate their presence and proximity to them (Chang et al., 2015; de Lange, 2009; Licoppe & Inada, 2010). Mobility has spatial implications relevant to consider in exhibitions where the environment itself has a significance: location-bound historical material.

Mobile technologies have emerged as formidable storytelling tools (Jenkins, 2004; Nisi et al., 2004; Sprake, 2012), as locational stories are an effective method for presenting educational history materials in an enjoyable manner (Aylett, 2006; Beale, 2011; Jensen et al., 2014; Tallon & Walker, 2008). In addition, interactive narratives can have inherent value because interactivity helps users internalize the material more intensely (Vorderer, 2003). The understanding of locational storytelling has been further studied and implemented in the design of XTR and elaborated on in [P10].

Regardless, the number of mobile interactive experiences relying on mobile phones to create activities beyond descriptive information or guidance indicates growth toward playful experiences that use the exhibition as gameboards. Mobile interactions as trails of investigation, exploration, and discovery are approaches that reappear with emerging technologies that enable novel ways of interacting and experiencing cultural heritage content. For example, activities and tasks, such as solving open questions (Cabrera et al., 2005) and collecting items or locations via check-in or taking photos (Cork, 2016; O'Hara et al., 2007) indicate the approaches verging on games and gamification of the exhibition experience (Beale, 2011; Jensen et al., 2014). This frame offers evocative trails where the descriptive information delivery is not the priority but is considered a part of the evocative content, such as personal memories, fictional narratives, and performative activities, which unite enlightenment and experience by utilizing technologies to facilitate evocative experiences. Naturally, games and other gamified approaches can steal users' attention away from the factual and focus on the mechanics or goals of the game, which must also be considered when designing games and playful experiences that unfold in exhibitions. A third alternative to the standalone and mobile frames presented is a combination of both as *assemblies*.

3.1.3. FRAME: ASSEMBLY

Assemblies describe the use of interconnected technologies that tether multiple exhibits and objects by embedding interactional threads across exhibitions. In contrast, standalone installations work isolated from other installations, whereas assemblies work together, for instance, as part of an overarching narrative or activity layer. In a sense, it denotes a combination of both standalone and mobile. HCI research in museums (Hornecker & Ciolfi, 2019) has been increasingly concerned with interactions around distributed systems, with multiple points of interaction and interfaces that are part of an interconnected ecology of components, where the sum of the system is a larger interactional narrative. Thus, assemblies can comprise a few components in a simple system and complex and layered constructions that link analog and digital elements with displays, mobile elements, and the physical environment. As a concept, *assembly* was proposed in the context of exhibitions as design schemes for interactive experiences centered around a set of design principles for a coherent narrative linking of various components (Bannon et al., 2005; Bowers et al., 2007; Fraser et al., 2003). In defining assemblies, they emphasize the importance of mobility, e.g., a portable object/device, as a critical component for designing an assembly unified by an activity in which users can engage. In this situation, mobility, and portability connect various elements across the exhibition, which fulfills some of the qualities of assemblies. *Trailblazers* (Trailblazers, 2015) and the *North Sea Movie Maker* (The North Sea Oceanarium, 2013) are examples where the interaction is based on reconnaissance in the exhibition and looking for specific artifacts or locations while using the mobile as a tool, taking a bearing of the location of the artifact. In the Movie Maker application, scenography also plays a critical part in positioning the user to provide the backdrop for a scene. Upon locating it, the user must interact with the mobile device to either unlock or record a sequence and move to the next item. These examples clarify the interplay between mobile devices and exhibits, where the narrative is fragmented but involves more than just mobile or standalone. Mobility and context sensitivity are critical to both guide and facilitate the user to points of interests. Another way to couple mobile devices and physical installations in an assembly is to augment the reality that can augment physical environments and objects with digital layers. A good example is the augmented reality dinosaur exhibition (Figure 29) at Tasmanian Museum and Art Gallery, which reinvents standalone installations like the Jurascope from Museum für Naturkunde by creating a space where the user must move around to explore and discover an animated dinosaur that starts as a fossil where meat, muscles, skin, and hair are gradually added as the animation progresses.

Figure 29: The dinosaur exploration game exhibition. Top-left: Shows the physical set designed specifically for the digitally augmented layer. Top-right: Shows the digital layer projected onto the set. Bottom-left and bottom right pictures show the dinosaur as the fossil comes alive and a fully re-animated dinosaur.

Assemblies provide options for linking the multiple features and assets of an exhibition through interaction frames that offer various components that can create a resonance between physical and virtual qualities. However, the drawback with assemblies is that they can be complex and time-consuming to create and maintain, and ambitious regarding hardware and software, making this interaction frame unviable for smaller exhibition sites with limited resources and expertise (Hornecker & Ciolfi, 2019, p. 33).

3.1.4. INTEGRATION OF FRAMES

The three presented frames can be further examined regarding the type of interaction mediated and the platforms and technologies or forms of delivering interactive experiences (Hornecker & Ciolfi, 2019, p. 33). They are:

× **Embedded and embodied interactions:** Interactivity is interlinked with material, tangible aspects of spaces and artifacts, and embodied aspects of the visitor experience (Bannon et al., 2005; Benyon, 2014; Benyon & Resmini, 2017; Horn et al., 2009; Hornecker & Buur, 2006; Ishii & Ullmer, 1997; Snibbe & Raffle, 2009; Wakkary et al., 2009).

× **Extended realilty:** Interactivity is a seamless overlay of digital interactive content that reacts to physical and analog environments and objects. This type includes augmented, mixed, virtual reality, and extended reality—AR, MR, VR, and XR respectively (Ballagas et al., 2007; Bekele et al., 2018; Benford et al., 2011; Benford & Giannachi, 2012; Billinghurst, 2017; Ioannides et al., 2017; Jerald, 2016; Jung et al., 2016; Milgram & Kishino, 1994; Moorhouse et al., 2019).

× **Multisensory experiences:** Interactivity triggers both audio and visual digital content delivery and involves other sensory modalities (audition, exertion, haptic, taste, smell, vision, etc.) (Augstein & Neumayr, 2019; Levent & Pascual-Leone, 2014).

Different technologies can be implemented across the three interaction frames. For instance, XR could be part of an assembly, a standalone installation, or a separate mobile experience. In addition, multisensory experiences and embedded and embodied interactions have introduced museums to integrate exertion and sensory activities, which include both analog and digital activities. The examples are using biofeedback through bodily interaction in art museums to perform artworks, testing physical prowess through exertion in science centers, and using taste, touch, and smell by brewing and sampling beer in a beer-brewing museum.

XR, which includes AR, MR, and VR, has been utilized within cultural heritage where technologies have been used to track and augment physical layers with digital content. The technologies implemented as standalone have been used to educate users and enhance exhibitions for exploration, virtual reconstruction, and full-fledged virtual museums (Bekele et al., 2018). HCI research, in particular advancements in the field of mobile, pervasive, and ubiquitous computing, has over the past years made context-aware technologies inexpensive and thus accessible as hardware that has gained traction in museums, as discussed earlier in 1.3 and throughout subsection 3.1. XR, or more specifically AR and MR, was experimented with in early prototypes, which eventually led to the high-fidelity prototypes presented in [P06; P07; P09; P10].

3.1.5. DESIGN CHALLENGES

The state-of-the-art investigation into exhibitions and the current implementation of interaction frames, modalities, and technologies through the vocabulary borrowed from *Human-Computer Interactions in Museums* (2019) in the previous sections clarified designing and developing digitally mediated experiences that are suitable for a small house museum with limited resources and other design restrictions, as mentioned in 1.3. All three frames and the underlying forms of experiences can be used in the design of technologically driven explorative exhibitions to mediate the dynamics of enlightenment and experience, but by including the site and considerations about automation, resources and restrictions, standalone installations, and assemblies become unfeasible, while the mobile interactions approach offers a technologically viable way.

Standalone installations are feasible indoors but not outdoors. This frame also requires a redesign of the existing exhibition, integrating digital technologies that must operate unattendedly and without oversight. Assemblies present interesting opportunities for hybrid interaction, which can link the physical exhibition with layers of digital interaction, but, as mentioned, they can be complex and time-consuming to create and ambitious regarding hardware and software, making this frame unfeasible for smaller exhibition sites with limited resources.

The examples and frames investigated qualified mobile interactions over standalone installations and resource and development of assemblies, as previously discussed in section 1.3.3.1, through field study and additional scientometric reviews, presented in this section. There are, however, also a set of design challenges that arise from studying existing solutions that bring several designs and development considerations into focus through this field study and the state-of-the-art investigations presented in 3.1. The challenges describe the criteria necessary to answer [SQ_02] and [SQ_03]. The design challenges (DC) are listed in Table 1, along with references to the studies that address the challenge:

DC	DESCRIPTION	STUDY
01	Seamless integration of digital content layers into physical exhibits and exhibitions forms hybrid environments that do not distract users but support them by guiding them while also leaving freedom to explore.	[A] [B] [D]
02	Integrate elements that resonate with social experiences in explorative settings.	[B] [C]
03	Foster learning and motivation: related to striking a balance between enlightenment and experience through exploration.	[C] [D]

04	Identify user preference for content (audio, text, video) to avoid overload (e.g., lengthy audio or video sequences, too long or difficult text to remember, etc.) and ensure that the content presentation resonates with the exhibition.	[D]
05	Narrative structures that fit linear storytelling might not be the same for automated exhibitions with no specific linearity regarding exhibits. Additionally, narrative structures may not be generic across interaction frames; location and exploration could impose challenges in structuring a narrative.	[D]
06	Exploring novel technologies or novel ways to apply technologies might involve technically complex setups, a trademark of HCI researchers that should be reported so that it can inform future iterations on the design and development of similar systems.	[A] [B] [D]

Table 1: Overview of DC that emerged from field studies and state-of-the-art investigations documented in [C1], which set the direction for the research project's expansive elements, detailed in section 4.

3.2. Experience Entanglement

From a philosophical perspective, life is a continuum of experiences that gain meaning from an ever-changing series of contrasts (Graburn, 1977). These experiences may be cyclical, such as the daily cycle of routines and breaks, repeated on a weekly, monthly, or yearly cycle, marked by seasons, work versus vacation, and weeks and weekends. Other experiences may be linear: childhood, adulthood, old age, birth, and death. In making sense of the naturally differentiated passage of time, human societies have imposed social markers to demarcate occasions and stages. Within this framing, the ritual function of going to museums and similar voluntary activities serves as a social marker by punctuating life in a memorable way (Graburn, 1977). In this framework, museums are inextricably linked to the phenomenon described in subsection 1.3.3.: liminality. Liminality is, in a sense, the magic of a trip: an out-of-the-ordinary experience. Museums are environments designed for scientific thought, but they can also enable visitors to engage in magic or mythic thoughts. Both mythic and scientific thoughts are ways of making sense of the world, and both are present in everyday thinking processes. The former results from living and experience, while the latter is usually the result of education and discipline (Graburn, 1977; Lévi-Strauss, 1989). Another way of relating this rationale to the interaction between user and exhibition in a technology-mediated setting is that museum exhibitions provide a liminal setting where both mythic and scientific can be part of an experience. The following subsections detailing experiences from different domains are essentially an elaboration and further discussion of the connection between 1.1, 1.3, and 1.4 to both explain and qualify how learning can be motivated intrinsically through the notion of flow, curiosity, and exploration, and playing games, while understanding the user, the visitor, and the player is based on motivation, which leads to specific types that have informed the design of exploration systems (XTR and ARA) for enlightenment and experience in automated exhibition sites.

3.2.1. USER EXPERIENCE

In section 1, the term user experience, from an HCI perspective, was presented and discussed. However, the term user experience in this thesis enmeshes two additional types of experiences: the *visitor experience* (VX) in museums and *player experience* (PX) in games. So then, how does experience relate to a system designed for all three? That is, the user-system, visitor-exhibition, and player-game interactions. Different models and frameworks exist, such as the technology as experience framework (McCarthy & Wright, 2004) and the user experience design taxonomy (Jensen, 2013b), as discussed in section 1. This subsection will present the two additional fields through an overview of existing models and frameworks and explain how these frameworks are part of the studies in section 4, where the design and evaluation of XTR and ARA are detailed. In HCI, user models describe aspects of human behavior or HCI by depicting how the core features and processes underlying a phenomenon are structured and related to one another (Sharp et al., 2019, p. 92). Donald Norman (1988) developed models of user interaction based on theories of cognitive processing stemming from cognitive science to explain the way users interacted with interactive technologies, which led to a "seven stages of action model" that describes how users move from intent and execution to evaluation of actions concerning their goals (Norman, 1986, 2013). More recent models characterize the core components of the user experience by detailing what users want in their interactions, such as Marc Hassenzahl's (2010) model of user experience design.

Based on these existing approaches, similar user models specific to exhibitions and games were investigated. A small-scale literature review revealed multiple metaphors that describe visitors in museums, viz. visitor types, and players in games, viz. player types. In this thesis, experience is a central term that links both technology and its application in the museum context. Therefore, the visitor experience and the player experience, which are both parts of the user experience, will be presented here as they were part of the design, development, and evaluation of the two systems: XTR, which is reported in [P06; P07; P10], and ARA, which is reported in [P09]. The intent of presenting VX and PX is to extend the frameworks presented in the exordium with other existing frameworks, specifically targeting museums and games that could better inform future exhibition exploration experiences.

Existing visitor type and player type frameworks will be introduced in the following section, which were used directly in designing XTR and ARA. Consequently, the ARA guide was evaluated through traditional user experience and usability metrics, while the game XTR used specific game- and player-centric methods to evaluate the play and player experience. Therefore, the following subsection will seek to present the theoretical background that shaped the two systems directly by understanding visitor types and player types that are inextricably linked to the visitor experience and player experience.

3.2.2. VISITOR EXPERIENCE

Reverting to at least 1977, the *visitor experience* entered the conscience of both practitioners and researchers (Graburn, 1977), where exhibition design focused on the meaning and experience of the visitor (Graburn, 1977) and has since expanded to *visitor studies* (Falk & Dierking, 2013; Roppola, 2012) and visitor *behavior studies* (Solomon, 2014; Yoshimura et al., 2014). These studies inform the design of exhibitions in a user-centric view and highlight different phases of the visitor's experience, such as memory, decision, and behavior (Falk & Dierking, 2013), and emphasize the difficulties in capturing and measuring it due to the subjective nature of experiences. Falk and Dierking (1992, 2013, 2016) offered a way to understand the users' *museum experience* based on user types and the contextual model of learning linked to before, during, and after a museum experience, describing why users visit museums, what they do, and how they learn. In it, they posit that a visitor experience is influenced by physical context (architecture, physical exhibit design, and exhibited objects), social context (shared visits, presence of other visitors, and interactions with staff), and personal context (motivations, preferences, and knowledge) (Falk & Dierking, 2013; Hornecker & Ciolfi, 2019). Roppola (2012) unmasked how visitors interfaced with exhibition environments through visitor studies, offering an evidence-based conceptual framework for understanding the visitor's journey through an exhibition. However, visitors' active engagement in and with museums has physical, emotional, intellectual, and social dimensions (Perry, 2012). Following Csikszentmihalyi and Hermanson's (1995) study, new trends in visitor studies emphasize multisensory and emotional engagement and the sociality of the museum experience (Bedford, 2014; Falk & Dierking, 2013; Hornecker & Ciolfi, 2019; Levent & Pascual-Leone, 2014; Macdonald, 2007; Perry, 2012).

In science and technology museums, visitor engagement and participation are uplifted by using new media, such as games, interactive installations, and other forms of edutainment (Vermeeren et al., 2018) to encourage visitors to engage with the content on exhibit and experiment with the techniques on the show and appropriate the visiting experience by making it meaningful and memorable. Art museums have also adopted this trend, where it is more difficult to let visitors experiment with the collections (Vermeeren et al., 2018). A key insight gained from visitor studies concerning design and evaluation is the categorization of visitors into types based on behavioral aspects (dwell time, the physical path followed in an exhibition, gaze, orientation, etc.) (Levasseur & Veron, 1983; Serrell, 1997; Sookhanaphibarn & Thawonmas, 2009). In contrast, other studies have combined both behavioral signals and demographics (Mokatren et al., 2019). These visitor types have been instrumental in designing exhibitions and the content and activities for exhibitions. Visitors have been classified by various characteristics, such as the groups to which they belong (Hooper-Greenhill, 1994), the way they look or move in the exhibition (Dean, 2002; Serrell, 2015; Verón & Levasseur, 1989), and their experience (Falk & Dierking, 2000). These classifications have contributed to many metaphors for visitor types (Mokatren et al., 2019).

Initially, Falk (2009) and Falk and Dierking (2000) proposed visitor identity and identified five identity-related types, which were presented throughout section 1 and were also used to focus on one particular type of this project: the explorer. The five types originally proposed by Falk and Dierking (2000) are as follows:

- **Experience Seekers**: Motivated to visit because they perceive the museum as an important destination.
- **Explorers**: Curiosity driven by a generic interest in the content of the exhibition.
- **Facilitators**: Socially motivated.
- **Professional/Hobbyists**: feel a close connection between the content and their professional or hobbyist passions.
- **Rechargers**: Primarily seeking contemplative, spiritual, and/or restorative moments.

These have been modified with two additional identities that emerge among those visiting special types of museums, such as ethnical or national museums and exhibitions that are designed as memorials to specific events: *Respectful Pilgrims* (come to the museum because they possess a sense of duty or obligation; they see it as a way to honor the memory of those represented by the exhibition) and *Affinity Seekers* (come to the museum because it speaks to their sense of heritage and/or personhood) to accommodate for types that were not represented in the first version (Bond & Falk, 2013; Falk & Dierking, 2018). Likewise, their initial studies were criticized for not having empirical backing to their claims (Dawson & Jensen, 2011), which they have since addressed (Falk & Dierking, 2013). The visitor types presented by Falk and Dierking have been influential, with traces in most museum studies within HCI and even in practice. For example, the newest report on the national museum trend in Denmark also uses this taxonomy to analyze and interpret its visitors (SLKS, 2018). The visible link to the learning theories and didactic models, as discussed in 0, was made to one specific visitor type from Falk and Dierking's (2000) categorization, namely explorers. In other words, this project is limited to focusing on a very specific user type. It has focused solely on this type as its design objective for systems, as presented in studies [P09] and [P10].

Before Falk and Dierking's identity types, a different museographic typography from ethnographic observations of the behavior of several visitors in several museums was presented by Levasseur and Veron (1983; 1989). The ethno-methodologists arrived at four types of visiting styles (Verón & Levasseur, 1989) by analyzing visitors' movements and comparing them to four animals' behavior. Their typology suggests the following:

- The **ANT** visitor tends to follow a specific path and spends a lot of time observing almost all the exhibits.
- The **FISH** visitor spends most of the time moving around the center of the room and usually avoids looking at the exhibits' details.
- The **BUTTERFLY** visitor does not follow a specific path but rather is guided by the physical orientation of the exhibits and frequently stops to look for more information (but not deeply).
- The **GRASSHOPPER** visitor seems to have a specific preference for some pre-selected exhibits and spends time observing them while tending to ignore the others.

This typology drew attention, as it has appeared in many HCI-related museum literature (Mokatren et al., 2019; Sookhanaphibarn et al., 2011; Sookhanaphibarn & Thawonmas, 2009; Kuflik et al., 2012; Lanir et al., 2013), a majority handling mobile interactive technologies in exhibitions. Recent studies have built systems to both quantitatively test the veracity and integrity of the typology through eigenvectors and, more recently, through artificial neural networks and k-means, tried to identify and predict the user types modeled over Verón and Levasseur's typology. These studies concluded that in the early stages of the visit, butterfly, and grasshopper type behaviors can be predicted with high accuracy, while ant and fish type prediction is not easy from the beginning, as it takes time to catch patterns in the visitors' sequence of actions with exhibits (Mokatren et al., 2019; Petrelli & O'Brien, 2018; Zancanaro et al., 2007). Predictions such as these can be used to deliver design content that aligns with a particular visitor type to optimize the overall visiting experience for that type but requires a system to capitalize on visitor behavior patterns.

In this study, the visitor type that is a model for the visitor's experience is focused on the explorer type due to the inherent psychometric properties described as curiosity-driven, with a generic interest in the exhibition's content. XTR and ARA were designed to foreground this user-specific type, using this as a guiding design principle. This does not mean that other user types are excluded, but systems designed specifically for other user types would need other guiding design principles. As discussed in 1.4 and 1.6, the explorer type is linked to a particular genre of games. Adventure games, and as discussed, there is a convergence of terms, which draws analogies between exhibitions and playgrounds, the activity of visiting an exhibition and playing a game, and visitors and players. Specific game mechanics and gameplay elements support the explorer in the adventure game frame: exploration, collection, and puzzle solving. The visitor types presented here were also instrumental in creating a dialogical design tool, OMG, reported in [P08].

3.2.3. PLAYER EXPERIENCE

> We live in a world of systems. [...] For such a systemic society, games make a natural fit. While every poem or every song is certainly a system, games are dynamic systems in a much more literal sense. [...] games are machines of inputs and outputs that are inhabited, manipulated, and explored. (Zimmerman, 2014).

Games are defined as "a system in which players engage in an artificial conflict, defined by rules, that results in a quantifiable outcome" (Salen & Zimmerman, 2004, p. 80). The practice of designing games is defined as "the process by which a game designer creates a game, to be encountered by a player, from which meaningful play emerges" (Salen & Zimmerman, 2004, p. 80). The concept of meaning and play in the context of games are presented by Huizinga (1949) as follows: "It is a significant function—that is to say, there is some sense to it. In play there is something 'at play' which transcends the immediate needs of life and imparts meaning to the action. All play means something." (Huizinga, 1949, p. 1).

Meaningful play, or meaning, play, and games, is central to the player experience and, therefore, the goal of a successful game design, to which Salen and Zimmerman (2004, pp. 31–37) provided two useful definitions: one is a *descriptive* definition and the other an *evaluative* definition. The descriptive addresses the mechanism by which all games create meaning through play, while the evaluative explains why some games provide more meaningful play than others. Both are presented below.

Descriptive: Meaningful play in a game emerges from the relationship between player action and system outcome; it is the process by which a player acts within the designed system of a game, and the system responds to the action. The meaning of an action in a game resides in the relationship between action and outcome (Salen & Zimmerman, 2004, p. 34).

Evaluative: Meaningful play occurs when the relationship between actions and outcomes in a game is discernable and integrated into the larger context of the game. Creating meaningful play is the goal of a successful game design (Salen & Zimmerman, 2004, p. 34). Discernability denotes the immediate outcome of an action that the player can perceive, and integration denotes that the outcome of an action is linked to the entire game system.

While the definitions provide both conceptual and practical understanding of how to design games and why, they decode only part of the player's experience. What is the experience, and what drives humans to play games?

Raph Koster (2005) presented a compelling argument that games are teachers. He stated that "fun is really just another word for learning" and that "a good game is therefore one that teaches everything it has to offer before a player stops playing" (Koster, 2005, p. 46). From his perspective, "fun" is the positive feedback that the brain produces for learning and mastering patterns. In this frame, fun is a critical part of both motivation and flow. He argued that the opposite of fun is either noise (e.g., patterns we do not understand) or boredom (e.g., simplistic patterns that have nothing to teach). Noise and boredom are destructive to fun, motivation, and flow (Csikszentmihalyi, 1990; Koster, 2005). In this subsection, the focus is to present what motivates humans to play games and, similar to the previous subsection, to provide insight into the design of XTR and ARA that stems from different fields of studies. The explorative elements in both systems, XTR particularly, were highly influenced by reviewing the existing literature about player motivation, curiosity, emotion, exploration, flow, and types of players.

In HCI games research, one of the aims of games and play research is to understand what constitutes engaging player–computer interaction (Malone, 1981). Insights gained from studying these interactions have been applied to design more appealing games and playful interactions, evaluate qualities of the PX, and create interactive systems that motivate humans to motives beyond entertainment, for example, serious games and gamification (Tyack & Mekler, 2020). The transfer of game design elements to more serious digital programs can be traced to 1980, when Thomas Malone (1982) and Ben Shneiderman (1983) transferred heuristics learned from computer games or game interfaces. This led early

HCI work to explore games as inspirations for desirable product qualities. John M. Carrol (1982) analyzed text adventure games, such as *Adventure* (Crowther & Woods, 1976), which advanced the notion of a research program on the relation of fun and ease of use (Carroll & Thomas, 1982). With the expansion of HCI from utility and usability toward user experience (Buchanan, 2001; Hassenzahl, 2010), hedonic attributes (Hassenzahl et al., 2008), motivational affordances (Zhang, 2008), and foregrounded pleasurable and fun products (Blythe et al., 2003; Blythe & Monk, 2018; Jordan, 2005).

Concepts and theories from motivational and positive psychology have seen widespread adoption among HCI game researchers to describe and analyze games (Boyle et al., 2011; Komulainen et al., 2008). Human wellbeing is a significant factor in decoding a player's experience, as wellbeing emphasizes internal states over external circumstances, experience over behavior, and self-determination over external control. The concept of flow (Csikszentmihalyi, 1990) and self-determination theory (Ryan et al., 2006; Ryan & Deci, 2000a) are among the central viewpoints often discussed in game design concerning motivation and player enjoyment, reflecting the well-being and the positive attributes of playing games (Fullerton, 2019; Salen & Zimmerman, 2004; Schell, 2019; Walz & Deterding, 2014). These viewpoints propose that human beings actively seek intrinsically valued states. PX's tenets will be presented here through a presentation of self-determination theory (SDT) and the theory of flow, as they have proven popular, particularly with HCI games researchers studying and reporting on PX.

Edward Deci and Richard Ryan's (2017) work on SDT describes human needs regarding physical and mental needs, which go beyond human desires, and unfulfilled needs lead to mentally unhealthy humans. It does so by presenting three mental needs: *autonomy* (a sense that actions are performed willingly), *competence* (the feeling of having an effect), and *relatedness* (a sense of belonging in relation to others and reciprocal care and value). At its core, SDT is a scientific macro-theory that integrates certain core concepts and related psychological theories of human motivation, growth, and wellbeing (Deci & Ryan, 2000; Ryan & Deci, 2017).

Basic psychological needs theory (BPNT) advances three needs that motivate organismic processes: autonomy, competence, and relatedness. Satisfaction with these needs promotes intrinsic motivation, internalization, and wellbeing—this is also referred to as *need satisfaction* (Ryan & Deci, 2017). In playing games, need satisfaction has been found to predict game enjoyment (Haerens et al., 2015) and persistence (Neys et al., 2014, 2014; Tyack & Wyeth, 2017). The opposite has also emerged within SDT around psychological needs: *need frustration* denotes the active opposition of basic needs that leaves humans incapable, controlled, or banished (Ryan & Deci, 2017). The negative counterpart provides clues to avoid in designing systems. However, fewer studies have investigated experiences of need frustration in games (Tyack et al., 2020), while need satisfaction has been proven to stimulate a positive response through player–computer interactions or the PX. Motivation, along with need satisfaction, is perhaps the core construct of SDT. SDT differentiates the three types of motivation (Ryan & Deci, 2000b): *intrinsic motivation* denotes an activity that is pursued for its inherently interesting and enjoyable qualities, *extrinsic motivation* denotes activity pursued for a separable outcome, and *amotivation* denotes the absence of intentional motivation, i.e., when a person is no longer aware of why they are pursuing an activity. Intrinsic and extrinsic motivations are not binary; the complexity of intrinsic and extrinsic motivations is more nuanced and could perhaps be better outlined as a continuum ranging from internal to external. An activity can internalize intrinsic motivation through external rewards, while the opposite is also true. The state is not fixed at either extreme, but there are points between the two where motivation can be introjected, identified, and integrated (Schell, 2019), and losing awareness of why an activity was pursued in the first place, leading to amotivation. Motivation is not an additive act of adding extrinsic motivation to already intrinsically motivating activities, which may slide the continuum toward external, draining intrinsic motivation. This is also among the major concerns of gamification that relies on extrinsic incentives, such as points, badges, and rewards (Schell, 2019), which is another point of critique that games designed in this way miss the systemic nature and complexity of both game design and game-player interaction (Bogost, 2014).

SDT, through the concepts of need satisfaction and intrinsic motivation, is considered core to the PX and has been applied to study various motivational processes, including the motivational pull of games (Ryan et al., 2006), inform gameful design and gamification (van Roy & Zaman, 2017; Walz & Deterding, 2014), and analyze the PX. This has contributed to a shared vocabulary for discussing what makes games engaging and has been widely applied to analyze PX, inform game design, and model player-computer interaction. Intrinsic motivation, in particular, is proposed as an innate human propensity for activities perceived as interesting and enjoyable and integrates organismic factors, which direct the assimilation and organization of external stimuli into the developing self. Thus, individuals are considered to experience well-being to the extent that their actions reflect the truest values of self (Ryan & Deci, 2017).

As elaborated in 0 and 1.4.3, intrinsic motivation plays a critical role in enabling the optimal conditions for learning in exhibitions through the concept of flow (Nakamura & Csikszentmihalyi, 2014), which in turn has been influential in studying the PX (Mekler et al., 2014; Sweetser & Wyeth, 2005) and modeling optimally challenging games (Constant & Levieux, 2019) and the effects of choice, novelty, and suspense on intrinsic motivations in educational games (Lomas et al., 2017).

Flow is an experience "so gratifying that people are willing to do it for its own sake, with little concern for what they will get out of it, even when it is difficult or dangerous" (Csikszentmihalyi, 1990, p. 71), and it comprises eight elements:

- a task that can be completed;
- the ability to concentrate on the task;
- concentration is possible because the task has clear goals;
- concentration is possible because the task provides immediate feedback;
- the ability to exercise a sense of control over actions;

× a deep but effortless involvement that removes awareness of the frustrations of everyday life;
× concern for the self disappears, but the sense of self emerges stronger afterward; and
× the sense of the duration of time is altered.

Combining these elements produces a sense of enjoyment so rewarding that people feel that expending energy is worthwhile simply to feel it (Csikszentmihalyi, 1990). An important precursor to a flow experience is balancing a challenging activity that requires skill (Figure 30). An activity needs not be active physically, and the skill necessary to engage in it need not be a physical skill. Flow experience often occurs with goal-directed activities, bounded by rules, and requires mental energy and appropriate skills. For instance, reading: "Reading is an activity because it requires the concentration of attention and has a goal, and to do it one must know the rules of written language. The skills involved in reading include not only literacy but also the ability to translate words into images, to empathize with fictional characters, to recognize historical and cultural contexts, to anticipate turns of the plot, to criticize and evaluate the author's style, and so on." (Csikszentmihalyi, 1990, pp. 49–50). Retrospectively, activities such as games, sports, and literature have been developed to enrich life (Csikszentmihalyi, 1990). The core element in flow is that the activity must be intrinsically rewarding. This resonates with games because people play games for the experience itself, as there is no external reward. Every flow activity provides a sense of discovery, a creative feeling of being transported into a different reality.

There has been a significant interest in understanding the players and their experiences with the activity of gaming, drawing from SDT and flow that have helped establish multiple inventories to both inform the design and evaluate the PX, such as *Player Experience of Needs Satisfaction* (PENS), developed by Scott Rigby and Richard Ryan (2007) based on SDT, *BrainHex* (Nacke et al., 2014; Tondello et al., 2019) and the *Player Experience Inventory* (PXI) (Abeele et al., 2016, 2020), etc. These were reviewed and applied in study [D] reported in [P10] and elaborated on there.

Flow has subsequently been transferred to game design by refining and extending the elements of flow to model player enjoyment in games using heuristics in the games usability and user experience literature, resulting in a model: GameFlow—player enjoyment in games (Sweetser & Wyeth, 2005). Since its first appearance, the GameFlow model has been widely used in games research, and over time, spawned various tweaked GameFlow models and used to evaluate games and applications, including mobile games (Chu Yew Yee et al., 2010; Omar & Ali, 2011; Paavilainen et al., 2009), educational games (Brown et al., 2007), XR games (Finkelstein et al., 2011; Khoo et al., 2008), and other non-game applications (Sweetser et al., 2017).

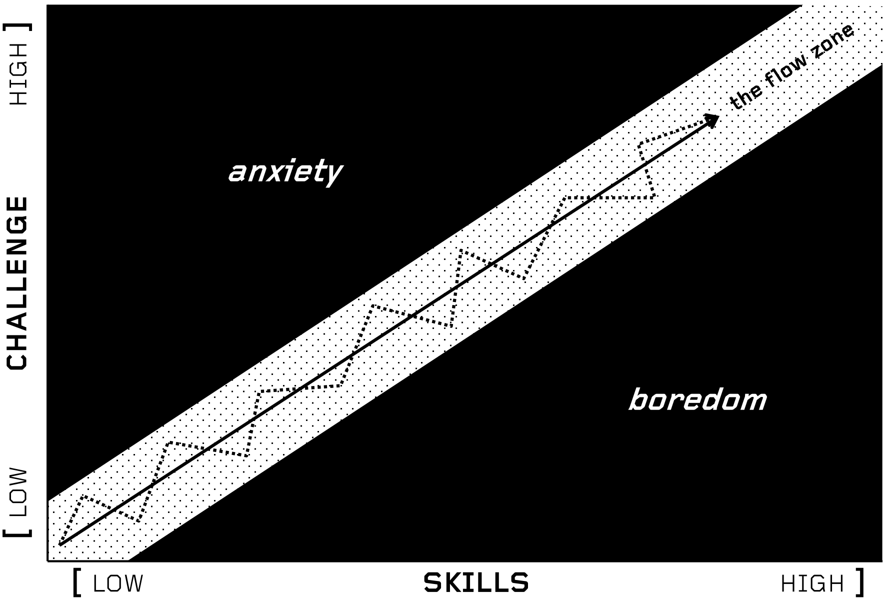


Figure 30: Flow: the balance between challenge and skills of activities in both mind and body. The straight arrow shows a progression over time balanced between challenge and skills, also referred to as the optimal conditions for flow. The dashed zigzag arrow indicates the optimal way to implement this, and perhaps a more realistic way to illustrate that the balance oscillates between tension and relaxation. Adapted from Czikszentmihalyi (1990, p. 74) and Schell (2019, p. 147).

GameFlow provides a set of heuristics that guide designers to keep the player's concentration through a high workload, with tasks that are sufficiently challenging to be enjoyable. This is often described as a cycle of tense and release, where tension and relaxation must be balanced, but a fluctuation between excitement and relaxation provides both the pleasure of variety and the pleasure of anticipation (Figure 30). In summary, the player must be skilled enough to undertake challenging tasks, the tasks must have clear goals so that the player can complete the tasks, and the player must receive feedback on progress toward completing the tasks. If the player is sufficiently skilled and the tasks have clear goals and feedback, then the player will have a sense of control over the task. The resulting feeling of the player is totally immersed or absorbed in the game, which causes the player to lose awareness of everyday life, concern for themselves, and alters their sense of time. The final element of player enjoyment, social interaction, does not map to flow elements but is highly featured in the literature on user experience in games (Sweetser et al., 2012, 2017; Sweetser & Wyeth, 2005). The GameFlow model establishes a link between the concept of experiencing flow and the player's experience of playing a game, which has been empirically validated in games research. Researchers and museum design practitioners have pinpointed the comparison between engaging in flow activities and the exhibition as a flow activity (Harvey et al., 1998; Latham, 2013; Visser, 2015; Vistisen et al., 2020). In some literature (Visser, 2015), the typical exhibition design and communication are positioned as a sub-optimal flow activity (Figure 31). The literature, however, did not report studies in which the GameFlow model was applied to a context-specific case in games for exhibitions, which could present an opportunity for developing a version of GameFlow for exhibitions where additional contextual and environmental factors are considered.

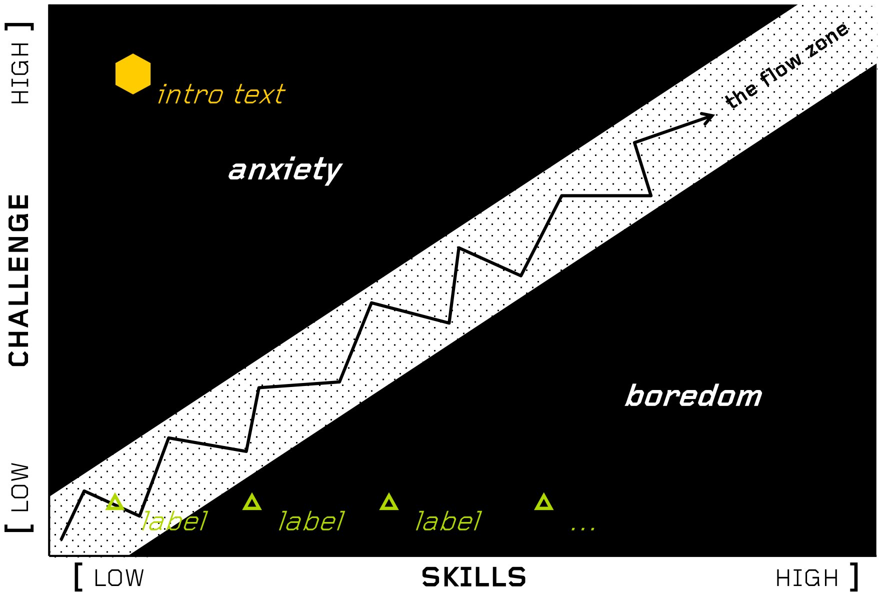


Figure 31: A mapping of typical exhibition design convention of priming visitors with introductory text followed by a string of labels throughout the exhibits, resulting in a detrimental experience to achieve flow in exhibitions. Adapted from Visser (2015).

GameFlow offers guidelines for creating optimal playing experiences, but not all activities have the same effect or capacity to induce flow. Different players may desire different kinds of experiences for which the game should be designed. The interrelationships among player motivation and game design, mechanics, aesthetics, and play style are complex. To design for a certain play style, types of players must be considered in the same way user models are established to optimize the design in HCI, and visitor types are studied to understand how to design exhibitions. Thus, the final subject covered here concerning play experience is player type.

Demographics refer to external factors, such as age, gender, income, ethnicity, etc., that can be useful to group and understanding the users. But these factors seldom reveal what each group finds enjoyable. A more direct approach focuses less on external factors and more on internal values, referred to as psychographics. Some psychographics reflect lifestyle choices tied to concrete activities (e.g., "hacker," "basketball fan," or "adventurer"), while others are not tied to concrete activities (Schell, 2019, p. 133). Instead, they examine what players find enjoyable and map those out. For example, the *Mechanics-Dynamics-Aesthetics* (MDA) framework (Hunicke et al., 2004) is a low-resolution framework that emphasizes gameplay characteristics through a list of emotions by formalizing the consumption of games from the designer's and player's perspectives (Figure 32). It is useful to examine emotions because different players will have different prioritizations of which emotional experience they seek, and game designers can have a target experience they seek to deliver.

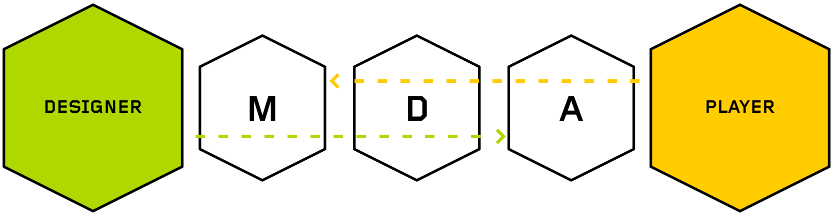


Figure 32: Shows the components of game consumption from a designer's perspective, who must consider game mechanics and dynamics to craft desired emotional responses, and from the player's perspective, the experience evoked by playing the game. Adapted from Hunicke et al. (2004, p. 2).

With MDA, as the authors recognize, there are limitations in listing all emotions. A useful tool that provides a high-resolution overview of emotions is Robert Plutchik's circumplex of emotions (also referred to as the "wheel of emotions" and "wheel of feels") and personality traits (Plutchik, 1960, 2001; Plutchik & Kellerman, 1980). In his work, based on psycho evolutionary theory and cognition, Plutchik used *emotion* as a general term for a complex group of phenomena, which he described as not simply a feeling state but as "a complex chain of loosely connected events that begins with stimulus and includes feelings, psychological changes, impulses to action and specific, goal directed behavior." (Plutchik, 2001, pp. 345–346). To create a useful model for mapping primary emotions, he created a circumplex model (Figure 33), which conceptualizes eight primary emotions, integrated as bipolar: joy versus sadness, anger versus fear, trust versus disgust, and surprise versus anticipation (Plutchik, 2001).

The three-dimensional circumplex model describes the relationships among emotion concepts, which are analogous to the colors on a color wheel. The cone's vertical dimension rep resents intensity, and the circle represents degrees of similarity among the emotions. The eight sectors are designed to indicate that there are eight primary emotion dimensions defined by the theory, arranged as four pairs of opposites. In the exploded model, the emotions in the blank spaces are the primary dyads—emotions that are mixtures of two of the primary emotions (Plutchik, 2001).

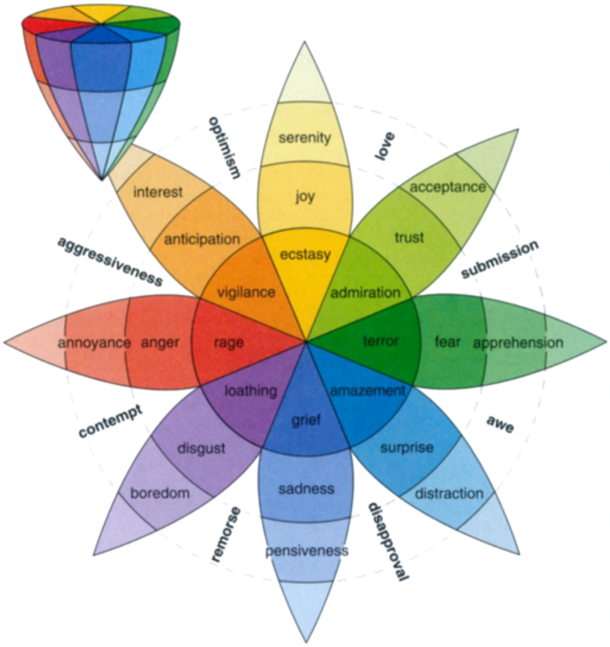


Figure 33: Plutchik's three-dimensional circumplex model that describes the relations among emotion concepts, which are analogous to the colors. In the exploded model, the emotions in the blank spaces are the primary dyads: emotions that are combinations of two of the primary emotions. Source: Plutchik (2001, p. 349).

Plutchik noted that throughout history, others have proposed models with emotions ranging from three to eleven dimensions as primary or basic elements, and that there is no equivocal way to settle on a precise number, as inferences and insights from other fields of study might suggest differently. This model, however, has been useful in that it integrates curious emotion, as discussed in 0 and 1.4.3, with exploration from an organismic perspective, directly linked to evolutionary traits as part of human beings (Plutchik & Kellerman, 1980). Plutchik even took it one step further and linked emotions to personality traits using eight dimensions, for example, the destruction dimension expressed as hot-tempered, quarrelsome, and aggressive, and the exploration dimension represented as adventurous and curious (Plutchik & Kellerman, 1980, p. 20). This connection was also made earlier, but the bridge here reenergizes the link and qualifies the type of game hinted at earlier (adventure games) and directly guides the design toward player types that are explorative and curious, which could potentially lead to intrinsic motivation and interest in the museum exhibition. All are presented to the player in a good game experience. Although both the MDA framework and Plutchik's circumplex provide detailed design objectives for an exploration game, they only cover parts of what to design to motivate players to be more curious and explorative. The final part reviewed here is an example of player motivations from established player-type taxonomies.

Richard Bartle's player types (1996) based on early massively multi-player online (MMO) type games, called "multi-user dungeons" (MUDs), produced four distinct types of players, which has become an influential scheme for categorizing play styles both in games research and game design practice (Fullerton, 2019; Salen & Zimmerman, 2004; Schell, 2019), and has inspired others to develop specialized models for social games (Kim, 2000) and gamification (Marczewski, 2018). The scheme, which he refers to as the *Player Interest Graph*, was developed by Bartle (1996) and derived from discussions about what players want out of a MUD. The four types are represented in a two-dimensional model (Figure 34: left): one between *acting* upon killers and achievers and interacting with explorers and socializers, and the other between *players* (killers and socializers) and the *world* (achievers and explorers) (Bartle, 1996). Bartle noted that these categories are imprecise, and the players may cross over, although one play style tends to dominate the preferences of a given player. Bartle later expanded his typology to specify eight player types, which integrates player interest into the typology (Bartle, 2003) to address some of the shortcomings of the original taxonomy, leading to the construction of the *3D Player Interest Graph* (Figure 34: right). The newer model is not a substitute for the older. It is an additional tool for designers to understand players, with categorizations that are inclusive of more player types and can be validated empirically.

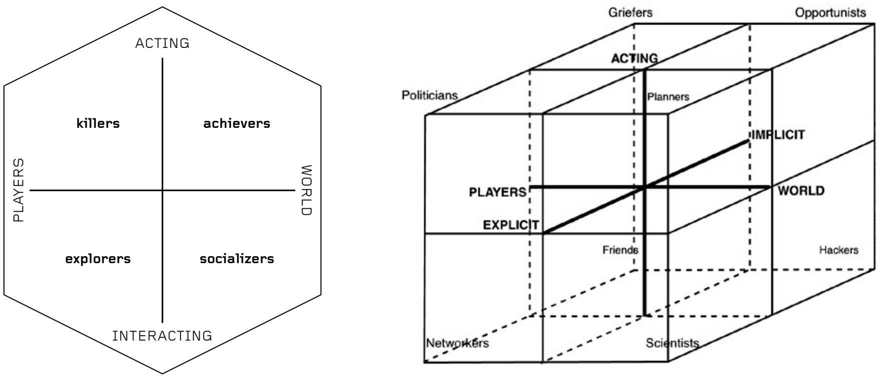


Figure 34: Left: Bartle's original taxonomy with four player types, adapted from Bartle (1996). Right: The typology expanded with implicit and explicit dimensions, resulting in a 3D player interest graph. Source: Bartle (2003, p. 139).

Bartle's framing of player types provides a lens through which to examine which type of games are most suitable to integrate the curiosity emotion, necessary for explorative behavior, and how the gameplay should be addressed to keep the player in flow. Bartle opined that his model can be used by game designers, but to understand player psychology, he refers directly to Nick Yee's *motivations,* which are backed by data sets (Bartle, 2009). Nick Yee's (2019a, 2019b) *12 Gamer Motivations clustered* under six categories (Figure 35). Yee (2006) built upon Bartle's framework using empirical data to establish models of gamer motivation, extending beyond MUD or MMO and providing a higher resolution understanding of a gamer's psychometric profile. This model resonates with

SDT, which makes it useful as a tool to design game experiences that target specific gamer motivations.

Action “Boom!”	Social “Let’s Play Together”	Mastery “Let Me Think”	Achievement “I Want More”	Immersion “Once Upon a Time”	Creativity “What If?”
Destruction Guns. Explosives. Chaos. Mayhem.	Competition Duels. Matches. High on Ranking.	Challenge Practice. High Difficulty. Challenges.	Completion Get All Collectibles. Complete All Missions.	Fantasy Being someone else, somewhere else.	Design Expression. Customization.
Excitement Fast-Paced. Action. Surprises. Thrills.	Community Being on Team. Chatting. Interacting.	Strategy Thinking Ahead. Making Decisions.	Power Powerful Character. Powerful Equipment.	Story Elaborate plots. Interesting characters.	Discovery Explore. Tinker. Experiment.

Figure 35: An overview of Yee’s 12 Gamer Motivations (Yee, 2015). Source: Quantic Foundry.

Lists and taxonomies are not without limitations. Sometimes they do not resonate well within the frames of certain contexts or the types of users targeted, but they do expand the vocabulary to more precisely determine the types of activities or experiences for which they are designed. The personas found within different player-type taxonomies also offer a shared language when multiple disciplines are involved in design, such as museum professionals, game designers, researchers, and actual users. Thus, player types offer a framework and an approach. They also assist designers in simplifying many complex processes, such as human emotions and motivation. For designing XTR, both Bartle's and Yee's models provided lenses to investigate what types of games fall under the categories that dominate the explorative player type. Looking at existing games through these lenses made adventure games interesting to examine and led to a focus on game mechanics and gameplay based on the adventure game genre. This type of game has features, such as gathering, puzzle solving, and traversing unknown areas as part of the core design. Also, games in general have the capacity to imbue the player's experience with autonomy, control, curiosity, challenge, choice, discovery, and interactivity.

3.3. Exploration Systems

The idea of bridging digital and physical spaces into hybrid environments in this research project was influenced by the term *cyberspace,* created by William Gibson (1984) in his book *Neuromancer*. The term cyberspace evolved from poetic prose created to capture and describe a vision of a cyberpunk future, where human users "jack into" computer systems to describe current-day technological trends; today cyberspace can be described as pervasive and ubiquitous computing technologies that surround or weaves itself into interactive experiences. Physical spaces and humanized places can be linked through computer systems to form hybrid environments for interactive experiences.

Digital technology has given games new relevance, and the rise of computers has paralleled the resurgence of games in our culture. Fields, such as systems theory, communications theory, cybernetics, artificial intelligence, and computer science have used games and game theory to further advance the fields. In HCI, ubiquitous and pervasive computing, presented in section 1.1, is the proliferation of computing into the physical world. Today, people interface with a multitude of gamified[9] systems in their everyday life, as current-day computer technologies have enabled a closer integration of contextual data, such as time, date, location, and biometrics, that are part of feedback loops and even larger systems of device, and ecosystems data. In many ways, current-day technologies manifest earlier visions to form hybridization between ubiquitous and pervasive computers and the use of game mechanics (Nova, 2014). Eventually, this has led to applications that can be fun, engaging, and playful for users (Nova, 2014, p. 396). For example, games that promote location-bound educational material (Bannon et al., 2005; Richardson et al., 2018; Zimmerman & Land, 2014) and games that promote physical activity through exertion (Jensen et al., 2010; Montola et al., 2009). These are examples of a class of mixed reality games that emerged and extended ubiquitous and pervasive computing paradigms into a playful manifestation termed *ubiquitous games* and *pervasive games*: games that blur boundaries between the game world and the real world, and where the game blends in with reality (Nieuwdorp, 2007). More generally, these types of game experiences are described as alternate reality games and mixed reality games (Flintham et al., 2003; McGonigal, 2011).

The term *exploration system,* presented in this thesis, is introduced to frame the specific theories employed, to distinguish it from related terms, and to direct attention toward *exploration* as a core feature. Exploration systems are defined as interactive systems that enable explorative behavior, which integrates context sensitivity and mobility as part of the mixed reality experience that utilizes mobile technologies. It is not exclusively an open-world adventure game in real contexts, as game is but one approach for exploration systems realized in XTR, while ARA draws on the same theories regarding curiosity, exploration, and motivation through game elements (i.e., a gamified system) but is not considered an actual game.

Regarding this definition, there are two aspects that are relevant to be discussed concerning designing exploration systems: *context* and *environment*. Specifically, how is context viewed regarding technical and technological variables and the experiential qualities related to the physical environment. The term context describes both the technical and sociotechnical factors that may impact the user's experience and the physical environment and the experiential qualities that the technologically mediated application may tap into, viz. theory regarding *space* and *place*. The latter has been hinted at and discussed throughout the preceding sections as the liminal void that exists in the user's subjective experiences at a given location. This is referred to as the physical environment,

[9] The trend of merging games into everyday activities, in recent times referred to as gamification, or the use of game design elements and game thinking in non-game contexts (Deterding et al., 2011)

while the former, context, will detail the variables that may influence the design of exploration systems, both the features and functionalities, and possible challenges.

3.3.1. CONTEXT

Throughout the literature, many views have been expressed on what *context* is and how it can be used for computing purposes, notably (Abowd et al., 1999; Coutaz et al., 2005; Dey, 2001; Dourish, 2004; Tamminen et al., 2003). Context is defined here as "...the sum of relevant factors that characterize the situation of a user and an application, where relevancy implies that these factors have significant impact on the user's experience when interacting with that application in that situation." (Jensen, 2011b, p. 2).

Thus, context is any information that is used to characterize the situation of an entity about the scenario of the application (Abowd et al., 1999; Dey, 2001). "An entity is a person, place, or object that is considered relevant to the interaction between a user and an application, including the user and applications themselves" (Dey, 2001, p. 5). Contextual information is used by the system to make decisions regarding the user and the task, i.e. "A system is context-aware if it uses context to provide relevant information and/or services to the user, where relevancy depends on the user's task" (Dey, 2001, p. 5).

This definition is made to better reflect the perspective of studying applications and focuses on the factors affecting the user experience, either directly or indirectly (Figure 36).

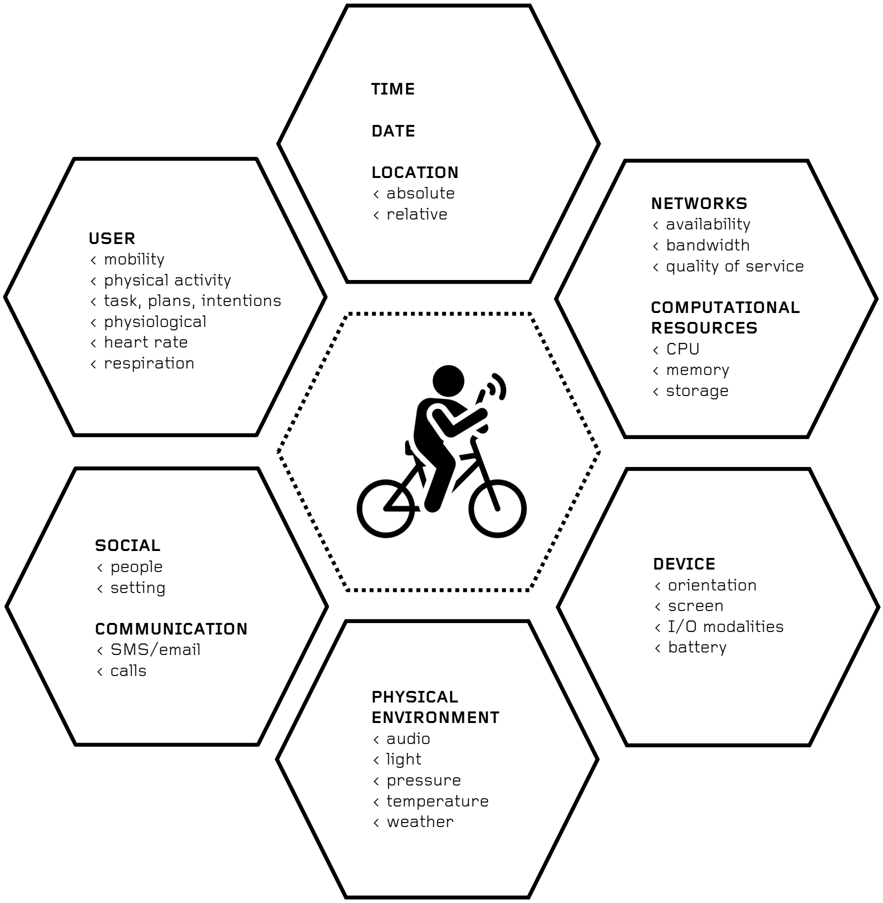


Figure 36: Examples of factors that can potentially impact the user experience of mobile applications. Adapted from Jensen (2011a, p. 11).

3.3.2. SPACE × PLACE

Space is defined as a natural science concept, the physical setting within which everything occurs. It is modeled in mathematics and physics as Euclidean, topological, and infinite. This approach is generally attributed to Descartes, who regarded space as an absolute containing all senses and bodies or the physical setting within which everything occurs (Meskell & Preucel, 2007, p. 215). Place can be regarded as the outcome of the social process of valuing space. They are the products of the imaginary, desire, and are the primary means by which space is articulated and transformed into a humanized landscape (Meskell & Preucel, 2007, p. 215). The distinction here is that places require human agents, and spaces do not, which is captured in the following quote from Tuan (1977):

> The relations of space and place. In experience, the meaning of space often merges with that of place. "Space" is more abstract than "place." What begins as undifferentiated space becomes place as we get to know it better and endow it with value. (Tuan, 1977, p. 6)

Spaces and places are also referred to as ecologies (Benyon, 2014), regarded as liminal (Bell, 2002), and in museum studies imbued with attributes such as *numinous*, referring to exhibitions as mystical and spiritual places (Latham, 2013). The transformation from space to place is certainly linked to experiential attributes. The terms place and space have been applied in many fields outside museum exhibitions, such as anthropology (Altman & Low, 1992), environmental psychology (Nielsen-Pincus et al., 2010; Steele, 1981), geography (Tuan, 1974, 1977), tourism and leisure (Kyle & Mowen, 2005; Williams et al., 1992), and sociology (Hummon, 1992). The various applications of the notion of place and space show the significance of spatiality in human experiences. Here, place is examined for how it can be instrumental in establishing location-bound experiences, particularly for informal learning and education in exhibitions, where past research has indicated that visitors can develop attachment and interest in places, which promotes learning motivation (Altman & Low, 1992; Lewicka, 2005).

Space and place are part of the design process of XTR and ARA because, as mentioned earlier, there are experiential dimensions that will influence the user, and, more interestingly, applications that are bound to a specific environment, such as the ones developed as part of this thesis, which have value beyond a set of latitudinal and longitudinal coordinates. They have cultural and historical significance. Here, the significance of merging interaction design, digital technologies, and geographies of the museum context to form a hybrid environment will be elaborated by examining how the two terms, space and place, are described and defined in HCI. This contributed to an understanding of human experience and how it can be linked to locations and environments through spatial theory, which was considered in XTR and ARA as a dimension that added an experiential layer that is inextricably linked to the location in which the interaction occurs.

In HCI, interaction design, and user experience, the concepts of spaces and places can be used to think about interactive experiences as spaces of interaction, places for experience, and hybrid environments (Benyon, 2014). Space is described as the notion of geometry and geography, and place is "space + meaning" (Harrison & Dourish, 1996). But the terms are also recognized as complex and subjective constructs that connect technology, mediated practice, and spaces of interaction (Dourish, 2006).

In the age of ubiquitous and pervasive computing, the concepts of spaces and places can be used to think about the environment in which interactive experiences occur and, therefore, the design of interactive experiences in social and technological environments. Thus, the user's environment is considered part of the overall experience (Benyon, 2014). Bringing the environment into the equation is important, as experiences mediated through technology are seldom described as humans, computers, and their interactions, but user experience as a whole and interaction design as the design for those experiences (Benyon, 2014). Furthermore, viewing environments for interactive experiences in spatial terms offers perspectives on spatial relationships integral to interactive experiences. Therefore, it necessitates considering spatial relations when designing for hybrid environments, combining both digital and physical, e.g., regarding insides and outsides, boundaries and horizons, movement and paths through spaces, landmarks and districts, and relations, such as on and off, in front of and behind, including layout, topology, density, direction, and distance (Benyon, 2014). These perspectives were examined at different stages of the development of XTR and ARA to understand the user's interaction concerning spatial affordances and constraints, which influenced the experience layers developed for the two systems.

Related studies have implemented mobile interactions that show promising results in effectively increasing visitors' knowledge of exhibition sites and artifacts, which enhances their motivation to learn and facilitates interaction among the visitors, the guidance system, and historical sites (Chang et al., 2015; Ciolfi & Bannon, 2007; Klopfer & Squire, 2008). This resonates with other studies that have indicated that technology-assisted teaching tools promote learning performance (Chang et al., 2014; Dunleavy et al., 2009; Liu et al., 2009; Zhang et al., 2014). Studies have also reported on the effects of place-based learning with mobile interactions (Zimmerman & Land, 2014) and hybrid reality games (de Souza e Silva & Delacruz, 2006) that show potential to develop attachment through interactive experiences (Chang et al., 2015). These studies qualify the use of technology-mediated increase of space and place, leading to heightened affection toward a particular location or environment, which has influenced the game design of XTR to integrate contextual factors and use the environment as part of the explorative experience within the boundaries of the exhibition site.

The notion of including spatiality in the design of exploration systems is to bring concepts of spatiality and people in spaces to understand the design of user experience from a different perspective by exploring the nature of experience in spatial terms in an age of ubiquitous and pervasive computing. This perspective is important because using concepts of space to look at experiences makes humans seen as being in social and technological environments. Therefore, to reiterate, the primary design consideration for creating exploration systems concerning the physical environment is not to split the user experience into humans, computers, and their interactions in spaces, but to focus on integrated experiences that can transform spaces into places through interaction design as the design for those experiences.

SECTION 04

... the street finds its own uses for things.

William Ford Gibson

4. STUDIES

This section summarizes the main contributions of each paper in a redux, by extracting this research project's primary points and contributions and clustering them into four studies, as described in section 2.3. The papers can be found in appendix [G] in their published form. Finally, section 5 summarizes how they relate to the research questions and discusses the implications and limitations of the contribution as a whole.

For each study, an overview showing the research objective is presented, which the research questions address, with a list of papers that are part of the study and the research activities executed during that phase. In addition, the research context and the expansive elements of that study will also be detailed in the overview.

[P01]	Vistisen, P., Østergaard, C. P., & Krishnasamy, R. K. (2017). Adopting the unknown through the known: Supporting user interaction of non-idiomatic technologies in exhibitions through known idioms of conventional technologies. *The Design Journal, European Academy of Design*, *20*, S3696–S3706. https://doi.org/10/ghzc7v
[P02]	Vistisen, P., Selvadurai, V., & Krishnasamy, R. K. (2020). Applied gamification in self-guided exhibitions: Lessons learned from theory and praxis. In O. E. Hansen, T. Jensen, & C. A. F. Rosenstand (Eds.), *Gamescope: The potential for gamification in digital and analogue places* (1st ed., Vol. 1). Aalborg Universitetsforlag. https://vbn.aau.dk/files/279738444/Applied_Gamification_Gamescope_Chapter.pdf
[P03]	Krishnasamy, R., Khan, S., & Germak, C. (2018). Mixed reality game using bluetooth beacons for exhibitions. *Proceedings of the Conference on Electronic Visualisation and the Arts*, 39–40. https://doi.org/10/ghzc7t
[P04]	Krishnasamy, R. (2018). Integrating smart objects into self-guided exhibitions: Challenges of supporting self-guided exhibitions through non-idiomatic technologies. *Proceedings of the 6th Workshop on Interacting with Smart Objects, 2082*(6), 17-22.
[P05]	Khan, S., Krishnasamy, R., & Germak, C. (2018, August 14–18). Design challenges in promoting inclusion for cultural heritage contents through low-cost technology. *DS 91: Proceedings of NordDesign 2018, Linköping, Sweden.*
[P06]	Krishnasamy, R. (2019). Towards game-guided exploration systems for self-facilitated exhibitions. *Proceedings of EVA London 2019 (EVA 2019)*, 164–171. https://doi.org/10.14236/ewic/EVA2019.32
[P07]	Krishnasamy, R. (2019). Designing digital exploration games for automated exhibition sites. *Proceedings of the 12th European Conference on Game Based Learning*, 104. https://doi.org/10/ghzc7s
[P08]	Madsen, K. M., & Krishnasamy, R. (2020). Our museum game: A collaborative game for user-centered exhibition design. In A. Brooks & E. I. Brooks (Eds.), *Interactivity, game creation, design, learning, and innovation* (Vol. 328, pp. 427–435). Springer International Publishing. https://doi.org/10.1007/978-3-030-53294-9_31
[P09]	Krishnasamy, R., Selvadurai, V., & Vistisen, P. (2021). Designing context-aware mobile systems for self-guided exhibition sites. In A. Brooks, E. I. Brooks, & D. Jonathan (Eds.), *Interactivity and game creation* (Vol. 367, pp. 21–44). Springer International Publishing. https://doi.org/10.1007/978-3-030-73426-8_2
[P10]	Krishnasamy R., & Vistisen P. (2022). Exploration game for automated exhibition sites: Design and evaluation of a mixed reality mobile application based on exploration and experiential learning for a self-guided cultural heritage site [Manuscript submitted for publication]. *ACM Transactions on Computer-Human Interaction.*

Table 2: Overview of the ten individual paper contributions.

4.1. Study [A]: Investigate Research Context

OBJECTIVES	Review and define the research project's context and area of interest, clarifying the discourse of enlightenment and experience in museum exhibitions. Identify the research project's problem and establish a baseline understanding of the project's scope and aims: test, review, and select state-of-the-art technologies.
[SQ_01]	What principles and criteria can be identified to design systems that mediate exploration in exhibitions?
[SQ_03]	How can experience technologies facilitate automated exhibitions?
PAPERS	**[P01]** Adopting the Unknown through the Known **[P02]** Applied Gamification in Self-guided Exhibitions **[P03]** Integrating Smart Objects into Self-Guided Exhibitions
ACTIVITIES	Scientometric reviews, observation studies, interviews, field studies, technology tests and reviews, paper presentations, and discussions.
CONTEXT	DESK RESEARCH / FIELD STUDIES
EXPANDS	Combines section 1 of the thesis and papers [P01; P02; P03] that are part of the initial investigative studies. Expanding the scope of automated sites is defined as how "enlightenment" and "experience" can be positioned as dyads in the museum exhibition discourse and how curiosity and exploration linked to game design can be used as core concepts to facilitate and mediate users in self-guided situations. The discourse around automated exhibition sites and the use of technology to mediate and facilitate the user is expanded upon, and unforeseen challenges were identified, such as first-use of new and novel ways of interacting with computing machines and integrating digital technologies into exhibitions that require organization-wide support.

Table 3: Overview of the research objective, questions addressed, papers, activities, context, and expansive element for study [A].

4.1.1. PAPER [P01]

Vistisen, P., Østergaard, C. P., & Krishnasamy, R. K. (2017). Adopting the unknown through the known: Supporting user interaction of non-idiomatic technologies in exhibitions through known idioms of conventional technologies. *The Design Journal, European Academy of Design*, *20*, S3696–S3706.

The paper discusses and argues for design considerations to face the challenges of using state-of-the-art or emerging computer technologies to mediate and facilitate automated exhibition sites. When the user's interaction is mobile, mobile technologies are positioned at the frontline to mediate information. However, when new and novel ways are explored to present useful information and offer practical guidance, it becomes increasingly challenging to rely on known repertoires of experiential knowledge to use the systems built around this type of technology. Design idioms that are lacking can be described as conventions learned rather than analogically or metaphorically transferred. Design situations are consequently termed *non-idiomatic* in this paper.

It discusses how technical implementation that utilizes the next wave of technologies can impact the system's utility, usability, and desirability, resulting in limitations of the user experience in mobile and context-sensitive applications. However, state-of-the-art implementations of context-aware mobile applications show widespread adoption and willingness among users to use these systems when they know what to do and how it works.

The paper identifies three patterns that impact the user experience negatively: (a) lack of understanding of the concept is a desirable addition to the visit (i.e., "What is the value of the app?"), (b) lack of understanding of the functionality (i.e., "What does it do?"), and (c) lack of motivation for using the concepts during the visit.

In addition to these patterns, other design challenges emerged, where the user had difficulties understanding the concept and how to interact with the underlying system. This pointed toward the related design considerations of integrating the content that the system provides into the overall theme and design of the exhibition site so that the connection to the context in which they are represented appears coherent and unambiguous to the user. An important lesson learned here is that acquiring new users in a system built on unknown idioms is increasingly difficult without human personnel to introduce and guide users through in their first use.

Although the contributions of this paper are mostly conceptual, it identifies user motivation that builds on the use of game design elements rooted in behavioral psychology that has shown positive to the user experience (desired outcomes). For self-guided situations, it was possible to motivate users to traverse the sites by playing games. Based on experiences from this paper, the results support the use of game design and mechanics as a path to examine the appropriation and adoption of non-idiomatic technologies.

4.1.2. PAPER [P02]

Vistisen, P., Selvadurai, V., & Krishnasamy, R. K. (2020). Applied gamification in self-guided exhibitions: Lessons learned from theory and praxis. In O. E. Hansen, T. Jensen, & C. A. F. Rosenstand (Eds.), *Gamescope: The potential for gamification in digital and analogue places* (1st ed., Vol. 1). Aalborg Universitetsforlag.

This paper addresses the problem of onboarding new users in situations where the user is not assisted. It presents the use of game design to introduce and incentivize new users to their first use and alleviate the challenges of not having human personnel to guide, instruct, or even persuade new users to engage with applications for self-guided exhibition sites.

This paper reports several game mechanics that have been identified in the implemented design solutions, and their effects have subsequently been explicated.

The results of these implementations reveal potential incentivized mechanics to onboard new users to a digital experience layer they are unfamiliar with and thereby invoke intrinsic motivation through game design elements.

The paper discusses the assistance from staff vs. self-facilitated acquisition of the app based on long-term data collection in periods where there had been personnel to assist the visitors in downloading or supplying a device with the application pre-installed and instructing them on how to use the app versus a period where there had been no personnel to assist the visitor. The number of users dropped drastically in periods without assistance.

The reported study demonstrates how game design elements and mechanics, such as rewards, progression, sharing, and implementation into the digital experience layer, can be used to trigger extrinsic motivation, resourceful in onboarding and retaining the visitors' interest and engagement throughout the visit and thereby support intrinsic motivation for sustained use of the app.

4.1.3. PAPER [P03]

Krishnasamy, R., Khan, S., & Germak, C. (2018). Mixed reality game using bluetooth beacons for exhibitions. *Proceedings of the Conference on Electronic Visualisation and the Arts*, 39–40.

This position paper presents two novel application platforms for building context-aware mobile guides for exhibitions. The conceptual systems are based on Bluetooth beacons and mobile phones and focus on enabling self-guidance using this technical setup. Previous studies have shown that this type of proximity-based interaction with mobile phones might not be fully understood by users and could therefore fail to gain traction. The objective of this position paper was to present the idea to peers and discuss the implications, limitations, and potential solutions that could then inform the design and implementation of prototypes.

User types and models were discussed as part of the feedback, and the technical setup using beacons could be interesting for indoor environments. However, mobile devices were criticized for being disruptive to the social experience, but in this context, where the objective is to design for self-guidance, phones were positioned as a highly capable platform regarding both technical capacity (i.e., hardware components) and technological capability (i.e., how and for what the components can be used). Strengths discussed involved the adoption and widespread use of mobile phones in exhibitions and being powerful platforms to provide relevant information to the user by utilizing contextual data and telemetry obtained from the user's location and use it to assist navigation and present content.

4.2. Study [B]: Design Explorative Experiences

OBJECTIVES	Generate designs that test different technology setups. Low-fidelity implementations are used to rapidly test and evaluate technology types—foci on technology type selection and content.
[SQ_01]	What principles and criteria can be identified to design systems that mediate exploration in exhibitions?
[SQ_02]	How can experience technologies mediate exploration in exhibitions?
PAPERS	**[P04]** Mixed Reality Game Using Bluetooth Beacons for Exhibitions **[P05]** Design Challenges in Promoting Inclusion for Cultural Heritage Contents through Low-Cost Technology **[P08]** Our Museum Game
ACTIVITIES	Concept development, prototyping, usability and user experience evaluation, co-design, and participatory design, paper presentations and discussions, and user research.
CONTEXT	LAB
EXPANDS	Combines parts of section 3 related to scientometric studies to understand phenomena that were observed in the explorative studies and tests, with papers [P04; P05; P08], to report on the design of multiple concepts and conceptual prototypes, and points toward developing two specific prototypes with attention to content and accessibility. This study expands on the technical considerations and technological dilemmas that emerge when users are forced to rely on digitally mediated ways of seeking information and guidance in an exhibition. The knowledge contribution in [P05] opens up ways to promote inclusion through low-cost technologies in exhibitions, while [P08] directly addresses challenges and emphasizes the opportunities with participatory design activities through collaborative and co-design efforts with the OM program members and collaborating museum institutions. This led to the creation of OMG, a design tool to support future participatory design activities.

Table 4: Overview of the research objective, questions addressed, papers, activities, context, and expansive element for study [B].

4.2.1. PAPER [P04]

Krishnasamy, R. (2018). Integrating smart objects into self-guided exhibitions: Challenges of supporting self-guided exhibitions through non-idiomatic technologies. *Proceedings of the 6th Workshop on Interacting with Smart Objects, 2082*(6), 17-22.

This position paper presents the conceptual setup for a mixed reality game, *Opdag Skansen* (later: XTR), and discusses the adoption of low-cost context-aware technologies for exhibition environments, how they perform for indoor positioning, and the ability to promote inclusivity and tackle phenomena related to the user experience in exhibitions: hyper congestion and museum fatigue.

The new design considerations derived from the presentation were learning through digital experience layers, particularly locational storytelling on mobile devices in exhibitions. This was further explored during design and detailed in [P10].

4.2.2. PAPER [P05]

Khan, S., Krishnasamy, R., & Germak, C. (2018, August 14–18). Design challenges in promoting inclusion for cultural heritage contents through low-cost technology. *DS 91: Proceedings of NordDesign 2018, Linköping, Sweden.*

This paper presents design considerations for increasing accessibility to cultural heritage contents. The discussion grew from the OM research program's agenda that museum exhibitions and their contents should be further democratized and that more user groups should gain access to the contents stored within. The paper investigates how low-cost technologies, specifically Bluetooth beacons, can be integrated into the exhibition with minimal impact on the existing exhibition design. The aim was to decipher how digital technologies can be embedded seamlessly into the exhibition and utilized to enhance the visitor's experience by alleviating cognitive and physical issues that can be disruptive to the visitor's engagement with the exhibition and its cultural heritage contents. Specifically, this was motivated by observed phenomena described as hyper congestion and museum fatigue. Hyper congestion is often the result of suboptimal physical exhibition design that leads to queues, which are detrimental to the movement flow, while museum fatigue is ascribed to both physical and mental strain that taps the visitor out of energy. These phenomena are linked to a related challenge: the visitors' expectations to see the entire museum. This can impact the openness necessary for a meaningful learning experience by causing a fixation on an external goal and anxiety over meeting that goal. Thus, if visitors feel they missed something, backtracking requires time and energy, which can hasten the fatigue if expended by the visitors. These phenomena can hinder the visitor's ability to learn or absorb the content, as museum learning is described as a voluntary, informal activity that influences what the visitor chooses to see in the exhibition. In this regard, navigation is an agency; if visitors are hindered or perceive navigation as an obstacle, the chances are that they will simply skip the exhibit.

The paper expands on the hypothesis that context-aware technologies embedded into the exhibition, paired with visitor's mobile phones, can enhance visitor's experience through navigational assistance and provide a personalized visiting experience that promotes visitor's knowledge absorption. Mapping challenges examine the idea for designing such a system by reviewing extant literature and in-depth analysis of field studies conducted separately by the authors in different museum contexts in Denmark and Italy, respectively.

The use of mobile devices has benefitted visitors because, as the extant literature revealed, systems designed for the exhibition can consider the individual user's interests and let the visitor exert some degree of influence over the visit and their traversal through the exhibition. By revisiting past research and extant literature, this study reinvigorates the discussion on transitioning from traditional exhibition to self-guidance, which places navigational duty on the physical exhibition. Although digital technologies, such as the systems studied in this paper, can assist visitors properly, facilitating first use and introducing emerging interaction paradigms unfamiliar to the user is very important. The paper triggered discussions about visitor movement analysis and behavioral patterns that can inform the design of systems for both guidance and content delivery.

4.2.3. PAPER [P08]

Madsen, K. M., & Krishnasamy, R. (2020). Our museum game: A collaborative game for user-centered exhibition design. In A. Brooks & E. I. Brooks (Eds.), *Interactivity, game creation, design, learning, and innovation* (Vol. 328, pp. 427–435). Springer International Publishing.

This paper addresses communication challenges that arise when many roles and disciplines engage in user-centered design activities in the museum context. Specifically, through the collaborative work in the research project, where multiple museum institutions participated in the OM program to bring their knowledge to the research projects, a schism between researchers and museum professionals when engaging in participatory and co-design activities revolving around digitally mediated solutions and emerging technologies became visible.

Based on these experiences, game design was used to create a dialogical design tool that could establish a vocabulary across professions and professional backgrounds, thus bridging the gap in communication between researchers and museum professionals.

This paper presents the concept of the game and establishes parts of the theoretical background for the game design, offset by two iterations that are based on insights from two separate playtests. These insights have been reworked and implemented into the current version of the game. The boardgame was designed around the notion of a third space: a void between two or more participants from different disciplines and roles. Different participants will irrevocably bring their professional backgrounds, experiences, and specialized language into a discussion during design activities. This can cause confusion and misunderstanding between participants. The third space offers a way to facilitate and mediate between participants, where a shared language and a vernacular can be established. Thus, the boardgame provides not only a setting but also a generative tool that provides structure.

The game set out to gather participants with different professional backgrounds to design exhibitions while retaining focus on user-centered design, using game design elements. The game has been useful in facilitating the user-centered dialogue of design and involved participants in more relaxed and playful ways. Also, the gameplay encouraged the participants to engage in a collaborative space where they could develop a shared language. As a proof-of-concept, the game has been explored and verified but with space for improvements.

4.3. Study [C]: Develop Prototype Systems

OBJECTIVES	Development and construction of high-fidelity prototypes. Small-scale studies to test, evaluate, and iterate on the two main exploration systems: XTR and ARA. Focus on technical setup to prepare for large-scale studies. Focus on system stability and robustness before final installation on-site.
[SQ_02]	How can experience technologies mediate exploration in exhibitions?
[SQ_03]	How can experience technologies facilitate automated exhibitions?
PAPERS	**[P06]** Towards Game-Guided Exploration Systems for Self-Facilitated Exhibitions **[P07]** Designing Digital Exploration Games for Automated Exhibition Sites
ACTIVITIES	Development and construction of high-fidelity prototypes, usability tests, and user experience test.
CONTEXT	LAB / FIELD
EXPANDS	Combines papers [P06; P07] and reports on technical and evaluative aspects of the two systems, leading to prototypes that integrate explorative elements in two distinct ways. First, the studies expand on game design and digitally mediated ways of supporting users in self-guided situations. Second, the study expands on the body of knowledge of developing and implementing explorative features through interactive mobile systems into exhibitions and how to shape the content to make it useful, usable, and desirable for the users.

Table 5: Overview of the research objective, questions addressed, papers, activities, context, and expansive element for study [C].

Note: In the following two papers, the Danish title of the game *Opdag Skansen* has been translated to *Discover the Redoubt* and the initialism *DtR.* This has since been corrected to *Explore the Redoubt* and *XTR* and, throughout the thesis, designated as XTR. The latter will be used in the presentation of the two papers.

4.3.1. PAPER [P06]

Krishnasamy, R. (2019). Towards game-guided exploration systems for self-facilitated exhibitions. *Proceedings of EVA London 2019 (EVA 2019)*, 164–171.

This paper presents a mixed reality game for smartphones (XTR) designed and developed to motivate exploration through game design at the exhibition site at Hals Museum and Redoubt. The game aims at automated sites that require facilitation and mediation beyond signage and text labels to guide and sustain user engagement throughout the visit. It does so by embedding exploration as a core element into a location-based puzzle and storytelling game designed to draw visitors' attention to specific points of interest. The game uses mobile phones and Bluetooth proximity beacons installed both inside and outside the exhibition site, and the content was developed through co-design activities with the museum personnel. The design process involved museum curators, custodians, hosts, and technology providers who developed the game for iOS and Android operating systems.

The application expands on the use of games and playful experiences in museums and cultural heritage sites that can enable curiosity and motivate users to explore and engage with the content in a situation where the site is automated and requires the user to take charge of facilitation. The paper presents game-guided exploration systems to tackle facilitation challenges in automated sites and sparks a debate about how games and play can support mediation and facilitation in automated exhibitions. Findings from two tests, one lab and one field, are reported, revealing insights into how the users interact with the game, both individually and cooperatively. For example, the users demonstrated different gameplay modes, such as singleplayer, cooperative, and competitive multiplayer modes. The tests and design strategies are formalized and presented as a preliminary exhibition games framework that maps out the elements used in XTR to tackle the challenges of automated exhibition sites through game design. Furthermore, it has shown how the design of games for automated exhibition sites should consider the many user types observed.

4.3.2. PAPER [P07]

Krishnasamy, R. (2019). Designing digital exploration games for automated exhibition sites. *Proceedings of the 12th European Conference on Game Based Learning*, 104.

This paper makes a case for using constructive learning theory when designing a mixed-reality, location-based game, XTR, to support users in an automated, self-facilitated exhibition site. In particular, this paper discusses how the game is designed to investigate how museum communication can be mediated through an equilibrium of "fun" and "facts" in an automated site. Museum exhibitions are widely regarded as environments where informal learning can occur and link educative content and entertaining experiences. However, the challenge of balancing education and entertainment remains a debated topic in museum research and practice. Users' expectations are often tempered by traditional museum communication, which is reflected in exhibition design that uses glass displays with labels, signage, posters, and looping audio and video content. In addition, available games and playful activities in exhibitions, such as scavenger hunts and quizzes, provide activities through an exhibition visit, supporting users in a self-facilitated visit through interactive experiences. But, due to limited research into the effect of this type of game-based learning in automated sites, the paper highlights the design process of XTR and the considerations that went into creating a system that seeks to balance playing games and learning in museums.

This paper emphasizes the design of XTR centered around the discourse of viewing museums as a space for public information and enlightenment and as a place for experience and entertainment. Enlightenment denotes didactic, educational, factual, and forming, while experience denotes emotional, engaging, entertaining, imaginative, involving, narrative, and playful. Thus, XTR is presented as a game designed as a learning and exploration system for exhibitions. Two play modes are described that show how both enlightenment and experience can be enmeshed in one system for exhibitions; exploration can guide users, while quizzes prompt the user to observe and retrieve information and subsequently reflect on the knowledge presented.

The findings report on preliminary tests indicate that the game encourages users to learn through exploration and can therefore bridge education and entertainment in an automated site.

4.4. Study [D]: Evaluate Exploration Systems

OBJECTIVES	Study the two exploration systems, XTR and ARA, in the wild.
[SQ_01]	What principles and criteria can be identified to design systems that mediate exploration in exhibitions?
[SQ_02]	How can experience technologies mediate exploration in exhibitions?
[SQ_03]	How can experience technologies facilitate automated exhibitions?
PAPERS	**[P09]** Designing Context-Aware Mobile Systems for Self-Guided Exhibition Sites **[P10]** Exploration Games for Automated Exhibition Sites
ACTIVITIES	User test.
CONTEXT	FIELD
EXPANDS	Concludes with papers [P09; P10] that evaluate the two proof-of-concept systems XTR and ARA from empirical studies in the wild. The two systems expand on using digitally mediated guides in automated sites and situations where there is no personnel available. The two systems address this separately. ARA investigates and reports on core functions that such a system must contain to be useful, how the system's interaction design should be usable, and how the content should be made available for it to be desirable. XTR shows that games can be useful to facilitate and support users in self-guided situations and that experience and enlightenment can be addressed in a way that positions both as a dyad through the design of interactive experiences. This study also expands on using narrative structures mediated through interactive and location-based storytelling. There are considerations about the story structure that must be emphasized early in the design phase. Ultimately, they expand on how both enlightenment and experience can be balanced through game design elements, such as curiosity and exploration.

Table 6: Overview of the research objective, questions addressed, papers, activities, context, and expansive element for study [D].

4.4.1. PAPER [P09]

Krishnasamy, R., Selvadurai, V., & Vistisen, P. (2021). Designing context-aware mobile systems for self-guided exhibition sites. In A. Brooks, E. I. Brooks, & D. Jonathan (Eds.), *Interactivity and game creation* (Vol. 367, pp. 21–44). Springer International Publishing.

This paper examines the design of digital systems created to support users in self-guided exhibitions. A location-aware smartphone guide, ARA, has been developed and implemented, which utilizes Bluetooth beacons to serve contextual information at the user's request. By using this application, a user study was conducted to investigate what types of content institutions perceive as relevant versus what kinds of content users find relevant. The mobile exploration system is designed for users to assimilate it into their visiting experiences at the North Sea Oceanarium.

Based on the field test, the application has been validated as a proof of concept, and users' attitudes were positive toward the use of mobile phones at exhibitions and signaled their openness toward institutions implementing a "bring your own device" strategy. Users' content preferences varied, but they generally agreed that the entry-level content should be sufficient for them to sample whether the information interests them. If it does, they should be offered additional in-depth information on specific content, which indicates that users desire to explore more content of their own volition instead of having it thrust upon them by the institution.

Additionally, the paper reports findings that influence the overall user experience and the implementation of a mobile exploration system. Removing unnecessary signage and labels will allow the exhibition to benefit, as it would lower the cognitive load on the user and possibly create more explorative and immersive environments. Conversely, the physical space at the exhibition must be designed to avoid overloading users' cognition with a plethora of information. A balance will provide the user with the freedom to experience the exhibition as they see fit while still being enticed to explore the site. The proposed technology can alleviate the cognitive load experienced by the user by facilitating their content selection.

The study contributes to understanding users' attitudes toward using smartphones to support their self-guidance in exhibitions. Furthermore, the results reported provide insights into designing for the interplay between the physical setting of the exhibition and the digital platform to inform the utility, desirability, and usability of mobile guides. Based on these findings, two design insights were derived that should be considered when designing future mobile systems for self-guidance in exhibitions: 1) multi-level content to accommodate individual user interest by scaffolding information layers from glimpses to an increasingly immersive experience, and 2) real-time location tracking with clear visual feedback. Thus, future iterations should aim to better balance the content, user, and physical signage of the exhibition with the mobile exploration system.

4.4.2. PAPER [P10]

Krishnasamy R., & Vistisen P. (2022). Exploration game for automated exhibition sites: Design and evaluation of a mixed reality mobile application based on exploration and experiential learning for a self-guided cultural heritage site [Manuscript submitted for publication]. *ACM Transactions on Computer-Human Interaction.*

This article discusses the potential of using elements from adventure games in museum exhibitions to support the use of automated exhibition sites through digital communication. It is based on the hypothesis that core concepts from adventure games can be transferred and used as one approach to unite the dyad of competing expectations between enlightenment and experience. Exploration games allow users to acquire both enlightenment and experience. Automated exhibitions are discussed as a setting for creating explorative experiences that provide users with various levels and types of interactions by capitalizing on elements from the adventure game genre. The explorative elements in the exploration game, XTR, designed for an automated site, are discussed theoretically and empirically. The game was designed and developed to target current literature and research gaps. The integration of game mechanics and objectives in the automated exhibition context aimed to foster users' motivation and interest in exploring the redoubt, whereas the use of interactive digital mediation was conceived to communicate cultural heritage content through an accessible and informal style.

The study investigates how visitors' behaviors at an exhibition site can be reprogrammed so that visitors become explorers in a knowledge playground, and it does this by asking if the current models of user experience are sufficient for capturing eclectic exhibition experiences that must provide both enlightenment and experience.

The article reports on ways to design a frame of interaction in a museum exhibition setting where users can immerse themselves and develop their own goals for the visit through a fusion of enlightenment and experience. Thus, a method is proposed in which digital technology is utilized to balance both enlightenment and experience. The setting for this study is an automated exhibition site—a historical house museum located within a redoubt from the 1600s. Initial user studies revealed a contrast between how visitors were active, curious, exploratory, and free roaming outside, while the same visitors were passive when they entered the exhibition building. This provided an opportunity to investigate how visitors can be motivated to become active participants in the exhibition. Specifically, this research addresses how to elicit curious, explorative, and inquisitive visitor behavior inside the historical house exhibition and extend active, interactive, and transactive user experiences throughout the visit.

XTR was tested in situ with 30 users using mixed methods, and this work combined observations, questionnaires, interviews, and digital behavior data. The study provides insights into ways to design digital exploration games as an experience-based learning approach for automated exhibitions that, through design principles, equilibrate enlightenment and experience. Finally, three insights are presented as design tactics for creating similar systems that target curiosity and exploration.

SECTION 05

Any sufficiently advanced technology
is indistinguishable from magic.

Arthur Charles Clarke

5. RESULTS

This section summarizes the overall contribution of this thesis. First, results and findings from the published research papers are combined to complete the report and address the research questions. Next, this work's implications and limitations are given concerning existing work, and directions for further research are outlined. Finally, the conclusions are given.

The hypothesis of this research project was derived from the challenge of supporting users in automated sites through digital technologies. Based on the field of research, the hypothesis is as follows:

Experience technologies can be utilized to mediate the dynamics of enlightenment and experience by integrating both into the design of explorative systems for exhibitions.

This thesis investigated the challenges of balancing enlightenment and experience within the discourse related to the museum context. Stemming from pragmatism, the aim of this interaction design research project was to examine the following research question:

How can experience technologies mediate explorative exhibitions in automated sites?

The praxis-inclined research question was elaborated with three sub-questions defined in 1.6, which addressed the use of experience technologies to support users in automated sites at several levels of abstraction, ranging from the conceptual level of the method and framework to the technical level of designing and developing exploration systems and the practical level through deployment in real studies. The research question was investigated through four studies in which the sub-questions have expanded the field of research by arriving at two proof-of-concept prototypes (XTR and ARA) used to evaluate aspects of the user experience relating to interaction in the exhibition context. As presented in section 4, these studies are examples of experience technologies based on mobile and context-aware applications that represent different configurations of exploration systems. The four studies demonstrated, in four phases, the challenges of designing self-guidance systems for users in automated sites and showed that enlightenment and experience can be balanced in the design and implementation of systems that utilize elements from game design.

The following summarizes the key contributions at each level, from conceptual, technical, and practical, while answering the corresponding sub-question.

5.1. Framework for Exploration Systems

[SQ_01]:

What principles and criteria can be identified to design systems that mediate exploration in exhibitions?

The answer to this question, the central discourse enlightenment and experience, was studied and discussed in section 1, where existing models for user experiences related to the museum context were also discussed. From these discussions, it was hypothesized that the elements necessary to mediate the dynamics of enlightenment and experience, such as curiosity as the emotional trigger to foster exploratory behavior, can lead to discovery or a sense of discovery, serving as the basis for developing interest. Thus, a conceptual framework was developed that foregrounded curiosity and exploration as precursors to discovery and interest development and was investigated further in the four studies.

In [P01], the challenge of the first use of emerging technologies that use unconventional interaction modalities (i.e., non-idiomatic technologies) was identified. This resulted in an important contribution related to reconsidering how to properly support a design intervention, as lack of support from the institution's organization can render any solution useless. Therefore, three patterns have been described that impact the user experience negatively [P01].

To tackle the challenge identified in [P01], ways of using game design elements were examined in [P02]. Incentivize mechanics, such as rewards, progression, and sharing in a social context, are useful tools to trigger extrinsic motivation for first use (onboarding) and extended use (retention). [P02] also have shown that game design elements can be leveraged to support intrinsic motivation, leading to sustained and long-term usage.

[P04] conceptualizes XTR as a mixed reality game and discusses visitor experience-related considerations, such as physical exhibition design, that can potentially impact the user experience negatively through physical fatigue. [P05] extends on [P04] by discussing the implications of the design of digital technologies for museum exhibitions that aim to be inclusive. [P04] and [P05] combined emphasized the importance of investigating the specific exhibition to select the optimal technological solution and contributed knowledge about designing digital solutions in exhibitions using low-cost technologies, where the goal is to promote inclusivity to the field of visitor studies.

Exploration systems have been introduced to conceptualize the conceptual framework for describing human-computer interactions with systems that enable and encourage explorative user behavior in exhibitions. Conceptually, exploration systems are interactive systems that enable explorative behavior, which integrates context sensitivity and mobility into the mixed reality experience that utilizes mobile technologies. In this thesis, the context is the exhibition, and the design challenge is the situation in which the user must rely on self-guidance. The concept of exploration systems has a broader scope, which will be reflected upon in 5.5, but here, the focus is on interactions in automated exhibition sites with applications on personal mobile devices and the context which can be sensed through those devices.

5.2. Mediation through Exploration Systems

[SQ_02]:

How can experience technologies mediate exploration in exhibitions?

The eclectic user experiences discussed in section 3 seek to integrate the enlightenment × experience dyad through game design. This is also discussed on a theoretical level in section 1.4 and on a conceptual level in section 3.2 to qualify games and playing them to realize a system that supports users while maintaining the balance between enlightenment and experience. The underlying philosophy was to imagine a trip to an exhibition site as an expedition to support self-guidance through game and play—a way to activate both physical and intellectual efforts and tap into faculties of the mind and body. Integrating elements from adventure games to mediate exploration can meet many subjective objectives from the user's viewpoint. Thus, to mediate enlightenment and experience through exploration, where both enlightenment and experience can be independent goals determined and pursued by the user, two prototypes were constructed to serve as proofs of concept, XTR and ARA, thereby implementing the conceptual framework into technical prototypes.

[P06] presents a high-fidelity prototype of XTR that details the technical setup, but the primary contribution of this paper is the use of game design to guide users in automated sites. It presents a strong case for implementing a game-guided application through which the challenges of facilitating self-guidance can be tackled. The contribution in [P07] is a concrete implementation of the conceptual framework that integrates learning theory into XRT to support users in automated sites. [P07] presents a specific way to unite enlightenment and experience in the design of an exploration system.

In this regard, exploration systems are a catalyst for both enlightenment and experience that can enhance or augment the type of experience that the user wants. The design, development, and evaluation have been presented in studies where the question of mediation is resolved in the design of XTR and wayfinding application with game design elements in ARA.

Addressing [SQ_02] resulted in an outcome and contribution that was not planned but became one of the primary contributions of this study, OMG, presented in 2.3.3.1 and 4.2.3.

5.3. Facilitation with Exploration Systems

[SQ_03]:

How can experience technologies facilitate automated exhibitions?

The final sub-question was addressed through technical implementation and practical use in tests for evaluation to understand how mobile technologies could be used to support users while mediating the explorative experience.

The conceptual framework was implemented into the technical prototypes and used to test the hypothesis on a practical level to determine how exploration systems can facilitate automated exhibitions. The studies reported in [C] and [D] detail the implementation and evaluation of the two systems.

Although [P03] does not contribute new knowledge to the field of research, discussions spurred on by the position paper among fellow academics informed later design decisions related to the technical implementation of proximity sensing and context-aware technologies in museum exhibitions.

[P09] contributes to understanding users' attitudes toward using mobile phones for context-aware and wayfinding applications in exhibitions that emphasize the importance of considering the physical exhibition design and the exploration system as one, rather than using exploration systems or similar digital platforms as an afterthought. The exhibition design, institutional organization, and technological setup must be thought of as parts of a complete user experience to ensure adoption and usage. Additionally, two design insights were derived that should be considered for designing future exploration systems through the evaluation of the ARA.

[P10] presents the summative evaluation of this study with the deployment of XTR at Hals Museum and Redoubt. The primary contributions from this study are three design insights gathered from studying XTR in the wild. The study presents these insights as design tactics for how explorative, game-guided systems can support users in automated sites. In this specific instantiation of an exploration system, elements from adventure games are linked to curiosity, exploration and discovery as important precursors to fostering personal interest development as part of supporting users, regardless of whether they seek education, entertainment, both or none. The explorative elements in XTR are discussed theoretically and empirically. Based on user tests conducted in situ with 30 users using mixed methods, the study derives the three following design tactics: 1) Link the digital game layer and the physical layout of the exhibition with the freedom to choose one's own path; 2) Provide a coherent exhibition experience that links activities in the digitally mediated layer with the physical exhibition site and its exhibits; and 3) Promote curiosity, exploration, and discovery for interest development and guidance, manifested through (adventure) game design and mechanics. These three must be the core design principles.

5.4. Limitations

The following section discusses some issues with the implemented framework in general and the limitations that the designed systems pose, many of which can be addressed in future studies, which will be covered subsequently.

The design of XTR elided the narrative focus early in the design phase and was added later during the late design stages and the early development phase. This means that storytelling and narrative structures are not explored properly in the final version of the game. Similarly, narratives could have been useful for the ARA to provide more depth through a narrative layer integrated into the exhibition ecology. There are fundamental issues with the current implementation and execution of the narrative parts, which focus more on designing locational storytelling that is non-linear, such as emergent narratives. Other ways to play games that came to attention were subversive play styles, where players can try to break the rules while playing, but gameplay supports it.

XTR was designed on the presumption that games can be designed to support different users with different motivations in exhibitions. Although flow theory provides some coherence in capturing different types of experiences across various media in a multiplicity of settings, a more specialized framework could have been a useful tool to design games meant to be played in exhibitions.

The option to use Bluetooth beacon technology for proximity sensing was based on state-of-the-art reports and to follow the path that Apple and Google were supporting by integrating beacon support into their mobile operating systems. Unfortunately, this technology was not mature enough and was abandoned abruptly in late 2017, when the development of both XTR and ARA had already begun. Well aware of the risk that the systems would be deprecated shortly, the project went ahead with the technology. Another technical limitation of beacons is that they are extremely inconsistent across different devices. Depending on the Bluetooth version and how it was integrated into the mobile phone, the signal strength varies so much that it is erratic. Nevertheless, the conceptual framework and the architecture of exploration systems can be evaluated using prototypes that can be extended or reused to create other newer systems, regardless of the technical implementation. The technical implementation can be re-evaluated and upgraded with more robust and future-proof systems once the proof-of-concept has been evaluated, as they have with XTR and ARA.

5.5. Directions

While the framework has been tested in two unique systems, it is relevant to consider whether the findings and experiences can be generalized to a broader range of exhibition sites (i.e., is it useful for all museum exhibitions?). The applications studied should be seen as particular instantiations of a broader class of mobile systems for exhibitions. It would be interesting and relevant to conduct more studies with other configurations to investigate the dimensions of exploration systems. This would also allow for replacing the current implementation with Bluetooth beacons with alternative hardware for proximity sensing. Wi-Fi triangulation has emerged as a more secure and robust iteration for indoor use.

First use is a persistent problem, which has been documented across multiple exhibitions in this project, where state-of-the-art technological systems are practically invisible and abandoned unless visitors actively seek out information about it. This has been reported in [P01] and in part of the three-year field study of sites collected in the DataFrame [C1]. However, there are many situations in which visitors cannot get the required assistance to acquire and use these systems. This should be imperative for future studies because it will be left unused or rejected without proper onboarding and first use. The museum institutions carry a significant part of the responsibility in this obstacle: exhibitions that dedicate resources to facilitate first use and onboarding have more success, with the developed systems being used by the visitors [C1]. In an automated site, this is particularly an interesting challenge, as the contributions of this study have uncovered, but more work needs to be done to find a feasible solution to acquire the attention of new users.

Exploration systems for knowledge acquisition or informal learning in museum exhibitions were part of the conceptual framework, and there is educative information in both XTR and ARA, but this implication was not originally part of this study. Therefore, evaluating the learning potential was not pursued as an objective for contribution but should be addressed in future studies to expand exploration systems' capacity and capability in automated sites.

This abstract framework provided a way to include many user types, and through the contributions, it became obvious that designing these systems using tactics that allow for open-world exploration enables users to create ways to play the game. Emerging games and narratives are useful tools in designing locational storytelling. This project barely scratched the surface of what is possible with locational storytelling on mobile devices for exhibition sites that can be inside, outside, or both combined.

An important limitation in systems such as XTR and ARA is that they require quite powerful devices to fully benefit the experience. Therefore, it is important to investigate future solutions in which less powerful mobile phones can be used for exploration systems. Perhaps, even seek solutions with more inclusive technologies for demographic groups where state-of-the-art devices are not prevalent.

5.6. Conclusion

This thesis investigated the nature of experience technologies in exhibitions designed to support users through facilitation and mediation, where enlightenment and experience are central to the design process. It is concluded that exploration systems can be core to the user experience and provide support in the required situations. The exhibition ecology must be part of the design process to ensure the ecological validity of the usability, utility, and user experience of exploration systems.

The primary contribution of this thesis is the conceptualization and implementation of a framework for exploring integrating game design elements and context-aware mobile systems that address some of the core challenges of existing methods of supporting users in automated sites. This is an addition to the current methodical arsenal for researchers and practitioners who want to design and implement experience technologies for exhibitions and study phenomena related to user interaction and the resulting experience. The proposed approach in this project is a combination of existing methods, and design interventions tweaked and tested in relatively uncharted territory: automated exhibition sites.

Another major contribution is the design, implementation, and study of the prototypes XTR and ARA. These both serve as technical and practical proofs of concept based on the conceptual framework that integrates enlightenment, experience, and game design into a synchronized exhibition experience. The prototypes were not only instrumental in the realization of studying exploration systems in real contexts to gather real feedback from actual users but have also developed into a commercially available product (ARA) and a permanent part of the exhibition site (XTR) at Hals Museum and Redoubt for users to experience.

Another primary contribution is designing and developing the dialogical design tool (OMG), used internally in the OM program, individually by researchers in their respective projects, and externally by heritage stakeholders, museum institutions, designers, researchers, and practitioners.

The individual studies investigated in this project and the contributions described above articulated the design tactics and the development of computer technologies, viz. exploration systems. Besides investigating the research question regarding how computer technologies, as a medium to evoke user experiences (i.e., experience technologies), can be utilized to support users in automated exhibition sites through the facilitation of mobile devices and mediated through explorative elements from game design, the research in each of the studies has also contributed to their respective fields.

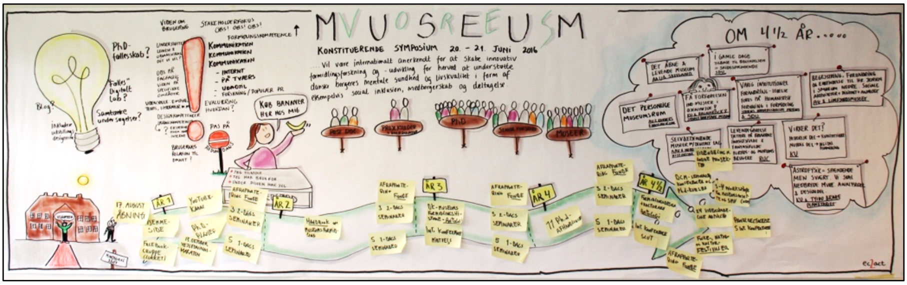


Figure 37: The shared objective of the OM research program with the individual research projects and foci mapped out in a timeline. Source: Our Museum.

This project's contribution to the research program was to explore computer technologies' capacity and capability to support users in automated exhibition sites through communication, facilitation, and mediation. The OM program addresses the interplay between enlightenment and experience and how it influences museum communication since these concepts operate as dimensions of museums' societal engagement (Figure 37). As mentioned in the introduction, this project was conceptualized as part of the research and development objectives of the program to contribute to the theoretical, empirical, and practical development of museums' communication practices, with a focus on three analytical dimensions: *institutional dimension*, *representational dimension*, and *user dimension*.

The institutional dimension was realized through active collaboration with museum institutions rather than strictly using the museum to study and reconfigure with design interventions. Consequently, the development of OMG contributes a methodical and practical tool for researchers and practitioners to understand and combine different disciplines to design and develop exhibitions, including particulars, such as automated sites. The representational and user dimensions were prioritized in this project through both the conceptual framework for constructing exploration systems and the technical implementation and practical studies. The systems (XTR and ARA) contribute to the representational dimension with tangible instantiations of experience technologies that communicate, facilitate, and mediate user experiences in exhibitions. Finally, the user dimension, which was at the core of developing the systems, uses exploration to mediate user experiences in exhibitions. The user-oriented perspective was critical in guiding the design and development and evaluating the systems to provide insight and a reality check. The overall contribution of this thesis incorporated the dynamics of enlightenment and experience as part of the designed systems to contribute to the program's objectives as a dyad (i.e., a way to bring balance between enlightenment and experience).

The work presented here concludes this project's contribution to the shared objective of the OM research program and an expansion to the field of research, where human-computer interactions, exhibitions, and game design align. Therefore, in this thesis, it was realized that a balance between enlightenment and experience could be achieved through experience technologies.

It's a magical world. [...]
Let's go exploring!

William Boyd Watterson II

SECTION 06

There's never enough time to do all the nothing you want.

William Boyd Watterson II

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QUOTES REFERENCED AT SECTION BREAKS:

- **SECTION 01:** *"Time moves in one direction, memory another. We are that strange species that constructs artifacts intended to counter the natural flow of forgetting."*
  SOURCE: William Ford Gibson, *Distrust That Particular Flavor*, 2012

- **SECTION 02:** *"When you want to know how things really work, study them when they're coming apart."*
  SOURCE: William Ford Gibson, *Zero History*, 2010

- **SECTION 03:** *"THE MATRIX HAS its roots in primitive ar-cade games [...] in early graphics programs and military experimentation with cranial jacks. [...] Cyberspace. A consensual hallucination experienced daily by billions of legitimate operators, in every nation, by children being taught mathematical concepts . . . A graphic representation of data abstracted from the banks of every computer in the human system. Unthinkable complexity. Lines of light ranged in the non-space of the mind, clusters and constellations of data. Like city lights, receding. . . ."*
  SOURCE: William Ford Gibson, Neuromancer, 1984

- **SECTION 04:** *"... the street finds its own uses for things."*
  SOURCE: William Ford Gibson, Burning Chrome, 1986

- **SECTION 05:** *"Any sufficiently advanced technology is indistinguishable from magic."*
- **SOURCE:** Arthur Charles Clarke, *Profiles of the Future: An Inquiry Into the Limits if the Possible*, 1973
  &
- *"It's a magical world. [...] Let's go exploring!"*
  SOURCE: William Boyd Watterson II, *Calvin & Hobbes*, 1995

- **SECTION 06:** *"There's never enough time to do all the nothing you want."*
  SOURCE: William Boyd Watterson II, *Calvin & Hobbes*, 1988

- **SECTION 07:** *"The future is there ... looking back at us. Trying to make sense of the fiction we will have become."*
  SOURCE: William Ford Gibson, Pattern Recognition, 2003

SECTION 07

The future is there... looking back at us. Trying to make sense of the fiction we will have become.

William Ford Gibson

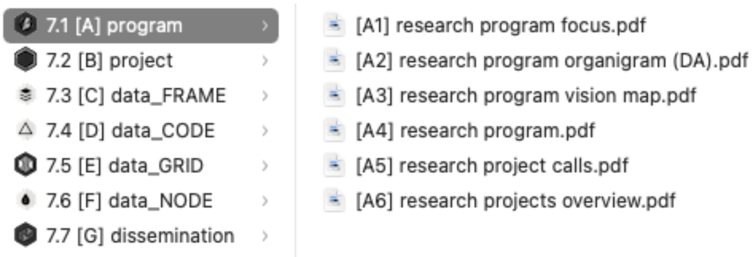
7. APPENDIX

Appendices are referenced in the thesis as, e.g. [A; D] for appendices 7.1 and 7.4, while [B-E] indicates appendices 7.2, 7.3, 7.4 and 7.5.

All the material listed in the appendix have been made available exclusively for the assessment committee through online repositories. Others may request access by contacting the author.

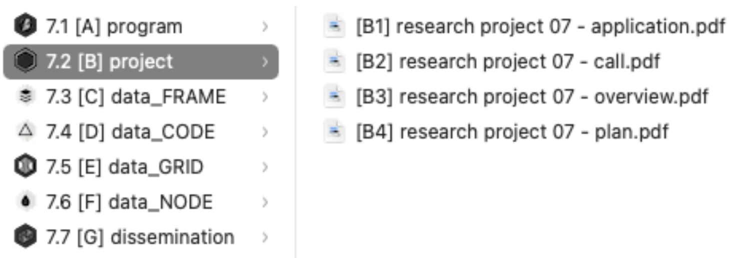
7.1. [A] program

This folder contains the 'Our Museum' research program's application detailing the program's theoretical framing and foundational thesis as well as organizational structure, roles, planned activities, etc. and a focus brief that was compiled throughout the program's runtime to define and align terminology across projects and collaborators: essentially a vocabulary to assist the programs with a shared language. It also contains a map of the research programs vision, that was created at the first meeting with all Our Museum program members.



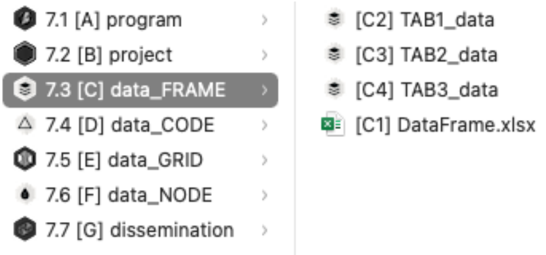
7.2. [B] project

This folder contains an overview of the 13 projects with each project's primary research focus, along with the initial project description and planned objectives for this research project. Additionally, the application is included as it contains the pre-understanding of the research context.



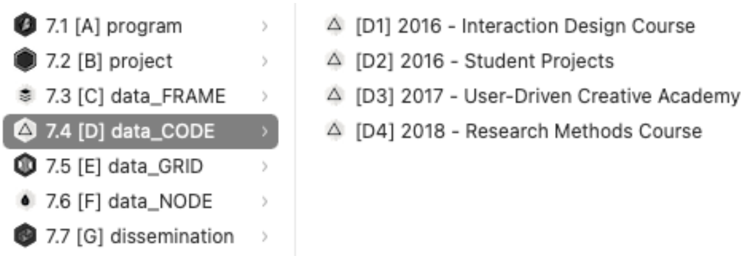
7.3. [C] data_FRAME

Three data tables combined: a scientometric review [C1_TAB1], a field study of exhibition sites [C1_TAB2] and a state-of-the-art review of mobile applications [C1_TAB3]. In addition to the table, there are folders included that contain additional data from field studies that were part of the coding.



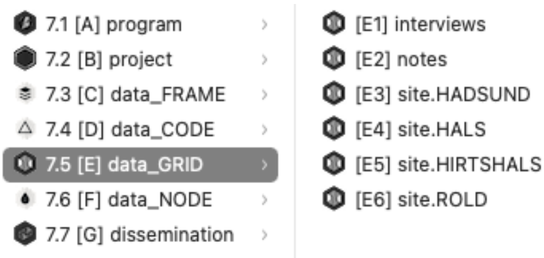
7.4. [D] data_CODE

Data retrieved from collaborative studies and co-design activities with students at Aalborg University. The data includes interviews, in both audio-format as well as transcribed text; pictures and videos from field studies; and concepts development processes as well as the actual concept presentations.



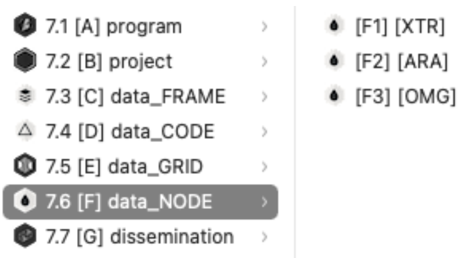
7.5. [E] data_GRID

A collection of all the raw data collected in this project open to scrutiny. Privacy-sensitive data is excluded, as have the data I have not obtained permission to share. Additionally, certain nodes of data have been anonymized. All data disclosed in this file are GDPR compliant.



7.6. [F] data_NODE

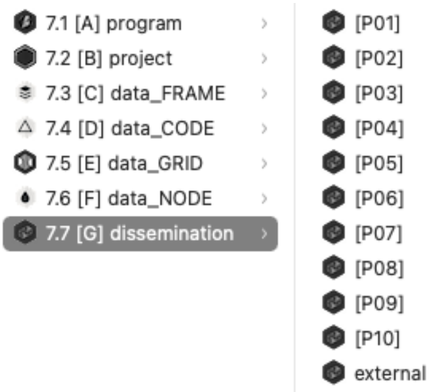
Data from collaborative design activities with participants from the Historical Museum of Northern Jutland and the Our Museum program participants. All the data from the design activities of the development of [XTR] and [ARA] are contained here along with [OMG], that contains high-resolution version of the *Our Museum Game* boardgame overview along with manual and the data collected from multiple iterations of test and evaluation.



7.7. [G] dissemination

Each of the ten full text paper contributions are included here, named according to the same designation used throughout the thesis. Additionally, co-author declarations are included named [P##-CAD] for papers where co-author declarations apply.

The 'external' folder contains news articles, public talks, and other public communications outside of academia, such as interviews. This folder also contains a file that combines all ten papers into a single document entitled [P01-P10] - COMBINED.pdf, to make the reading/printing of the papers more accessible to the assessment committee.



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