Investigating the Potential of Tabletop Natural User Interfaces Tools in Improving the Nunaliit Cybercartographic Atlas Framework

by

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This thesis dedicated to

My parents

For their endless love, support and

encouragements

Abstract

This study presents the results of an on-going work, which offers a comprehensive qualitative analysis of natural hybrid interfaces (touch-based, gesture and tangible interfaces), as a human-computer interaction technique that has the potential to promote a methodological approach to the design of a new form of collaborative tabletop interface within the Nunaliit framework and its cybercartographic atlases.

The study provides empirical evidence for the feasibility and value of incorporating collaborative interactive large displays in a mapping creation process. The results of this study are based on a usability study comprised of twenty participants and semi-structured interviews with ten professionals from various fields and experiences. The study confirms the potential benefits and applicability of employing this novel approach as an alternative to the more conventional user interfaces that are currently in use. The study offers several insights and design guidelines which will be indispensable when implementing this novel interface, particularly in the new collaborative Nunaliit framework, and offer a new opportunity for cartographic mapping contexts in general.

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"Until that day I'll think of you, the love we shared, the memories too." Chris Belden.

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1. Chapter: Introduction

1.1. Overview

In the last two decades, we have witnessed interesting advances in research on interactive tabletops in both academic and industrial contexts (ITS, 2013). The new developments in display hardware have caused the widespread proliferation of digital tabletop technologies together with new interaction possibilities, such as multi-touch interfaces (Han J. Y., 2005). This thesis will make a contribution to this research by exploring a holistic computational interaction with tabletop interactive displays. An interactive tabletop is defined as "a large surface that affords direct, multi-touch, multi-user interaction" (Benko, 2009).[1] In addition, it can be argued that the emergence of multi-touch, gestures and tangible interaction techniques *(hybrid or natural interactions)* have the potential to enhance users' collaboration and innovation. There are many challenges, however, especially when manipulating complex spatial data sets, such as maps. The goal of this study is to explore a novel interactive approach using a multi-touch gestural and tangible interface in shared mapping contexts, which supports different map creation processes such as, reviewing, editing and adding information through tabletop collaborative Nunaliit atlases.

It would be significant to clarify at the beginning of this thesis that, there are three major components involved in the work of my research centre: Geomatics and Cartographic Research Centre (GCRC) which are: cybercartographic theory, the Nunaliit framework and cybercartographic atlases. Cybercartography is a new theoretical concept proposed by D.R. Fraser Taylor (1997, 2003). In order to apply this theory, Taylor and

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[1] Benko, (2009) arrived at this definition by surveying of 58 tabletop researchers and experts.

the GCRC team created the Nunaliit Framework software, which made it easy to tell stories and highlight relationships between many different forms of information from a variety of sources, using maps as a central way to connect and interact with data. The third component is cybercartographic atlases, which are the main products of the Nunaliit framework. More description about those three components is provided in Chapter 2. This study contributes to the Nunaliit framework software and focuses on investigating the potential of developing new tools as a part of the Nunaliit framework development process.

This study adopts a theoretical and experimental approach for the creation and evaluation of natural interaction interfaces as a new iterative development process for the formation of cybercartographic atlases using the Nunaliit framework[2] (Taylor, Lauriault, Hayes, 2014). Furthermore, I create a paper prototype which is used to evaluate various possible concepts of natural hybrid interactions (tangible, multi-touch and gesture), while also examining the most promising interaction options. These were evaluated based on user study usability tests and semi-structured interviews to determine their utility. The present study uses the results of these tests to garner a better understanding of the most viable interaction approaches for implementing a fully functioning cybercartographic atlas that uses a tabletop as part of the Nunaliit framework. I anticipate that these new tools will facilitate users' interactions with the atlases. The study also highlights some potential additional design improvements.

Nunaliit is a framework designed to make it easy to bring stories and data together, using maps as a connecting focus. Nunaliit aims to make it easy for anyone to

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[2] Additional information about Nunaliit framework development see the official Nunaliit website: http://Nunaliit.org)

build a cybercartographic atlas, telling stories and exploring the relationships between space, time, knowledge, and our senses in very innovative way. (Taylor, Lauriault, Hayes, 2014).

The Nunaliit Framework has the potential to benefit from the adoption of these new natural interfaces in the existing framework. This promising technology could be an invaluable and innovative tool for Nunaliit to achieve its goals regarding usability. First, Nunaliit provides spatial and temporal interaction for its users. These two dimensions are significant to the representation of the mutual environmental relationship between Indigenous and local spatial knowledge, particularly in a Canadian context. The proposed tool will represent this relationship in very natural ways that enable users from different backgrounds to input their data easily and accurately. Secondly, Nunaliit clearly meets the theoretical concepts for the employment of these natural user interfaces. Therefore, the use of tabletop natural user interface tools can help create new generation of Natural Cybercartographic Atlases.

Finally, Nunaliit is at a manageable application scale and has intensive spatial and temporal interaction dimensions. Thus, this study provides evidence for the benefits and applicability of employing different natural interaction interfaces as an alternative to the more conventional user interfaces that are currently in use. In addition, the study offers design guidelines for the Nunaliit system, which will be an essential element to the implementation of this promising technology into collaborative operational Nunaliit atlas.

1.2. Motivation

What are the benefits of introducing a novel natural hybrid interface that can be used within the existing Nunaliit Cybercartographic framework?

Terrenghi (2007) describes the design of hybrid interaction paradigm in her Ph.D. thesis, where interactive surfaces incorporate facets of the physical and digital worlds. In addition, Horn, Crouser and Bers (2012) consider combining tangible and mouse-based computer programming to create hybrid interfaces. They use the term hybrid interface to refer to single interactive system that consists of two or more equivalent interfaces.

Natural or hybrid interactions (Touch based gestural and tangible interactions) are a relatively modern user interface research area that aims to incorporate the digital and physical environment interaction in a way that bridges the gap between the virtual environment and the real physical world. This interaction not only utilizes tangible objects, but also engages the user's body, senses and emotions. Therefore, the user can touch, feel and manipulate the interaction, while acquiring direct continuous feedback. In other words, hybrid interfaces aim to leverage the user's physical interaction experiences into a digital form, thereby enhancing the ease of use and the effectiveness of user interaction.

The motivation for this study stems, in part, from the arguments made by Ishii and Ullmer (1997), pioneer researchers in tangible interactions. They inspired the author to understand how we can best combine and implement a promising technology within the existing Nunaliit Framework in a creative way; one that engages Nunaliit users, and enables them to manage the map by creating, adding, editing and manipulating their own map information and enjoying the benefits of collaborative mapping interactions.

Another motivation for applying this novel approach in cartographic atlas contexts is that it will introduce an original user interface for digital mapping, while also enabling users to manipulate maps collaboratively in real-time interactions.

1.3. Objectives

The Nunaliit framework research team has applied a user-centred design approach throughout every version of the Nunaliit system via a meaningful iterative design process. In most cybercartographic atlases, however, there are still several ongoing challenges regarding use and usability concerns. This could be due, in part, to the difficulty in identifying the users of an online product. Cybercartography is also multisensory in nature (Taylor, 2006), which creates real challenges in terms of designing an interface that is efficient and easy to work with, when the general users are unknown to us.

One of the goals of cybercartographic atlases is to engage the public, as individuals and groups, in map creation. The existing Nunaliit framework has been successful thus far, and improvements are underway that will make the interaction even easier. This study, thus, contributes to Nunaliit framework developments by investigating a new form of interaction.

This study presents a comprehensive analysis of natural hybrid interfaces (touch based gestures and tangible interfaces) as a human-computer interaction technique that has the potential to promote a methodological approach to the design a new form of collaborative tabletop interface with Nunaliit cybercartographic atlases. It attempts to answer the following research questions:

To what extent are hybrid interaction interfaces useful in enhancing collaborative user interaction with cybercartographic atlases? Can these interfaces help improve their usefulness, ease of use, or enhance an atlas user's experience while viewing, adding or editing map information?

To help answer these questions, the author developed a paper prototype, which he used to evaluate several different possible concepts of hybrid interaction. In doing so, he was able to determine the most promising interface options and recommend the best options, by combining an assessment of previous studies with the results of the evaluation carried out in this study.

1.4. The Scope of the Study (Hypotheses)

The study aims to demonstrate that employing natural hybrid interaction technology in the Nunaliit framework will enhance the users' experiences and improve the map, particularly in relation to their ability to navigate, view, review and add-editing maps; all of which aims to enhance the ease of use for map creation in a collaborative setting. As a result, we hypothesise that the cybercartographic atlas users will require less cognitive function when utilizing natural hybrid interactions than is required with the current user interface.

To answer both these questions, we focus on the correlations between cybercartographic theory and natural hybrid interaction technology in multi-sensory interaction approaches. Cybercartography uses multisensory interaction in the creation of its maps and represents the mutual relationship between people and their environment. Likewise, natural hybrid interfaces enable multisensory concepts to be applied in a fully interactive application where users can choose from a range of map creation options while they create their own maps.

The present study establishes the foundation for integrating a natural Hybrid interaction style into the existing Nunaliit framework. Moreover, it serves as a primary iterative design and exploration process from which we can create a new collaborative user interface for cybercartographic atlases.

In this study I conduct several usability experiments with participants from wide range of disciplines within Carleton University and some of them from Ottawa University. The first experiment is used to test both how the users perform on the proposed interfaces and then let users choose their preference interface options upon the completion of the given tasks. For this study, participants interacted with a paper prototype (mocked up map). Participants were encouraged to express their ideas and comments throughout their participation of the study usability tasks. By the end of the testing, participants were asked to complete a questionnaire that inquired about their thoughts on the proposed prototype, perceptions, satisfactions and other recommendations.

Then the second primary methods were conducting semi- structured interviews. Interviewees in this method were experts from both academic and industrial professions. I employed semi-structured interview methods to gain more insights about user needs from the proposed design of implementing hybrid interfaces in the Nunaliit framework, discussed the potential benefits and challenges of this approach, and attempts to justify the users preference interfaces, as well as the most promising hybrid interaction options (tangible, touch& gestures interfaces). Further details about usability testing and semi-structured interviews are presented in Chapter 3.

1.5. Contribution

This research contributes to both geography and Human Computer Interaction (HCI) knowledge by opening a collaborative and interdisciplinary dialogue among professionals in both fields, while also creating a novel approach to the improvement of map interaction in a multi-user context. This study will advance the visualization of the spatial and temporal geographic information, establish a new collaborative approach to map creation, and leverage the technical and design aspects from human-computer interaction (HCI) into rich cartographic applications, such as the Nunaliit Cybercartographic Atlas Framework.

The proposed tools will allow people to interact with maps via familiar tangible objects, multi-touch, and gestural interfaces, and give users the freedom to take advantage of the rich physical and digital world while creating their own maps. In addition, the approach should also appeal to young tech-savvy users who can utilize the new cybercartographic atlases, especially those dealing with traditional knowledge in Canada's north. This study hypothesizes that implementing these high-tech tools in the Nunaliit framework will be more engaging for those youth to learn and contribute to this rich culture in more innovative ways.

1.6. Thesis Structure

This study is presented in seven chapters. The first chapter introduces the topic of natural hybrid interface interaction and discusses the motivation, objective, hypotheses and the scholarly contribution of this work.

Chapter two reviews the relevant background information relating to natural hybrid interfaces (tangible, touch and gestural interaction), the Nunaliit framework, cybercartographic theory and cybercartographic atlases. This is followed by a discussion of the usability evaluation.

The third chapter discusses the methodology used in the study, including details of the design and implementation of the usability testing experiment.

The fourth chapter describes the data analysis process and the main results obtained from that analysis.

The fifth chapter discusses the results obtained from the usability test and semi-structured interviews, including the usability concerns and the participants' comments on the Nunaliit framework, design and interaction.

The sixth chapter offers a discussion of the new user interface guidelines for the Nunaliit framework and provides design recommendations with which to integrate the hybrid interfaces into the Nunaliit framework.

The study concludes with a summary of the main findings and suggestion for future work. And discuss how we answered the central goal of the study as well as proved the validity of the central question and hypotheses.

1.7. Publication

Bani-Taha, O. (2014, November) Part of this study was presented at the 2nd Multidisciplinary Symposium in Geography. In Panel 2: *Geospatial technology issues and urbanization*. The University of Ottawa. Ottawa, Canada. http://www.chinaeam.uottawa.ca/chinanet/Newscontent.html?20141115.html

Bani-Taha, O. (2015, May). Investigating the Potential of Tabletop Natural User Interfaces Tools in Improving the Nunaliit Cybercartographic Atlas Framework. Oral presentation delivered at the *Graduate Research Conference* at the department of geography and environmental studies, Carleton University Ottawa. Retrieved from http://carleton.ca/geography/dges-student-research-conference/

2. Chapter: State of the Art

Integrating a hybrid interface in the Nunaliit Framework development requires us to undertake usability testing while also carrying out an evaluation of the previous work in the field. This section will provide a concrete design structure and evaluate our results against those of similar studies. Thus, this study evaluates the large body of research within the domains of the Nunaliit framework, cybercartographic theory, cybercartographic atlases, hybrid interaction (tangible and touch-based gestural interactions), relevant implemented cases and usability design. This review is important in underpinning the discourse relating to the implementation of a natural hybrid interface in a cartographic context, and to achieve a well-designed theoretical and practical approach.

This study adapts the content analysis technique for collecting and examining the content of text, which is typically used in the social sciences (Schloss, & Smith, 1999). The same approach was employed throughout the literature review to discuss some of the related interaction options and concepts that are addressed in this research. This approach assists with the organization of the available literature, resulting in a comprehensive analysis of the related research.

2.1. Nunaliit Framework

The Nunaliit Framework was born out of a multi-disciplinary research project led by Fraser Taylor and his team in the Geomatics and Cartographic Research Centre (GCRC) at Carleton University in Ottawa (Nunaliit.org, 2014). The name given to the software– Nunaliit – derives from the Inuit word for "settlement", "community" or "habitat". This name was applied to this cybercartographic framework to emphasize the community-based approach that drives and motivates the development of the software in different domains: (1) open specification approaches; (2) modularity; (3) “live” data; (4) geospatial storytelling; and, (5) audio-visual mapping (Caquard et al., 2009).

As we mentioned earlier in Chapter 1, there are three major concepts involved in GCRC work: cybercartographic theory, the Nunaliit framework and cybercartographic atlases. Cybercartography is a new theoretical concept proposed by D.R. Fraser Taylor (1997, 2003). In order to apply his theory, Taylor and the GCRC team created the Nunaliit Framework, which made it easy to tell stories and highlight relationships between many different forms of information from a variety of sources, using maps as a central way to connect and interact with data.

The main products of the Nunaliit framework are its cybercartographic atlases, such as Homelessness, Living Indigenous Knowledge, Kitikmeot, Canadian Trade with the World and the Antarctica atlas. A cybercartographic atlas is different from the traditional concept of an atlas, offering itself as a kind of metaphor for diverse quantitative and qualitative data sets, which are linked by location and presented in a variety of new ways (Engler, Scassa and Taylor 2013, Taylor and Pyne 2010; Pyne and Taylor 2012).

Since this study investigates the potential application of a new interface into the Nunaliit framework, it is useful to provide a brief discussion of the major components of the Nunaliit framework software, especially cybercartography and the Nunaliit Framework, with a particular focus on its challenges. This review provides the reader with a better understanding of the nature of the Nunaliit framework and how this study can contribute to the ongoing iterative Nunaliit improvements.

2.1.1. Cybercartography Definition

In 1997, Fraser Taylor developed the concept of cybercartography as "the organization, presentation, analysis and communication of spatially referenced information on a wide variety of topics of interest to society in an interactive, dynamic, multisensory format with the use of multimedia and multimodal interfaces" (Taylor, et al. 2014). Thus, Cybercartography is a new paradigm for maps and mapping in the information era. This definition reveals the multisensory nature of the cybercartography approach which required ongoing improvements to meet its growing demands and keep up to date with the current interfaces technology developments. This validates the needs of implementing creative methods such as Hybrid interfaces to represent different topic of interest of indigenous knowledge that the public can contribute to the map and understand them in very natural and easy way.

2.1.2. Cybercartography Theory and Practices

Since Fraser Taylor launched the (GCRC)[3] in early 1990s, cybercartography has inspired and assisted in the growth of various iterative atlas projects. In a recent publication, he listed cybercartography's "major elements", stating that it:

> (1) is multisensory using vision, hearing, touch and eventually smell and taste; (2) uses multimedia formats and new telecommunications technologies such as the World Wide Web; (3) is highly interactive and engages the user in new ways; (4) is applied to a wide range of topics of interest to society, not only to location finding and the physical environment; (5) is not a stand-alone product like the traditional map but part of an information/analytical package; (6) is compiled by

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[3] https://gcrc.carleton.ca/confluence/display/GCRCWEB/Overview

teams of individuals from different disciplines; and, involves new research partnerships and the private sector. (Taylor, 2005, & Taylor, 2014)

In short, cybercartography is a holistic concept which combines several elements (multisensory, multimedia, highly interactive and engaging users, informational analytical package and multidisciplinary), which are informed by the mutual interaction between theory and practice (Taylor, et al. 2014).

2.1.3. Nunaliit Framework Development

The cybercartographic atlases were developed over the course of two decades, involving a series of iterative processes that included design, implementation and usability testing phases. These development processes resulted in ongoing modifications to the map structure and system function. (Taylor 2005, Taylor 2014).

Nunaliit has been designed to make it fairly simple to create interactive mapping web sites based on user own data and multimedia, and to permit Nunaliit web users to contribute adding/editing information where permitted. (Nunaliit.org, 2014)

Since, the establishment of the Nunaliit framework in 2003, it has an ongoing development. A good example of these improvements made to the Nunaliit framework is offered by Glenn Brauen, who created several innovative sound mapping features for some of the maps in the atlases that were released with this project (Brauen, 2006).

GCRC team discussions are often a rich source for leveraging new ideas and feedback, particularly when it comes to making design and development decisions. For example, the idea of applying a new interface design into the Nunaliit iterative development largely stemmed from communications between our interdisciplinary team.

Nunaliit framework development was inspired by cybercartography's broad applications in both science and art, and acknowledges the holistic relationship between science, which includes geospatial technologies, and art, which extends to storytelling (Plusifer et al., 2005). This methodology guides the design and development phases of cybercartographic atlas projects by pursuing a direction that adequately conveys a variety of perspectives. Taylor (2014) outlined that it is very much a 'bottom up' technology. Therefore, the needs of the Nunaliit users are major factors driving Nunaliit's development.

2.1.4. Cybercartographic Atlases

Cybercartographic atlases are the main products of the Nunaliit framework. These atlases incorporate all kinds of qualitative and quantitative information, linked together in a spatial and temporal mapping context. The distinctiveness of the cybercartographic atlases is owed to their bottom-up approach, as they are community-driven and owned atlases. Cybercartographic atlases are interdisciplinary and comprehensive in nature, with an emphasis on knowledge sharing, storytelling and enhancing awareness of different viewpoints.

Brauen et al. (2011) investigated the Lake Huron Atlas which was produced by the Nunaliit framework. They discussed the Lake Huron Treaty Process as an open source atlas toolkit that involved many disciplinary to create such a holistic research approach. They examined the iterative process in multiple scales, and its requirements to create and promote atlases by utilizing these web-digital open sources. Their work will benefit the current study throughout its explicit illustration details of the open source software characteristics, which shall be considered when designing a new generation of the Nunaliit framework such as the proposed implementing of Hybrid interfaces in this study.

Another good example of a web-based atlas is the cybercartographic Atlas of Antarctica (*The Atlas*) created by Plusifer, Parush, Lindgaard and Fraser (2005) They developed *The Atlas* approach based on extensive user needs analysis (UNA), in which the general public was identified as its targeted user. They carried out the UNA evaluation in an early stage of the atlas, before any expensive designing was underway. In addition, they used the user-centred design approach, which provides clear details of interface elements, usage and information acquisition. By undertaking such an analysis, they were able to avoid some challenges in terms of cartographic user representation, while also enhancing the system development process.

2.2. Aboriginal Knowledge and interactive Mapping Concerns

This section summarizes the importance of taking indigenous traditional knowledge into consideration when implementing the proposed system design of the new collaborative Nunaliit framework, particularly since this new technology will be used by Inuit peoples in Canada's' north.

During the last two decades of the twentieth century, there have been several mapping developments for indigenous contexts throughout the world, which have resulted in the creation of a particular research field within human geography and critical cartography (Hirt 2012). Indigenous organizations and societies, supported by non-governmental association activists and researchers (primarily geographers, cartographer and anthropologists), have mapped their terrains in order to demonstrate the historical continuity of their occupation of specifics land, as well as to maintain or repossess their territorial rights and fortify their cultural identities (Chapin, Lamb and Threlkeld 2005).

Cultural aspects are essential to all areas of the framework's design, including its user interfaces. Culture develops through social interactions that occur at various scales, from smaller community groups to entire nations (Hofstede 2005). The impact of culture on the usability of an interface is defined as "culturability" (Barber and Badre 1998). Various cultural groups have been shown to use the same interfaces in different ways (Faiola and Matei 2005). There are a number of specific cultural factors that impact usability, including the use of language, the representation of time, currency and other units of measure (Fernandez 2000).

Pumpa, Wyeld and Adkins (2006) challenge the current practice of using digital media to communicate Australian Aboriginal knowledge practices in a learning context. They argue that any digital representation of Aboriginal knowledge practices needs to examine the epistemology and ontology of these practices in order to design digital environments that effectively support and enable existing Aboriginal knowledge practices in the real world. Therefore, designing any new digital representation of Aboriginal knowledge required to resolve the conflict between database and narrative views of knowledge at the very begging stage of the design.

New tools, such as digital cartography, offer unique opportunities to capture and create traditional forms of knowledge, particularly in instances where people's relationship to the land has a high cultural significance (Taylor and Pyne 2010). Interactive atlases offer great potential for mapping the traditional knowledge of indigenous communities; there are still, however, several challenges to overcome. For example, Scassa, Engler and

Taylor (2015) highlight a distinct legal and ethical concern in regards to mapping traditional knowledge, especially given the close relationship between knowledge and traditional lands. Thus, they recommend that any design or implementation of indigenous digital cartography projects should make this issue a primary consideration from the outset of the project's design.

Duerden and Kuhn 1996; Chapin et al. (2005) described that the significance of indigenous peoples mapping and representing their territories and local environment has been widely acknowledged in the past. The indigenous perspectives were acknowledged in the early stage of the establishment of the Geomatics and Cartographic Research Centre (GCRC). Particularly, the GCRC has invited Inuit peoples to become partners in the creation of innovative digital atlases, known as cybercartographic atlases.

2.3. Natural Hybrid User Interfaces Interaction

Hybrid User Interface (HUI), which was first proposed by Feiner and Shamash (1991), refers to a diverse environment, rich in interaction techniques, which supports different kinds of devices or interfaces used in complementary ways. Hybrid interfaces are differentiated by the use or combination of multiple components, which can be multiple devices or multiple user interfaces.

The designers and developers of computer interfaces use the term Natural User Interface (NUI) to refer to a user interface that is effectively invisible or becomes invisible with continuous learned interactions by its users (Werner A. König, Roman Rädle, and Harald Reiterer, 2009). The word "natural" is used because most computer interfaces use artificial control devices whose operation has to be learned. NUI relies on a user being able to carry out natural motions, movements or gestures, which lets them discover how to control the computer application easily and quickly or manipulate the on-screen content. NUI offers an innovative style of interaction that it builds upon a user's pre-existing knowledge of the everyday, non-digital world (Jacob et al., 2008). Therefore, NUI leads to a more natural and reality-based interaction. Throughout this study I used a combination of both terms, which we call Natural Hybrid User Interfaces (NHUIs), as it reflects the potential use of various user interfaces, including Tangible User Interfaces (TUIs), multi-touch and gestural interfaces. In the following discussion, we provide a general description of these kinds of interfaces, followed by relevant examples of their implementation.

2.2.1. Tangible User Interfaces (TUIs) in Geospatial Contexts

While the current computer interface is powerful and provides an early example of the impact that this method can have on HCI and productivity, there is an increasing need to use new and innovative ways of interaction, such as tangible interfaces. TUIs strive to enhance human productivity by making their digital tools easier to use. They achieve this by developing human spatiality, our natural ability to act in physical space and interact with physical objects (Sharlin, 2004). Fitzmaurice was the first to distinguish TUIs from other interfaces—though he called them ''graspable'' user interfaces. Fitzmaurice (1996) defined a graspable user interface as ''a physical handle to a virtual function where the physical handle serves as a dedicated functional manipulator.''

Ishii and Ullmer (2000), pioneer TUIs researchers, proposed and established the term ''tangible user interfaces,'' which they defined as ''devices that give physical form to digital information, employing physical artifacts as representations and controls of the computational data.'' In both instances, the authors essentially define a TUI as a connection between the physical object and the digital information or function it embodies.

Thereafter, TUIs became an established research area, particularly via the contributions of Hiroshi Ishii and his Tangible Media Group, as well as those of other research groups worldwide (Share and Hornecker, 2010).

Ishii & Ullmer (1997) argued that users should not be restricted to conventional Graphical User Interfaces when interacting with computer software, especially, when interacting with digital information. Instead, they suggested utilizing physical objects in the real world, as previous researchers had developed rich languages and cultures with haptic interaction in a genuine physical environment. The ultimate goal of their tangible interaction work was "to take advantage of natural physical concordances to achieve a heightened legibility and seamless of interaction between people and information" (Ullmer, 1997).

Ishii argued that TUIs gives physical form to digital information and computation, which enables the direct manipulation of bits (Ishii, 2008). The aim is to facilitate collaboration, learning and decision making, using digital technology which takes advantage of people ability to grip and manipulate physical elements.

Ratti et al. (2004) described how TUIs, which is an emerging concept in human-computer interaction, could be applied to Geographic Information Systems (GIS). Their discussion centred on a novel interface for GIS that would apply the recent technology in TUIs, thus drawing on the TUI’s interaction between familiar tangible objects and the powerful numerical simulations of GIS. In order to test the validity of this claim, the authors introduced and examined two conventional modelling materials: Illuminating

Clay and SandScape. They presented an alternative model to the text-driven system in GIS that permits the user to interact with geographical information, thus allowing them to modify the interface by combining tangible objects with augment reality.

This study explores the benefits and limitations of using TUIs on the Nunaliit framework as an alternative interface option in the creation of cybercartographic atlases in collaborative setting.

2.2.2. Touch-Based Gestural Interaction[4]

Touch-based gesture research has received ample attention in HCI research circles over the past few decades. As early as in 1963, Sutherland (1964) created a trailblazing project, Sketchpad, which is heralded as one of the earliest examples of human-computer interaction research. The project used stroke gestures in graphical human-machine communication.

It is beyond the scope of this study to conduct a detailed review of the history of touch-based gesture interactions. Yet, this review highlights two important historical changes in gesture based interactions: (1) the shift from pen gestures to finger gestures; (2) the evolution of stroke gestures to multi-touch gestures. Through a discussion of both changes, this study demonstrates the effect these previous works had on the trajectory of the research outlined in this thesis.

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[4] The term *gesture*, in a multi-touch environment, does not relate to the expressive gestures used in human face-to-face communication, but instead to familiar and conventional hand movements used in some particular tasks. The aforementioned literature also classifies the surface gestures as multi-touch or multi-finger and whole-hand.
The term *multi-touch* refers to an interaction style that allows users to interact with more than one finger at time, taking into account hand movements as well as gestures (Wu, Balakrishnan, 2003; Freeman, Benko, Morris, & Wigdor, 2009).

Gestures are a desirable feature of the natural user interface, as it is a powerful, efficient and handy input style. “A gesture is a motion of the body that contains information” (Mackinlay, 1991). From a HCI perspective, gestures can be categorised into two groups: two-dimensional surface gestures and three-dimensional motion gestures. In surface gestures, users can draw gestures on the touch screen in two dimensions. For example, the flick gesture requires the user to contact the digitizer in a quick flicking motion. The zoom gesture, on the other hand, is used to enlarge or reduce an object by moving fingers in the opposite direction or bringing them closer together. In comparison, motion gestures can enable users to interact with a device in three dimensions, by turning or rotating the device, or by moving the hands, face or other parts of the body without holding the device.

According to Ni (2011), we can summarise the core benefits of gesture-based interactions as follows: (1) the user can quickly convey the gesture, which acts as a command where gesture can replace the verbal command, rather than by looking for and subsequently choosing an icon, which may be time-consuming; (2) in comparison with tapping on an icon, gesture input is a more fluid form of movement that is closer to drawing, thereby offering a natural input style for the user. The aforementioned characteristics of these gestures can meet the requirements of NHUI and contribute to the growth in its popularity.

Buxton (2008) demonstrated that “multi-touch technology has been in existence for decades, and Apple made this technology famous by using it in the iPhone, iPad and iPod Touch devices”. In tabletop, the technology is scaled to large display surfaces, improving a table’s natural affordance or propensity to multi-touch sensing. Furthermore, implementing touch-based interaction on mobile devices has been strongly linked to the introduction of Personal Digital Assistants (PDAs). Therefore, users became aware of and familiar with touch-based interaction by using the stylus pen in the early 1990s with Apple’s Newton, and afterward with Palm OS devices and Pocket PCs (Bellucci, Malizia, and Aedo, 2014). Thus, the acceptance and popularity of touchscreens on PDAs (iPhone, iPad and Android mobile devices), merged and expanded the interaction with touch-sensitive displays by means of multi-touch techniques.

Multi-touch techniques for small screens can be applied to large a display, which has in turn influenced the development of gesture terminology for tabletop surfaces, as well as user acceptance of such gestures (Wobbrock, Morris, and Wilson, 2009). In addition, tabletop gestures can be two-handed, as a result of the increased size of the display surface, but the use of two hands is not mandatory for multi-touch input.

This study focuses precisely on surface gesture using two dimensions. Owing to the prompt growth of multi-touch screen devices, gestures on touch screens are an increasingly important interaction modality. A touch-based gesture is the movement trajectory of the users fingers and hands contact on the touch-sensitive surface. Finger and pen gestures are the two predominant forms of touch gesture. Gestures can be used in a number of application scenarios for touch screens.

2.2.3. Tabletop Implementation Cases

In the last two decades, a wide range of research has been conducted in horizontal, direct-touch tabletops. The applications of the research became well-known to the general public after the production of Microsoft’s Surface and, more recently, Microsoft’s Surface Hub (Microsoft, 2014), and Jeff Han’s multi-touch table (Han, 2006). An increasing number of interactive multi-touch and tangible interfaces are being created to support tabletop group activity and collaboration in various domains, such as schools (Cao et al., 2010), museums (Horn et al, 2012), (Hornecker, Marshall, Dalton and Rogers, 2008), seminar rooms and study labs (Shaer et al, 2010).

The use of interactive tabletops, as well as the research activity around them, is continuously increasing, with the final aim of their use in public and collaborative settings. As previously mentioned, the interactive tabletops have become increasingly common in recent years and are presently being developed for more interesting uses. In particular, large multi-touch surfaces are becoming a useful tool for collaborative work, in which multiple users are able to interact at once with shared screens. Therefore, it has been broadly implemented to support a wide range of collaborative activities, such as regional planning, climate forecasting, focus group brainstorming, designing and managing the outcomes of natural disasters.

Several studies explored how interactive tabletops support collaboration and learning (Do-Lenh, Kaplan, and Dillenbourg, 2009; Olson, Leong, and Horn, 2011). Other studies have proposed new interaction techniques based on tracking gestures and motions above a digital tabletop (Genest, 2011). In addition, several conferences have discussed the various implementations for tabletop, such as the ACM Conference on Interactive Tabletops and Surfaces (ITS, 2010), and the ACM Conference on Human Factors and Computing Systems (CHI) (Cherry, 1998).

A recent article has provided a comprehensive analysis of the tabletop computing literature, which underlined the major aspects that structure the input space of interactive tabletops: (a) improvements in hardware technologies that have triggered the growth of interactive horizontal surfaces and (b) concerns interrelated to new forms of interaction styles (multi-touch, tangible, and touchless) (Bellucci, Malizia, and Aedo, 2014). They also present a taxonomy that offers a comprehensive assessment of the current developments in this research stream, while also outlining the opportunities and challenges for such novel touch and gesture-based interactions between the user and the surrounding computational environment. There are various examples of the tabletop modalities, such as the Reactable, KinectArms and Museum Multi-touch table.

a) The Reactable:[5]

The *Reactable* is an electronic musical instrument with a table-based use of TUIs for control and visual feedback. Jorda (2008) noted that the Reactable instrument is heavily inspired by the analogue modular synthesizers of the 1960s, and utilized the same modular synthesis format when creating signal chains of multiple generator, effect and control modules. The idea of simultaneously playing and constructing the instrument is conceptually imitative of the visual programming environment that runs the synthesis 'engine' of the Reactable.

[5] http://www.reactable.com

Xambó et al. (2013) described a long-term lab study involving groups of expert musicians who improvised with the Reactable. This study examined their interactions, focusing on *interface*, *tangible*, *musical* and *social* phenomena, and revealed practice-based learning between peers in situated contexts, and the new forms of participation, all of which facilitated by using the Reactable tangible interface compared to traditional musical ensembles.

Xambó et al. (2013) found that the Reactable's lack of territorial constraints and its automated connection mechanism promoted exploration and creative discovery, which was a positive motivator for collaborative learning in creative group activities. In brief, the study suggested that this approach could promote collaborative and peer learning, which can potentially inform constructivist approaches to learning, which could be applied to the use of computationally enhanced tabletop environment in other domains.

b) Museum Multi-Touch Table

Hornecker, Marshall, Dalton, and Rogers (2008) conducted a field study of an existing interactive tabletop in the Berlin Museum of Natural History. Users (specifically, museum visitors) were invited to employ a wide variety of gestures during their interaction with the devices; different interface elements invited different types of gesture. The analysis revealed that the design of the tabletop interfaces for an open setting created some challenges for the user, such as noticeable glitches in the interaction, requiring visitors to make an effort to learn how 'the interface works'. In additions, users seemed to be disturbed from the actual and current content—leading to short holding times, while most of the visitors engaged, at least temporarily, with the table when browsing the question-and-answer sections regarding the animal species. Furthermore, this study noted that the discussion amongst visitors was centred mainly on how to interact with the tabletop, along with a few comments, indicating only a slight engagement with the content.

Tabletop interaction can support collaborative and face-to-face interaction, which can potentially provide valuable opportunities for using a computationally enhanced tabletop environment in various domains. This study explores the potential of utilizing a tabletop in cartographic domains. We are hopeful that this technology will be useful tool to positively motivate collaborative participation in map creation.

2.4. Usability Design Outline

Bevan, Kirakowski, and Maissel (1991) demonstrated that the term “usability” was first introduced in the 1980s, at which time it referred to user-friendly attributes. In addition, the international standard (ISO 9241-11), provides guidance on usability and defines it as “the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use” (usabilitynet.org, 2006).

Rubin (2008) suggested that a usable website consists of four elements: usefulness, effectiveness, learnability and satisfaction (Nielsen, 2013). Nelson and Rubin agreed that these attributes are essential to assess the ease with which user interfaces are used.

Bevan (2008) argued that the definition of usability can be extended to encompass user experience, by interpreting satisfaction as: likable, pleasurable and comfortable In addition, Schneiderman (1992) introduced the "Eight Golden Rules," which is an essential guide to creating a well-designed and interactive user interface. These rules include: consistency, enabling shortcuts, informative feedback, walking the user through more complicated tasks, offering simple error handling, permitting easy reversal of actions and keeping it simple.

In this study, I considered all of the aforementioned usability rules and principles when designing the study evaluation tasks, thereby examining and measuring the compatibility of the Nunaliit framework with these standards.

3. Chapter: Methodology

The objective of this chapter is to provide a detailed discussion of the methods that were used in the study, including particulars of the design and implementation of the usability testing experiment.

This study uses a qualitative approach as the primary method of inquiry to answer the research question and realize the goals of the project. In addition, we limit the use of quantitative approaches to the collection of some descriptive data about the study participants and the measurement of user satisfaction and their perceptions of the proposed hybrid collaborative atlas. The reason for choosing the aforementioned methodology is summarised in the following paragraphs.

3.1. Qualitative approach

Given the complexity of the spatial mapping domain and the nature of the Cybercartographic atlases, the aim of this study is to capture peoples' relationship with their environments through different qualitative methods, such as storytelling and participatory study. This study requires a qualitative analysis to reveal areas where we may encounter usability issues of the proposed technology, while also gathering feedback so as to provide the most promising interaction options that can be implemented in the Nunaliit framework.

Qualitative studies also offer more leeway in their design, as they are not limited to the potential outcomes that we believe are essential, whereas quantitative studies have a clear hypothesis and research structure from the outset (McGuigan, 2015). The flexibility offered by a qualitative approach allows us to understand a wide range of potential users' thoughts and opinions, which in turn informs our findings. Likewise, in research we cannot make assumptions, such as assuming that we know what would help users; therefore, it is important to seek understanding of the users' needs. This research was conducted with the purpose of generating solid theoretical and practical design guidelines, which will be used in implementing the Reactable technology in a mapping context.

3.2. Quantitative approach

We collected quantitative data by administering a short questionnaire (see Appendix D) to our participants, in which they were asked to rate their experiences and expectations with regards to the application of Hybrid interfaces in the context of map creation, including editing and viewing the map as a part of creating the cybercartographic atlases using the Nunaliit framework. The use of a quantitative approach in this study is limited to a statistical description of our participants and displaying some quantitative results of the questionnaire. The sample size is limited to twenty participants, and as such, it is too small to make generalized results regarding the findings, especially as the participants vary in terms of experience, age and education. Also, this study uses a paper prototype, which might not be adequate for collecting accurate data for the completion of the usability tasks and measuring the actual system errors.

3.3. What Method of Qualitative Inquiry Should We Use?

This study adopted a method by which qualitative research data was partially analysed while testing and interviewing were still taking place. This allows the researcher to constantly refine the test and interview content, as well as the interview schedule. It also affords the opportunity to review every test or interview just after each session or interview is completed.

In this study, it is important to evaluate participants' feedback perceptions, in order to gain different insights about the proposed hybrid interfaces into cybercartographic

Nunaliit atlas. This type of qualitative analysis is challenging, since the same piece of data or text can be understood in different ways and lead to diverging results. This is probably because that every researcher brings his own experience to the analysis process (Dawson, 2009). Therefore, the author kept focusing on the participants' interactions themselves and attempted to get more explanation from participants if we observed something vague to obtain more reliable data. Conceptually, there are several important methods used for qualitative data analysis, especially as it pertains to usability research and expert interviews. The most important methods are as follows:

A Thematic analysis classifies the results of a study into themes or main ideas, which are derived from what participants mentioned during the usability test, interview and questionnaire/focus group (Boyatzis, 1998). A number of HCI studies reported using thematic analysis to evaluate video recordings and interviews based on participants' use of testing prototypes (Pykhtina et al., 2012).

Recurring ideas are retrieved from the collected data and assembled into major themes. Thus, the data analysis is carried out as an ongoing process during data collection, which allows us to change themes or add new themes as the data collection process progressed.

Comparative analysis is closely linked to thematic analysis, as both methods are often utilised together to achieve the best qualitative analysis results (Dawson, 2009). In a comparative analysis, the data usually comes from different groups or participants, which are compared and weighed with the aim of finding distinct trends that belong to each group or theme. The researcher moves back and forth between the various texts and notes relating to the collected data from the study in order to identify these differences, until no further new ideas appear. This type of analysis is used to identify characteristics of the different themes that are arising, while also addressing concerns arising from the results of the various groups by allowing for different data collection methods amongst the same group of participants. (Dawson, 2009).

Content analysis is probably the most used data analysis method. It is a quantitative means of analysing qualitative data, as it endeavours to mechanically give codes to ideas from the resulting text at the end of the data collection process, after all of the interviews/questionnaires/focus groups have been finalized. The main difference between content analysis and thematic analysis is that a content analysis occurs at the end of the data collection process, while a thematic analysis is an ongoing process.

This study uses the abovementioned qualitative approach to uncover a wide-range of usability concern in regards to the proposed hybrid interfaces. It attempts to provide concrete design guidelines for the new generation of the Nunaliit framework. These guidelines are based on the findings from this study, which offer a better understanding of the benefits or challenges of using hybrid interfaces as input/editorial tools in the new form of the collaborative Nunaliit cybercartographic atlas framework. Thus, this study explains the potential for implementing this novel interaction technology in map creation.

The current research methodology collects relevant data from the usability study, conducts small-sized expert focus groups and semi-structured interviews, and then analyses the gathered materials in order to arrive at a more complete understanding of the most promising interaction options resulting from the creation of such a collaborative cybercartographic atlas.

The study categorizes the data into themes using a combination of themes prompted from the collected data and some of these themes which stem from relevant literature and our own experiences with the existing Nunaliit framework. Therefore, the study creates several interaction scenarios, and then designs them in a paper prototype format to facilitate the usability testing, so as to compare the different interfaces and come up with the most promising interaction options. The three interfaces tested in this study include: tangible, gesture and touch-based.

3.4. Study Methods

The study prototyping and interviews methods are divided into five phases: the development of low fidelity prototypes, the development of the evaluation task activities, experimentation with human participants, collecting information techniques and the analysis of the resulting data.

3.4.1. Development of low fidelity prototypes.

A user-centred design approach supports the use of prototyping techniques to help designers build software that is a better fit with user needs. This study designed a paper prototype to define, evaluate and then customize the most promising hybrid interactions (tangible, touch and gesture). Brown (2009) suggests that there are many benefits to using low fidelity, or paper prototypes, in the design process. In this study, for example, we are able to test the proposed hybrid interfaces without building an expensive prototype. This enables rapid iteration design, in which minor changes in wording or work flow are directly tested and the study’s proposed system can be evaluated at an early stage in the design process. In addition, it provides a unique insight into the user's actions, which is gained during interacting process.

> According to Snyder (2003), paper prototyping is a variation of usability testing where representative users perform realistic tasks by interacting with a paper version of the interface that is manipulated by a person "playing computer," and who has not been told how the interface is intended to work (p. 4).

3.4.2. Development of the usability tasks/ Scenarios

Dumas and Loring (2008) provide a useful summary of the types of tasks that should be used in usability testing. These include: (1) tasks that are essential, such as the most frequently performed tasks or those related to significant functions; (2) tasks where designers expect users might encounter difficulties; (3) tasks that enable a more in-depth analysis of the proposed system, such as tasks that have multi-functions or shortcuts; and (4) tasks that inspect the re-designed areas or relate to newly-added features. This study considers all of these criteria and the usability guidelines, discussed in the previous chapter, in order to design efficient usability tasks.

The proposed prototypes will encompass a wide range of task activities, which simulate the creation, editing, adding and manipulating of map contents. This process asks users to observe and interact with the Nunaliit framework to create cybercartographic atlases simultaneously.

Test participants completed various usability tasks during the evaluation sessions, as several of the tasks relating to the map creation process were designed to examine different aspects of the proposed hybrid interfaces. A photograph of the prototype is found in Figure 3.1. The study uses various tasks and scenarios to evaluate the potential usability aspects of the proposed hybrid interface in the Nunaliit framework. In doing so, it allows us to anticipate any potential challenges that the designer should be aware of, when implementing the functional system. In addition, these tasks are very similar to what the actual users would encounter in a real life context, when they interact with any cybercartographic atlas interface. Thus, this assures that the collected data is reliable and reflects the real experiences of the user when they utilise any cybercartographic atlases. full details of the study's usability tasks.

Figure 3.1: Study prototype

3.4.2.1. Usability Testing tasks and Prototyping Materials

Hi, "*participants name"*. My name is "*evaluator name"*, and I am going to walk you through this session today. Before we begin, I have some information for you, and I am going to read it to make sure that I cover everything.

You already have a good idea of why we asked you here, but let me briefly go over it again. We are asking people to evaluate an interactive collaborative atlas that we are currently designing, so that we can improve the design of the atlas. The session should take about an hour.

The first thing I want to make clear is that we are testing the atlas prototype, not you. You cannot do anything wrong here. In fact, this is probably the one place today where you do not have to worry about making mistakes.

As you use the atlas prototype, I am going to give you a few tasks and I ask that you think out loud, as much as possible; tell me what you are looking at, what you are trying to do and what you are thinking. This will be a huge assistance to us. Also, please do not worry that you are going to hurt our feelings. We are doing this to improve our atlas design, so we need to hear your honest reactions and input.

If you have any questions as we go along, just ask me. I may not be able to answer them right away, since we are interested in how people interact with the software with little to no outside guidance. But if you still have questions after we are finished, I will try to answer them to the best of my ability. In case you need to take a break at any point, just let me know.

You might also notice the camera that is recording. With your permission, we are going to record what happens on the paper prototype and our conversation. The recording will only capture your hands and fingers, not your face. In addition, it will be used to help us figure out how to improve the atlas design, and it will not be seen by anyone except the people working on this project. I am going to ask you to sign a consent form for us. It just says that we have your permission to record your voice, hands, and finger interactions, and that this recording will only be seen by the people working on the project.

1.4.2.2. Study tasks:

This study involves using different interaction techniques (tangible objects touch screens and hand gesture movements). Some actions can be done using all of these interactions, you need to choose one or you can try them all to distinguish which is most useful to make the required action. E.g. if you want to login, you can place a tangible object

to log into the atlas or you can tap on the login button.

Task 1: Log in to the atlas using the following paper prototype

a. You can place a login object 

on the map surface or you can tap on the login button.

Figure 3. 2: First initial version of the study prototype.

Once you place the login token or tap on login button, the following screen will pop up asking you to enter/create your login details (I will ask the participants if they have any comment for this function).

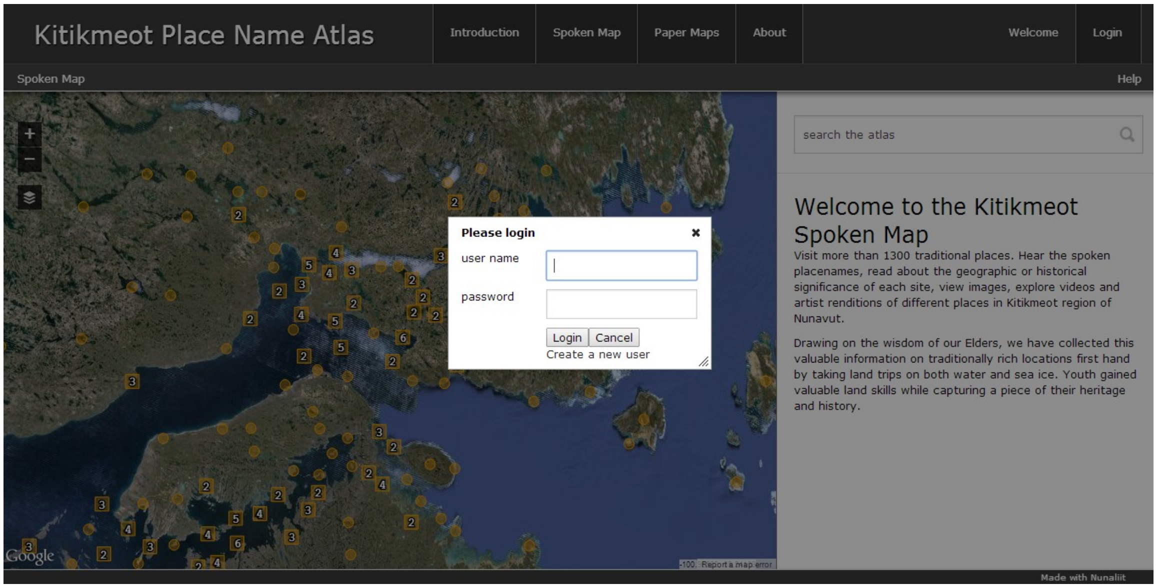


Figure 3. 3: logging in.

Task 2: Search function

Can you use a search option to find some information? To activate a search box you can simply place this token 

on the map surface or locate the search box and tap on it. For example, if you search "video", you can obtain the following results. If you would like to watch any of the videos, you can tap on the "more info" button to open the recorded video.

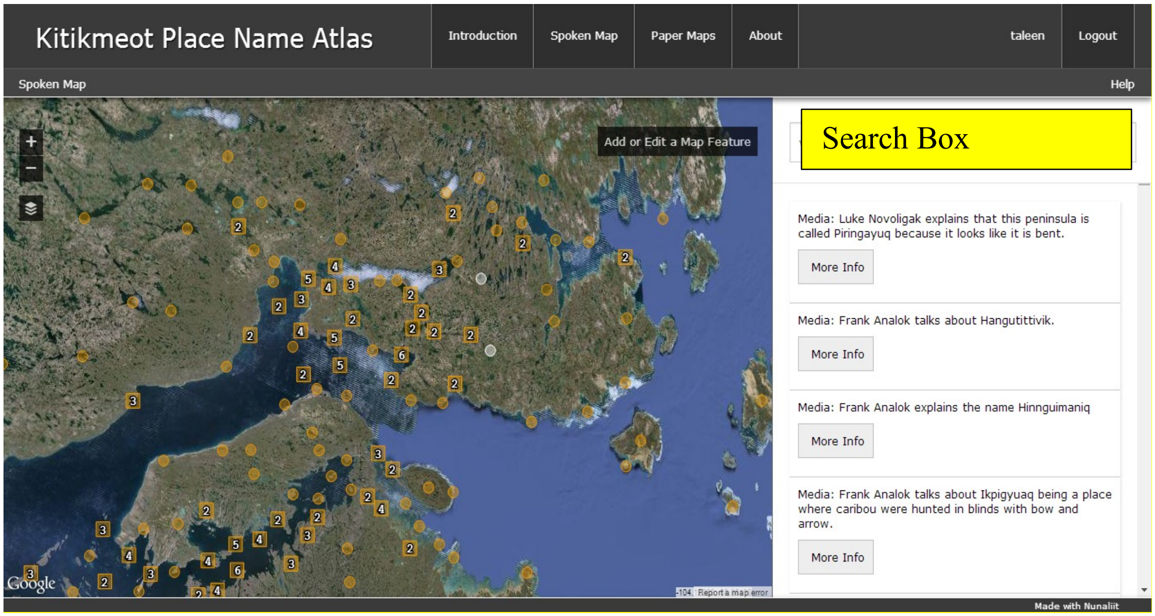


Figure 3. 4: Search function.

Task 3: Help function

Can you obtain more information about this atlas? You can do that by tapping on or

placing the tangible object 

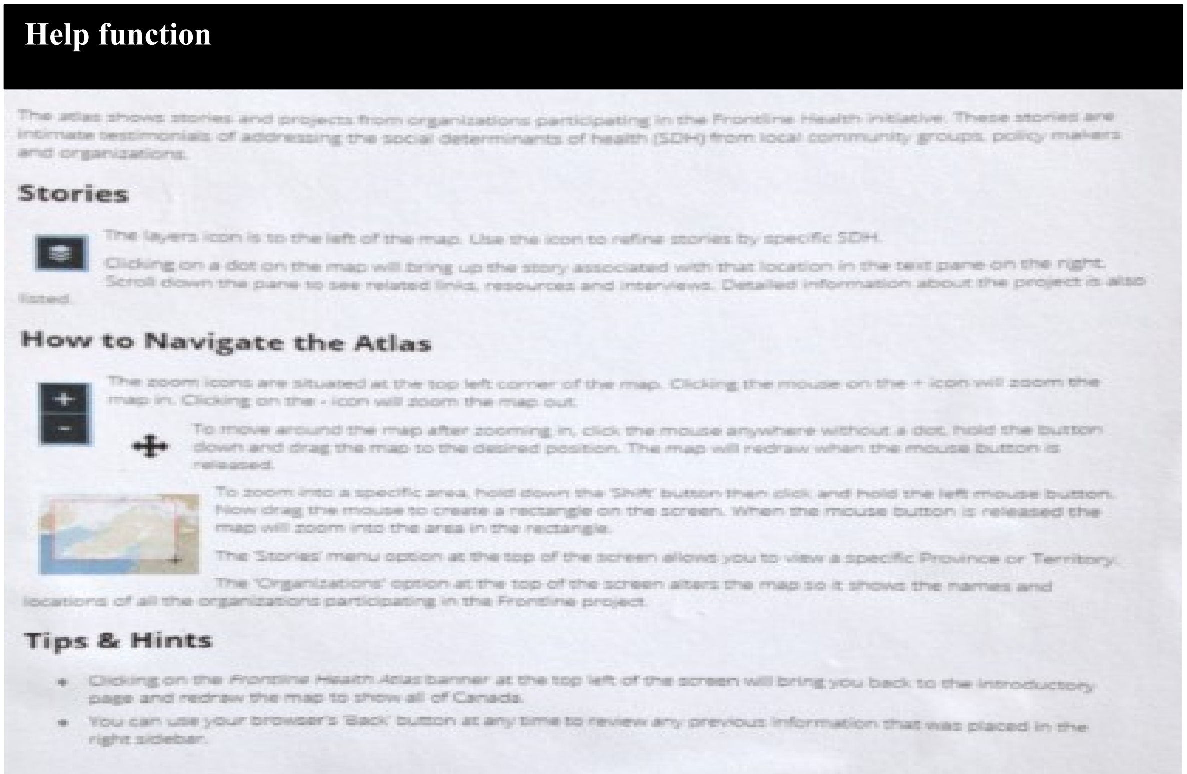
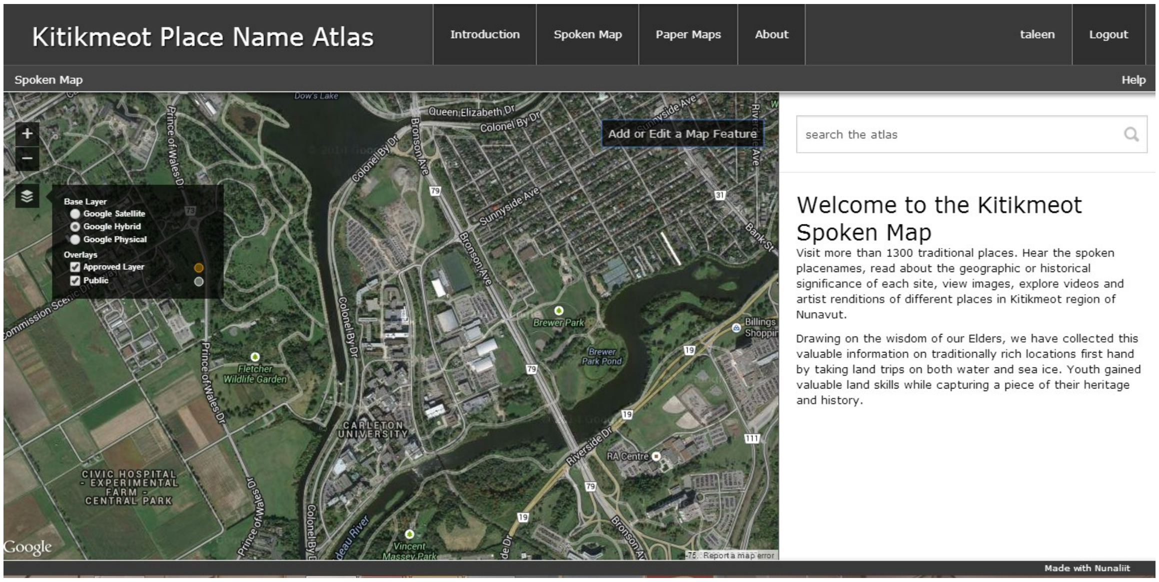


Figure 3. 5: Help function.

Task 4: Zooming the map

Zoom in/out  this feature enables you to enlarge or minimize the map, allowing the user to identify specific points of interest. For example, can you zoom in or locate "Carlton University"? (For these purposes we will provide a range of map scales, from a small scale which shows the world map, to larger scale that shows Ontario and finally a very large scale that provides a detailed view of Ottawa, where participants can identify their home addresses)



Task 5: Add/ Edit information to the atlas

This task includes two different map modes: **Add & Edit** mode

Add /Edit features: to enable this function you can place the "add/ edit" tangible objects

 or 

 to the surface of the map, or you can tap on Add/ Edit a Map Feature then a new screen will open as follows:

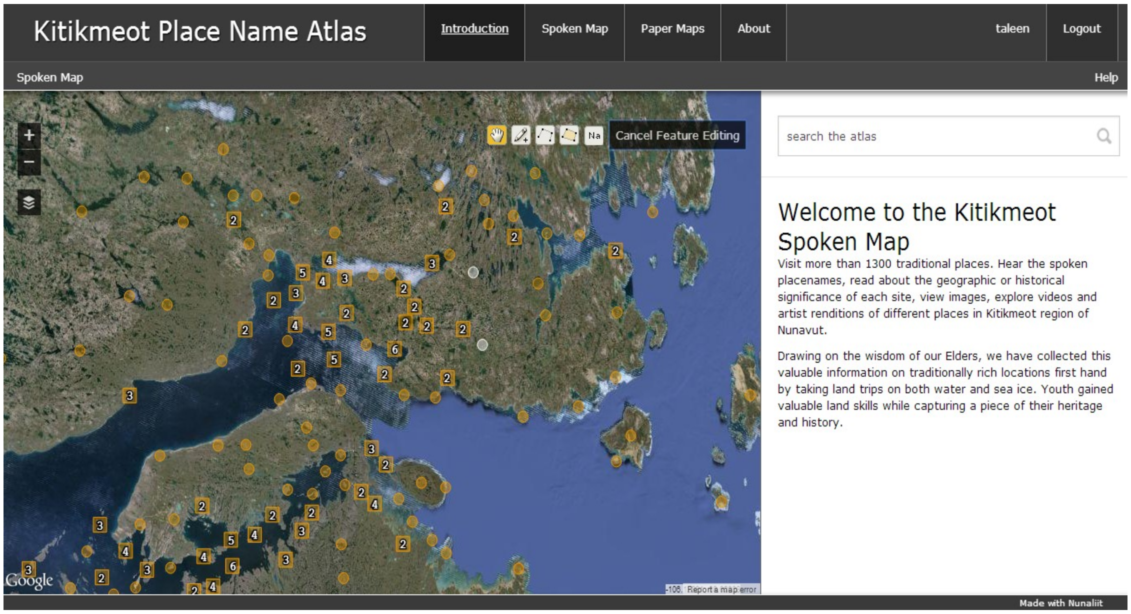


Figure 3. 6: Add/edit map features

There are a few options available in Add/Edit functions which I include them as an individual task as follows.

Task 6: Scroll/ pan the map.

This can be done either by using the tangible object "Pan" or using a single finger or the whole hand to pan (participants can scroll the prototype map in different directions)

Task 7: Add points.

For example, to add a place name, say your "home address", you can place the add object to the map surface or tap on "add point". Once you have identified your home, you can tap on that location to see the following screen, where you can type the name of the points and other details, which can be seen by scrolling down using one or two fingers. After completing the **form fill-in** you can save your entries by taping on save button.

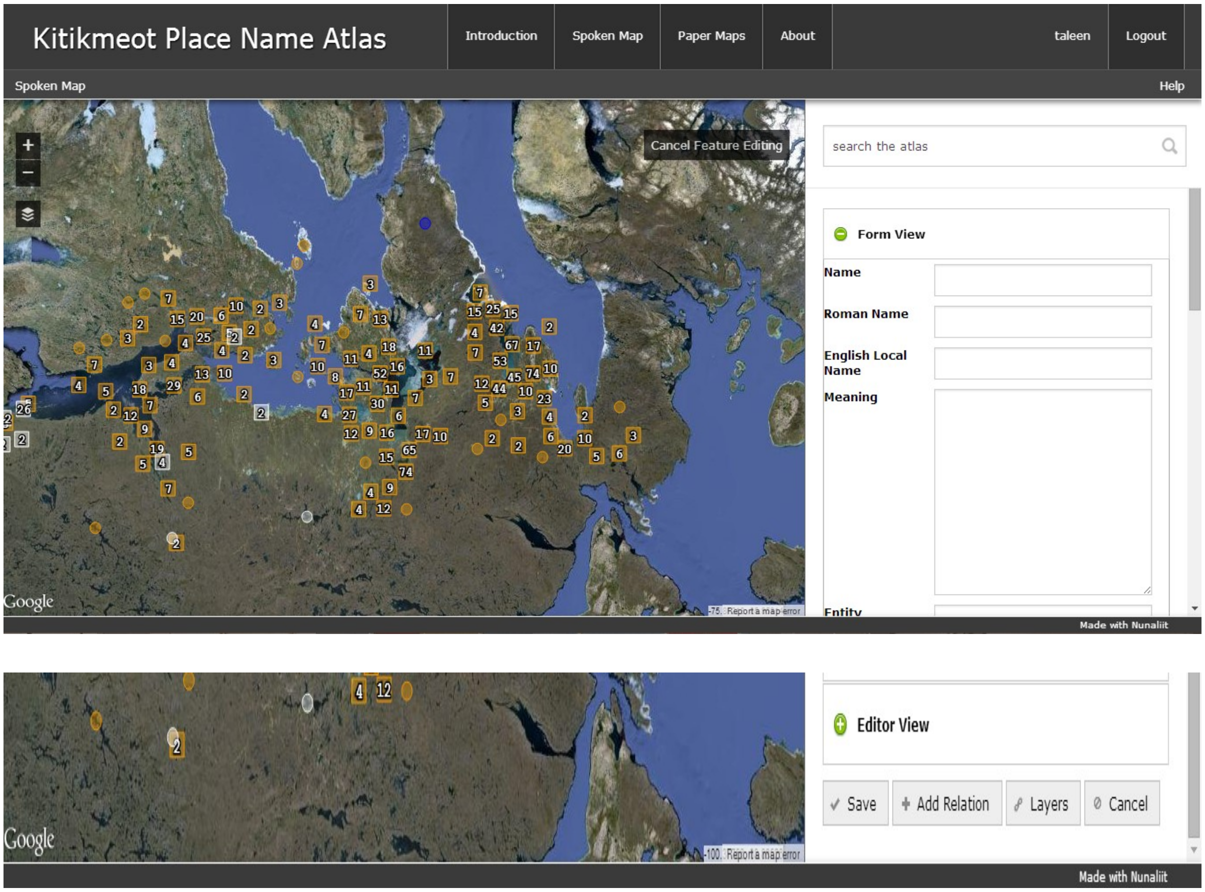


Figure 3. 7 Add point/ form fill in.

Task 8: add line

Draw a line between two or more points: to draw a line or trial between two distances, users can use their fingers or a marker to draw the line. For the purpose of this study, you can draw a line between any two or three of your favourite locations, for example: your home, your high school and a place where you met your girl/boyfriend. The following figure is an example of how to draw a line. Here we use the intersection of Bank St and Sunnyside and the River building at Carleton University to demonstrate how this function appears on the atlas. Then, you can fill out the “form fill-in” and save it the same as you did in “Add Point”.

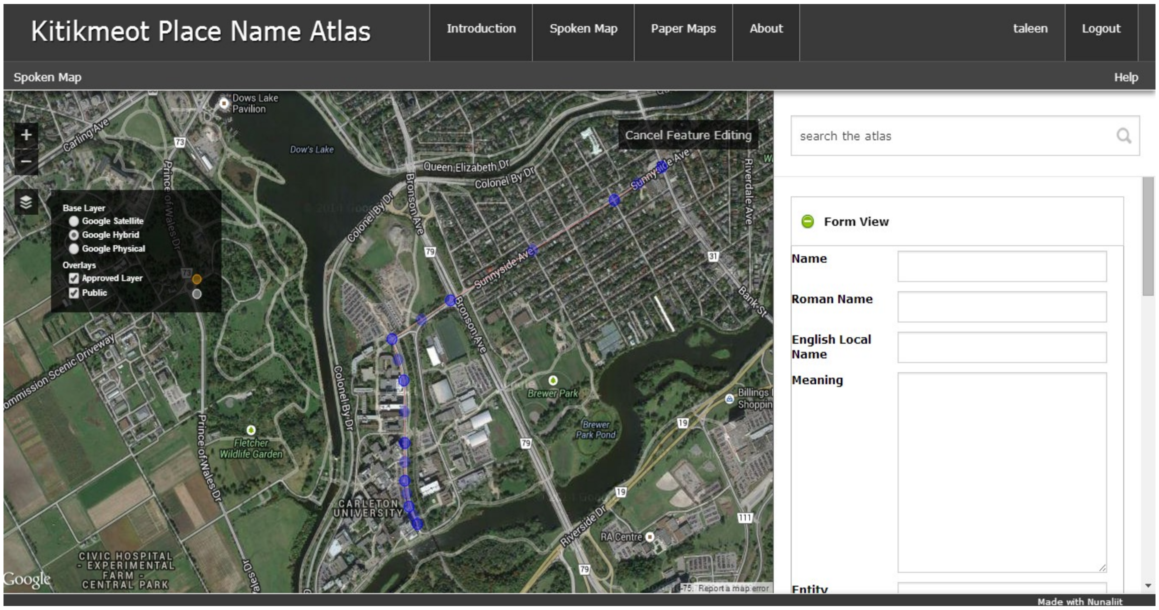


Figure 3. 8: Add Line/Path feature

Task 9: add polygon

Draw a polygon or area: to determine a specific area, users can use their fingers or a marker to draw a border line around the selected area. For the purpose of this study you can draw a polygon in your neighbourhood or the Carleton University campus. The following figure is an example of how to draw a polygon around Carleton University on the atlas. Then, you can fill out the "form fill-in" and save it the same as you did in "Add Point".

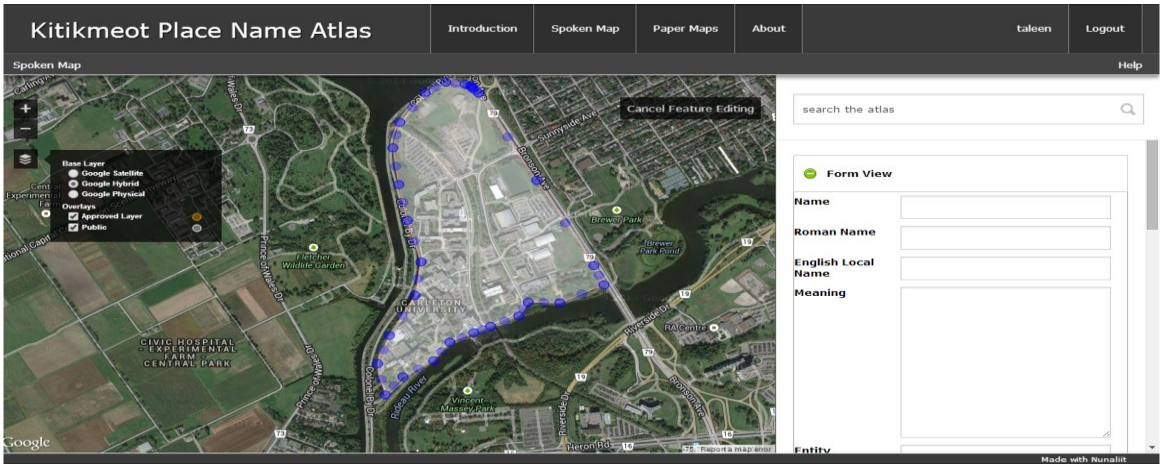


Figure 3. 9: Add Polygon Feature

Task 10: Logging out 

Before perform the last study task we asked participants whether they have any questions related to the usability tasks or any general thoughts. Then, if they do not have any questions, we asked them to logout from the atlas.

Finally, we would like to thank you for participating in our study. If you have the time could you please fill out a short questionnaire related to what you have done today? (If we run out of time, we may send an e-mail to the participants with the questionnaire, and then they can fill it up and e-mail it back to us)

3.4.2.3. Touch Gestures reference guide

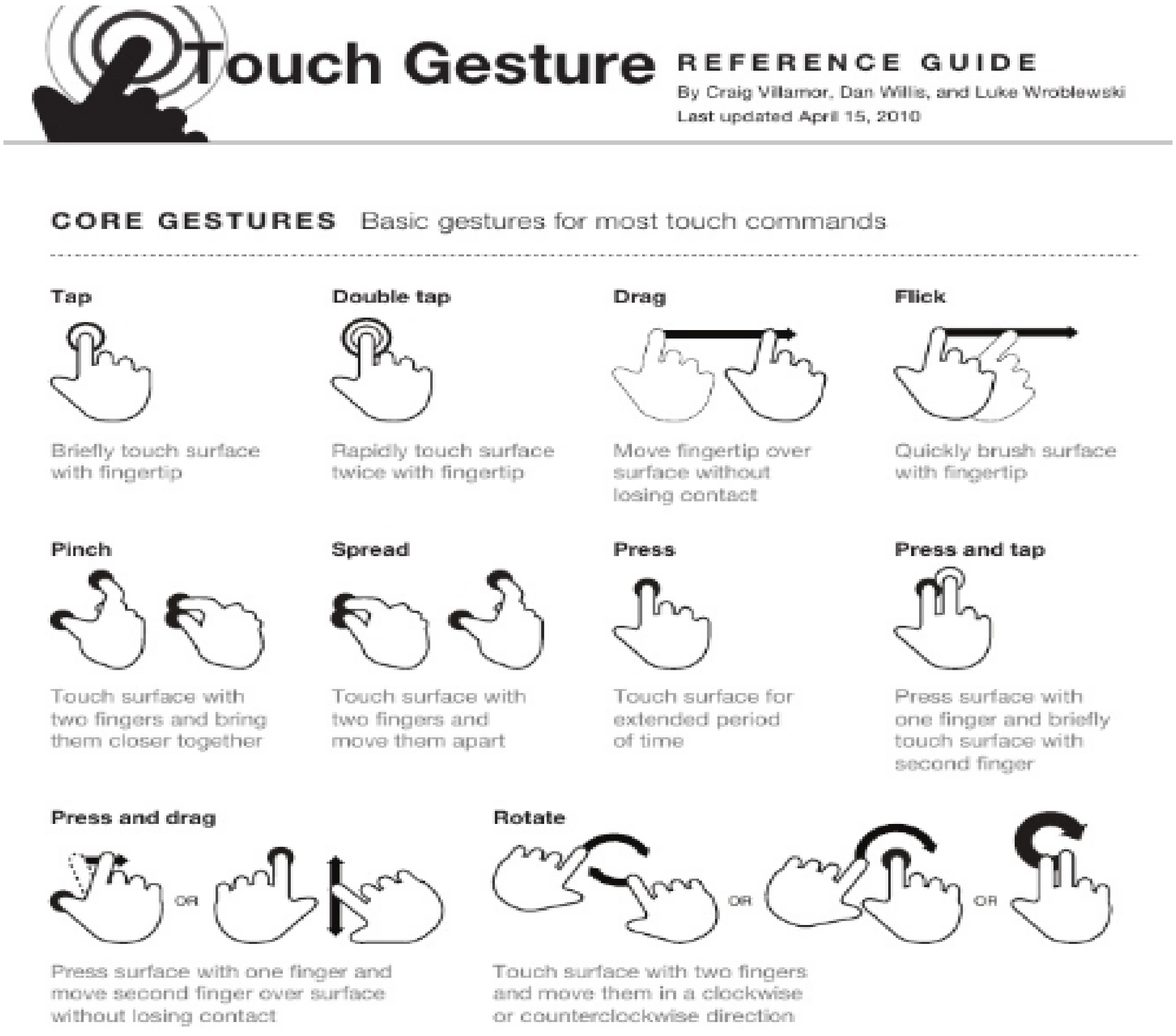


Figure 3. 1: Touch Gestures reference guide.

This picture shows some examples of touch gestures, which were very valuable to explain gesture interaction concepts and provide some examples to the participants, if needed.

3.4.3. Conducting tests with human participants.

In this study, we conducted several experiments with participants. The first experiment tests how the users perform study tasks using on the proposed interfaces, and then decide their preference interaction options upon the completion of the given tasks. Participants interacted with a mock-up map; they were encouraged to express their ideas and comments throughout their participation in the study's usability sessions. Upon completion of the tasks, participants were asked to complete a questionnaire which inquired about their thoughts regarding the proposed prototype, perceptions, satisfaction and other recommendations.

3.4.4. Collecting Information Techniques.

After recruiting participants for the study, we used three distinct methods to gather information pertaining to the usability of the proposed hybrid interfaces of the cybercartographic Nunaliit atlas which are; usability testing, focus group and semi-structured interview as explained in the following.

3.4.4.1. Usability testing.

The participants in this part of the study were students from different faculties at Carleton University. In this test, every participant was given map creation tasks to navigate (adapted from existing cybercartographic atlases), as explained in the previous section 3.4.2. Then, they were given a very short questionnaire to rate their experiences with the prototype, their thoughts towards the proposed system, their satisfaction with the prototype and to make other observations.

3.4.3.2. Focus group.

A Focus group was initially included in the research design to discuss, in depth, what each user needs from the design of the interactive collaborative Nunaliit atlas', their interface preferences, the most promising hybrid interaction options (tangible, touch and gesture interfaces) and if there were any limitations or other issues which could arise from using this system. This method was replaced, however, with semi-structured interviews, as it was difficult to arrange a suitable time for the focus group participants.

Thus, we met with them individually using an individual semi-structured interview. However, I found it is useful to report my attempts of using this method to draw future research attention of the importance of considering employing this method to learn more about the potential of this proposed technology in collaborative context.

3.4.4.3. Semi-structured interviews.

Semi-structured interviews were conducted with an open framework, which kept the participants focused, while also ensuring smooth communications regarding the study's proposed hybrid interfaces. Berge (2009) defines the semi-structured interview as a number of prearranged questions that discuss special topics during an interview. In addition, this method offers more flexibility to adjust the interview questions based upon the interviewer's perception of what seems most appropriate. The interview questions can be altered and clarifications given; inappropriate questions for certain interviewees can be omitted, or additional ones included.

The semi-structured interviews included experts from academia, as well as industrial professionals. The purpose of using the semi-structured interview method is to gain more insights regarding (1) what the user needs from the proposed designs of the hybrid interfaces in the Nunaliit framework, (2) the potential benefits and challenges of this approach, (3) to justify the users' preferred interfaces, as well as the most promising of the hybrid interaction options (tangible, touch and gesture interfaces). Further details about this study's semi-structured interview questions can be found in Appendix D.

3.4.5. Study recording techniques

Audio and video recordings were made to document user interactions in great detail, allowing author to observe and evaluate the movements of the users' hands and fingers during the interaction. However, their faces were not captured and participants had the right to check the recorded materials, once they completed the task. We were concerned with maintaining the participants' privacy and making the study convenient for them. In short, the audio-visual techniques enabled us to rigorously examine and analyse every possible interaction by the participants within the study's usability tasks.

3.4.6. Analysis of the resulting data.

This study uses qualitative methods to analyse the collected data, especially in terms of its appropriateness for capturing and analysing atlas user narratives and the mutual relationship between atlas users and their surroundings; both of that are major focuses of cybercartographic atlases. Therefore, author can evaluate and capture qualitative data to analyse and locate possible trends concerning the participants' familiarity with hybrid interactions (touch based, tangible and hand gesture user interfaces).

A quantitative analysis is a useful approach for measuring user satisfaction and their perceptions of the proposed hybrid collaborative atlas. We collected some additional data using a follow up questionnaire, upon the completion of the usability testing sessions. The questions were asked using Likert scales to evaluate participants' experiences during the study's usability map creation tasks.

4. Chapter: Data analysis and results

This chapter presents the data analysis process and the main results obtained from both the usability testing and the semi-structured interviews analysis. This analysis includes quantitative and qualitative results obtained from usability testing and qualitative analysis insights were acquired from the semi-structured interview method. This chapter is divided in two sections: Section 4.1 shows the usability tests quantitative and qualitative findings, while Section 4.2 presents the semi-structured interviews qualitative outcomes.

4.1. Usability testing findings

The author conducted the usability test at the HCI usability testing laboratory at Carleton University throughout November 2014 and January 2015. The purpose of the test was to evaluate the usability of the proposed hybrid interface designs in the Nunaliit framework to measure its information flow and the different perspective designs related to the proposed hybrid interfaces.

4.1.1. Participant statistics descriptive.

The present study includes twenty participants (eleven male, nine female), who were recruited from Carleton University. There was an age distribution of 20-50 years with the mean age of 28.7. Sixteen of them had not done any usability testing in the previous six months. Their education levels varied from a bachelor's degree to a PhD, with a wide range of industrial experiences. These data were collected from the post-testing questionnaire seen in Appendix C.

As shown in Table 4.1, we asked participants to rate their general background knowledge/information using Likert scales from 1-5 to rank their familiarity and usage of the technology. These questions pertain to the participant's age, familiarity with computers, using touch devices, willingness to use new technology and whether they were knowledgeable about technology. All of the participants were everyday users of computers, reporting 2 to 10 hours usage per day (mean = 5.9). All participants were familiar with the use of touch devices and were willing to learn and use a new technology.

Table 4.1: Distribution of Study Variables

Variables	N	Mean	Std. Deviation
Age	20	28.70	8.939
Familiarity with computer	20	4.60	.503
Hours spent on computer /day	20	5.9	1.972
Using touch devices	20	4.40	.681
Willingness to use new technology	20	4.50	.688
knowledgeable about technology	20	3.80	.834

4.1.2. Testing standards.

The usability tests were designed based on the study's overall goals. The author constructed the usability tests to ensure that the study was as comprehensive as possible and to gather both qualitative and quantitative data. In addition, the author performed a descriptive statistical analysis to provide supporting evidence for the potential usability concerns in the proposed system.

Prior to the start of testing, we provided the participants with basic instructions on how to use the prototype and set their expectations. While the participants were testing the system using the paper prototype, I observed them carefully. This was merely to observe their intuitiveness, satisfaction, limitations, confusion, etc. The result of this observation was found to be quite useful at the analysis stage. In addition to the answers from the written questionnaire and the comments regarding the proposed prototype, there was some discussion that took place after the testing. All notable observations and comments are emphasised later in this chapter.

4.1.3. Usability testing quantitative results.

The most important quantitative results of the usability evaluation are summarized in the following sections:

4.1.3.1. Task completion success rate.

I used the video recordings and the evaluator observations to monitor the participant's ability to complete the tasks. The task success rate refers to the number of successfully completed tasks divided by the number of participants. Table 4.2 provides a summary of the task completion rates. All participants successfully completed Task 1 (login/create new account) and Task 2 (search for information). Eighteen of twenty participants (90%) completed Task 3 (getting help), Task 6 (add points to the map) and Task 8 (edit previous entry). Approximately 85% completed Task 5 (add polygon/area) and Task 9 (edit polygon/area), whereas 75% of the participants were able to complete Task 7 (draw a polygon or area).

Table 4.2: Task Completion Success Rates

	Task 1	Task 2	Task 3	Task 4	Task 5	Task 6	Task 7	Task 8	Task 9
Success	20	20	18	16	17	18	15	18	17
Completion Rates	100%	100%	90%	80%	85%	90%	75%	90%	85%

These high percentages indicate that the paper prototype was designed well and the study participants were easily able to follow it.

4.1.3.2. Overall metrics.

This study asked the participant to rate the proposed hybrid interface prototypes using a questionnaire (see Appendix E), which used a 5-point Likert scale (Strongly Disagree (1) to Strongly Agree (5)) to evaluate nine subjective measures for each of the three proposed interfaces, including tangible, multi-touch and hand gesture. In the following sections, we present the results belonging to each interface.

4.1.3.3. Tangible interfaces.

Table 4.3 shows that three-quarters of the participants (75%) were willing to use tangible interfaces in map creation, while the same percentage indicated that they would use this technology in general. Seventy percent believed that table top technology is useful as a collaborative mapping tool to integrate tangible interfaces. Seventy percent of the participants also agreed that tangible interfaces assure the ease of use of the proposed system. This was supported by the fact that 85% of the participants agreed that tangible interfaces are a useful tool in mapping context. Interestingly, 80% percent of the participants disagreed with the statement that tangible interfaces are tiring and tedious. Generally speaking, this result supports the proposed study question that tangible interfaces will enhance the ease of use and the usefulness of the Nunaliit framework in a collaborative mapping context.

Table 4.3: Tangible Interfaces

Area of Assessment	Strongly Disagree (1)	Disagree	Neutral	Agree	Strongly Agree (5)	Mean Rating	Percent Agree
Ease of use	-	1	5	6	8	4.05	70
Natural performance		3	5	6	6	3.75	60
Tiring / tedious to perform	14	2	3	1	0	2.8	20
Accurate instructions	-	-	2	5	13	4.55	90
Willingness to use this option in map creation	1	2	2	9	6	3.65	75
Usefulness of tabletop technology in mapping	-	1	2	6	11	4.35	85
The capability of tabletop to enhance the ease of use in map creation.	1	3	2	7	7	3.80	70
Tabletop suitability in map creation	-	2	4	8	6	3.75	70
Willingness to use this technology in general	-	2	3	7	8	4.05	75

4.1.3.4. Touch-based interfaces.

Table 4 presents the participants' evaluation of the touch-based interface, where 100% of the participants agreed that touch-based interface enhances the ease of use of this application, and the majority of participants (80%) agreed that they would use the touch-based interface frequently in this system, if they were given an opportunity to do so. Eighty percent also agreed that the tabletop interactive atlas would keep them engaged in the map creation session. Furthermore, no one agreed that the touch-based interface was tiring or tedious during the interaction, while four participants were neutral in their answer and couple of them mentioned that they had some difficulties using touch devices, especially in cases where the display size is small. These individuals also indicated that they prefer to use traditional keypads (with physical button), but occasionally they need to use touch screens and they like to use a stylus with their iPad to be able to use these devices efficiently.

Table 4.4: Touch-Based Interfaces

Area of assessment	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Mean Rating	Percent Agree
Ease of use	-	-	-	4	16	4.80	100
Natural performance	-	1	-	2	17	4.75	95
Tiring / tedious to perform	13	3	4	-	-	1.55	0.00
Accurate instructions	-	-	-	8	12	4.60	100
Willingness to use this option in map creation	1	1	2	5	11	4.20	80
Usefulness of tabletop technology in mapping	-	-	2	5	13	4.55	90
The capability of tabletop to enhance the ease of use in map creation.	1	-	2	10	7	4.10	85
Tabletop suitability in map creation	-	-	2	4	14	4.60	90
Willingness to use this technology in general	-	1	2	8	9	4.25	85

4.1.3.5. Hand gesture interface.

Table 4.5 demonstrates the participants' evaluation of the hand gesture interface, where the majority of the participants (85%) agreed that the hand gesture interface assures the ease of use, and 80% agreed that this option is a very natural interaction, allowing the user to feel as if they are in control of the system by moving it, rotating it, etc. Moreover, 90% of the participants believe that using multi-touch and hand movements in the tabletop interactive atlas would keep them engaged in the map interaction session and that it would be a useful and friendly user interface. This is supported by the high percentage (90%) of participants who agreed that a hand gesture interface is a suitable option in map creation, especially in a collaborative setting. However, 10% agreed that hand gestures might be tiring or tedious during the interaction, especially for older users.

Table 4.5: Hand Gesture Interface

Area of assessment	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Mean Rating	Percent Agree
Ease of use	1	2	1	6	10	4.10	80
Natural performance	1	2	-	8	9	4.10	85
Tiring/tedious to perform	9	6	2	1	1	1.95	10
Accurate instructions	-	-	1	11	8	4.35	95
Willingness to use this option in map creation	1	2	1	6	10	4.10	80
Usefulness of tabletop technology in mapping	-	1	1	6	12	4.45	90
The capability of tabletop to enhance the ease of use in map creation.	1	-	3	9	7	4.05	80
Tabletop suitability in map creation	-	-	2	9	9	4.35	90
Willingness to use this technology in general	-	1	3	7	9	4.20	80

4.1.3.6. Summary.

The author recapitulates the detailed results of the previous tables through the creation of a comparative graph, as shown in Figure 4.1. Evidently, the self-reporting usability questionnaire demonstrates that participants are generally positive towards all three of the proposed interfaces (tangible, touch and hand gesture) as a useful tools to be implemented in the cybercartographic Nunaliit atlas. The touch-based interface appears to be the most favourable interface in most areas of assessment, such as ease of use, natural performance and accuracy. Generally, participants believe that this interaction option would be the most suitable interface in map creation and they were willing to use it as a first option, if they were given the opportunity to interact with the proposed hybrid interface system. Interestingly, all of the participants noted that this option would not be tiring or tedious during the interaction. The second most favourable option is the hand gesture interface, which had similar result to those of the touch-based interface, where participants believed that most of the actions in those interfaces required both participants' hands and fingers.

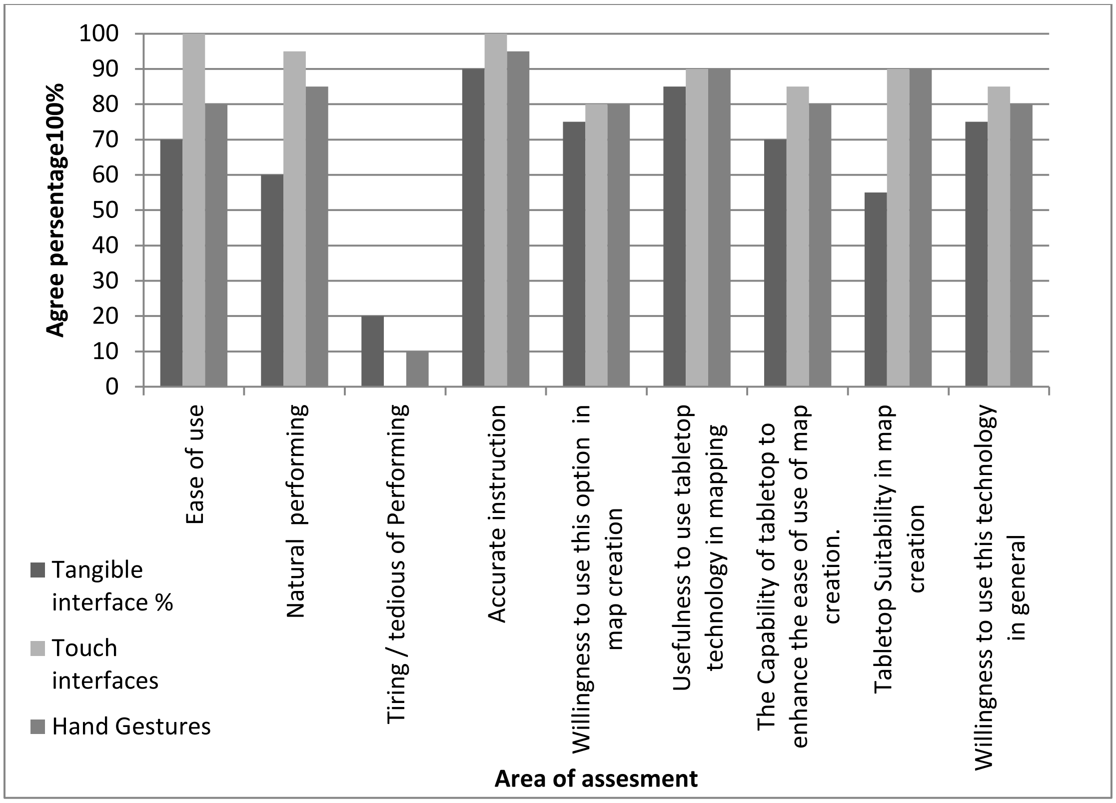


Figure 4.1: Comparison of the proposed hybrid interfaces. Note: The percentage axis refers to the number of participants who agreed and strongly agreed (scale 4 and 5 from Likert scale) divided by the total number of study participants.

The tangible interface were very closed in the participants agreed percentage compared to the touch-based and hand gesture interfaces, although there were slight differences in terms of how the participants perceived this interface. The results show that the tangible interface requires greater effort to make the software intuitive and to provide more reasonable interaction options in collaborative mapping context. I found that even though most of the participants believe that the tangible interface is not as popular as the touch-based and hand gesture interfaces, they have confidence that increasing the popularity of the tangible interfaces in the future will increase the its capability as an interaction methods in map creations. This is well supported by the fact that most of the participants agreed that a tangible interface is effective way to enhance the natural interaction and they demonstrated keenness to see the actual working prototype that would use the tangible interaction in the creation of a collaborative map. Although the participants responded to tangible interfaces in a slightly less positive manner than the other proposed interfaces, they nevertheless showed that there is great potential for using them in the implementation of a functional system, as it will increase the system accessibility for different users.

In addition to these nine areas of evaluation, the test evaluator asked the participants the following open-ended questions, which are discussed in the qualitative results section:

- Can you explain any comments that you have on any of these three interfaces: tangible, touch and gesture?
- What do you like most?
- What do you like least?
- Can you elaborate any recommendations for improvement for each of the proposed interface (tangible, multi-touch and hand gesture)?

4.1.4. Usability testing: qualitative results.

Qualitative data was collected from observations made by the test evaluator and video recordings of all the usability sessions, so as to track and investigate every possible interaction. The author divided the results of this section into four categories: usability concerns, tangible, touch-based and gestural interfaces. The results follow.

4.1.4.1. Usability concerns of the study.

As part of the observations process, the test evaluator created a usability concern (problem) list in order to record any issues that the participants experienced during the tests. This list consists of all the problems that the participants encountered during the course of the tests, as shown in Table 4.6.

Table 4.6: Usability Issues Table for the Three Proposed Hybrid Interfaces

Tangible interface issues/concerns	Touch interface issues/concerns	Hand gesture interface issues/concerns	General comments
Too many tokens on the map	Other users interruptions	Different ways to use hands might be confusing	Need a facilitator
The tokens might get lost	Direction of the interface (Who is going to face the map view?)	People need to be trained	Does this application support special needs users
How can multi-users perform interactions and does every user require a separate set of tangible tokens	The deeper zooming might result in a loss of text.	Some people do not like to use both hands, but in this system two hands might be necessary	Direct this interface to face the user who performing something in the map, and enable rotate interface for other users
The user requires training before using it	Could be tricky for a novice user	Good for three dimensional application	Using a hand to spin or rotate the interface might cause an interruption by another user
Allocate tangible interface for the major tasks	Not quite sure what touch pattern will be used to manipulate the map	Its hidden features need to be explained somewhere in the system	Collaborative multi-users
Tangible interface issues/concerns	**Touch interface issues/concerns**	**Hand gesture interface issues/concerns**	**General comments**
Not sure where to place the tangible token on the map	Add/edit map feature is not clear enough when using touch interface	Show zooming bar to manage the desired level of zooming	Some people may not like to use one particular interface
Some participants removed the token before completing the required action		User needs to get familiar with it	Engage and entertain user for the whole session
			Need to implement a stats bar on the screen for more functionality
Not suitable for certain tasks			The background map appeared crowded and were printed in red colour

Feelings of Uncertainty

At the beginning of the interaction sessions, one-third of the participants were not fully aware of what they were going to do or what they expected to see. This was observed in their body language and their eyes movements, as they tried to grasp and get familiar with the prototype. Others asked questions about the circle maps, especially in regards to the tangible tokens and their function. This uncertainty encouraged the test evaluator to give a five minute briefing in regards to the current system—the Nunaliit framework – and the purpose of this study. After an introduction to the system, the participants became very engaged while performing the planned usability tasks.

Natural Interaction

The majority of the participants confirm that the tangible interface is one of the novel interaction ways that makes users feel that they are in control of the system, as it allows the user to sense, grasp and see direct feedback while you move or place physical objects on top of the map surface. It is a good method in which to engage users for long interaction sessions, while also supporting learning and creating a fun environment to generate ideas in a collaborative setting.

4.1.4.2. Using tangible interfaces.

The collected data shows that most of the participants were excited to experience tangible interfaces as a novel interaction way to interact with interactive maps. Most usability testing participants claimed that this form of interaction is really new in a mapping context, although they were aware of other applications that use this technology, such as Microsoft Surface and media-Blocks (which is a tangible user interface based upon small, electronically tagged wooden blocks) etc. Yet, the proposed use of the technology is definitely new and the users were enthusiastic to see the actual system upon its completion.

On the other hand, several users had some concerns regarding the tangible interface in term of accuracy, suitability, mobility and affordability. For example, participants believed that the atlas maps represent spatial data that is complex in its nature and, thus, required a high degree of accuracy. In addition, almost one-third of the participants were convinced that tangible interfaces are good for some tasks (major tasks), but were not suitable for all tasks in the interaction process. One of them asked,

> *"Do we really need tangible tokens to login in to the atlas or logout?" but the same participant said "using tangible tokens would be excellent to add features to the map or to provide a friendly metaphor, like the circle shape, which will enhance the user's engagement with the atlas.*

Other participants criticized the possibility of moving this table, ensuring that the tangible tokens do not also get lost; they believe this technology will be expensive for the first generation of implementation.

This study proposed that using tangible interactions would make the map viewing, reviewing and adding/editing easier to learn and, thus, easier to use than the current version of the Nunaliit framework, as the newer version is more user friendly. The usability results support these hypotheses, demonstrating that the implementation of tangible interfaces in the Nunaliit framework makes the map intuitive, which allows the user to perform their interactions effortlessly. A group of participants showed high confidence while using the tangible interface, but suggested integrating other user interfaces, such as touch-based, to give the user the freedom to choose and perform map tasks with different interaction methods. The following are some participant quotes:

> "I *think that tangible objects are very exciting tools, as they could potentially make it easier for people who are less technologically inclined to add geographic information to maps".*
>
> *"It was a new idea that I would have never thought about before. It makes the whole experience more engaging and interactive. However, because it is something new, I feel like it could take a while to get used to it.*
>
> *"It good to see tangible options, but it is not the first thing I would use".*

4.1.4.3. Using multi-touch interfaces.

Participants showed a great desire to use touch interfaces as a preferred way to interact with the map, even though one quarter of the participants tried to touch the tangible token, instead of using these physical tokens to directly perform the required action. When the participants were questioned about their actions, they answered that they thought the tangible tokens were hot function buttons or keys. This confusion occurred at the beginning of the test because we used a paper prototype, which was challenging for participants who could not see an actual feedback for their interaction. However, after explaining the functionality of these tokens, the participants performed the rest of the tasks without any misperceptions.

The majority of the participants believe that multi-touch interfaces are a valuable option that should be utilized in the proposed design system. According to the participants, this type of interactions is well-known and most people have experience with it. Thus, they found themselves using the touch interface without any hesitations and it was the first option they considered when they needed to perform any task in the proposed system.

On the other hand, our observations showed that touch and gesture interfaces were not as comfortable when using large screens. Participants believed that touch and gesture interfaces might require more efforts on a large screen. For instance, in some cases dragging, panning or zooming across a large display, involves more direction than performing the same action on a mobile phone-sized screen, they found that some pinching that could be performed easily with one hand on a small mobile screen, needed two hands on the large display of the tabletop. In addition, using a large touch keyboard on a large screen requires more time to type, which could be more tedious.

4.1.4.4. Using hand gesture interfaces.

The results of the tests concerning the usability of the implemented gestures were also generally positive, though the gestures for manipulating, panning and performing free hand gesture need to follow a certain interaction pattern to avoid any confusion. This also supported by the fact that participants confidently responding to questions concerning hand gesture interfaces as a promising interaction option in the proposed cybercartographic Nunaliit framework tabletop atlas.

The following are general comments made by some of the participants in the usability test in regards to the whole proposed system:

> *"You know, I think it is very exciting to be able to use different options to interact with this system."*
>
> *"I wasn't very sure about what was happening and what would be*

happening if I changing anything. I would probably have liked more clear/explicit visual feedback in actual system"

"More instruction should to be given prior to the experiment in terms of the functionality of the tested prototype."

"It always seems great to have everything action and implemented in the UI in case users prefer to stick with the UI instead of tangible objects. From my test today, I seem to find the tangible objects as a shortcut to tasks I would like to perform and would be perfect for multiple users".

4.2. Semi-structured interviews findings

The author conducted ten semi-structured interviews with professionals from various experiences and interdisciplinary backgrounds, and researchers who are familiar with participatory research, some of whom were participating in the creation of the Nunaliit framework. These interviews replaced the proposed focus group method, as we found it challenging to gather those who had agreed to participate all at one time. The semi-structured interviews generated several useful ideas, which allowed us to arrive at a better understanding of the proposed hybrid interfaces, and to validate some of the results of the usability study. In addition, the interview findings provided valuable insights, which assisted our efforts to design the appropriate guidelines requirements for implementing the proposed hybrid interface in the Nunaliit framework, as shown in Chapter 6.

4.2.1. Interviews qualitative results themes.

Semi-structured interviews played a central role in our exploratory study to investigate the potential for implementing hybrid interfaces in the Nunaliit cybercartographic atlas, in particular, and the use of this technology in map creation, more generally. We used a thematic analysis to systematically identify and describe features of qualitative data, which would inform the design of new interface generation for the Nunaliit framework.

Fifteen overarching themes emerged from a detailed thematic and comparative analysis of the recoded video tapes of the interviews. The themes generated from these analyses highlight a wide range of assessment areas of the proposed system functionalities, as summarized in Table 4.7.

Table 4.7: Semi-structured Interview-generated Themes.

Themes	Sub-themes	Concepts
General thoughts	Overall impression Using tangible tokens Benefits of using three interfaces	Most interviewees showed a great interest in the proposed system and reveal their own beliefs on how valuable this technology will be in map creation; however, they introduced some other related concerns.
Atlas shape/size	Circle metaphor Size accommodates up to 5 users	The circle shape of the application is a natural metaphor to engage the potential users and enhance their interaction experiences.
Ease of use	Consistency Simplify the design Minimizing the number of actions required to perform one function Universal symbology Control the map Animation help menu.	This system enables an easier way of achieving the goals of the Nunaliit framework, such as interacting with the map effortlessly and effectively. This is achieved when a typical user can use this technology and perform all of the necessary functions quickly and without undue effort.
Cognitive work load	Motions required to perform certain actions	Previous research shows that there is no way to eliminate the cognitive load entirely (Whitenton, 2013). In fact, even if this was possible, it would not be desirable for the system design. Thus, we strive to minimize the user's cognitive load by utilizing the best usability practices and building on the existing user's mental model of the current interfaces from their previous experiences.
Collaboration context	Multiple users Free dialogue Sharing interaction with social media	Examine the design of the interfaces for multi-users collaboration from an interaction design perspective. And how this concept can make a positive contribution to the existing Nunaliit framework.

System content	Free text/form fill Drop down menu Add points Add lines Add polygon Edit previous entries Map as a connecting or trigger point Map as informative tools	The system design in this study uses the existing content of the Nunaliit framework and tries to improve the presentation of this content by introducing a new iterative generation of the Nunaliit framework that leverages the benefits of multiple interfaces to achieve the Nunaliit framework efficiently.
Map Navigating	Map orientation Interface orientation Map index	The designed circle shape in the proposed system, which will be used by multi-users, requires some level of organising tools or process to ensure the system efficiently supports this collaboration process.
Authentication process	Authentication option	Multi-touch displays and tabletops that are able to detect and track user interaction suffer from one drawback: they are not capable of analysing 'who' is currently touching and interacting with the system. Thus, user ID is desirable in collaborative working processes. It permits user authentication.
System functionality	Switching the mode Tangible	The proposed system sought to meet the Nunaliit framework mission. Thus, we strived to achieve these outlines by enabling the user to manipulated the atlas maps in a very easy way and provide them with various options when they intended to perform certain functions, such as adding points, lines, polygons, telling a story and much more.
Facilitators	Using facilitators	Our usability tests reveal that a mediator is needed to facilitate multiple user interactions and solve any potential issues, especially during the initial development process of this proposed system.
Value of the technology	Practicality Accessibility Learnability User experiences Engagement	The study hypotheses that this technology will be a valuable tool in the context of map creation.
Interface preferences	Tangible Touch Gesture	Providing different interfaces permits the user to interact freely with the system and increase the accessibility of this application.

Potential audiences	Participatory researcher Indigenous people Education	This technology will be available for use to a wide range of stakeholders, such as: participatory research, educational tools, planning tools (to generate new ideas on different topics) and much more.
Language preferences	English French Other	The existing Nunaliit framework supports both English and French as the main language of interactions. We would also like to integrate local indigenous languages, such as Inuktitut and Inuinnaqtun.
Potential design challenges	Multi-user identity Tangible and precise location Sharing information Privacy concerns	This theme opens the dialogue to reveal any potential concerns that designer need to consider when implementing the working system.

The semi-structured interview themes were generated by carrying out a comprehensive evaluation of the proposed hybrid interface technologies as an input adding/ editing tools in the Nunaliit Framework. In the following section the author highlights the most important results relating to the fifteen aforementioned themes.

4.2.1.1. General thoughts.

All of the interviewees expressed great excitement for the proposed system. They stated that this technology offers a high level of mapping that supports real time interaction. For example, interviewees liked the idea of having three different interfaces, which enhance the user’s ability and accessibility to perform functions in different ways. This feature is very promising for telling stories or adding information to the map dynamically, where the user could discuss a topic or share a story temporally and, once all users agree on the importance of selected points, they can ultimately transfer the discussed points permanently into the map. This flexibility of interaction enhances the natural interaction and keeps the users engaged for the entirety of the collaboration sessions. On the other hand, others believed that to achieve the goals of this innovative technology, the designer and developer need to adapt the findings of this study and leverage similar existing technology to implement a functional system; nevertheless promising that this technology will be valuable in map creation. Other related concerns were introduced. For instance, one interviewee from a geomatics background said:

> *"In the participatory research we used physical (paper) maps as a connecting point that enabled users to interact and discuss various topics. It enabled them to draw different ideas using markers and paper and then researcher needed to sit for a long time to edit and validate this information and finally digitize the collected data (enter them to the digital map) in order to prepare the data for other software and so on… I see that this proposed technology will be capable of performing all of these traditional methods…should this technology successfully achieve its goals, we will definitely notice the difference and value its importance".*

4.2.1.2. Atlas shape/size.

The majority of the participants and interviewees agreed that the proposed size of the atlas was useful in terms of enabling multi-user interactions in real time. We have chosen the reactable table to be optimized in the Nunaliit framework for several reasons: this circular shape are convenient to engage multi-users where it distributes the power between the users and make them feel equal while interacting with the system and, the table is a portable and can be folded on a compact shape which going to be very useful and easy to be used as a mobile adding/editing tools in the GCRC participatory research in Canada's' north, thus it will even enhance a more portable experience. This system is built upon the reactable musical instruments, which can be seen in Figure 4.2. The reactable is 85 cm (33.5 inches) in diameter, 90 cm (35.4inches) in height and the screen has a diameter of 68 cm (26.8 inches). The reactable is made of aluminium materials and an acrylic screen.

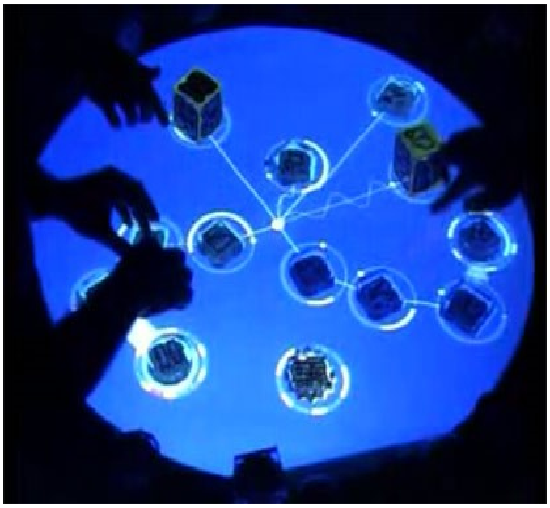


Figure 4. 2: Reactable system. Picture on the left retrieved from http://fronttoback.org/wp-content/uploads/2008/01/reactable.jpg. And the one on the right from http://blog.dubspot.com/files/2011/11/reactable_live2.jpg

I would like to share a quote from one of the interviewees in this regards:

> *"This circle shape is a very useful and respectful design. It distributes the power between the users and makes them all feel equal, thus contributing to the real engagement experience… I like the idea of enabling the 360 degree rotation function. What a real, natural interaction this system provided!"*

With respect to this quote we find some challenging in rotating the whole map which could lead to some sort of confusion between the users. Though we might consider rotating only the map labels (texts) this way user could drag and rotate the map labels to make it easier for them to read the map features from their position on while they interacting with the map. This area worth further investigation and I explained this challenging in the future study section.

4.2.1.3. Ease of use.

The interviews showed that the proposed hybrid interfaces provided smooth interaction processes, which assured its ease of use by a wide range of potential users. Most of the discussions in this theme suggested that this system could provide a successful user experience by focusing on several designs rules, such as: minimizing the numbers of actions required to perform one function, providing shortcuts or alternatives and optimizing the tangible tokens for the major tasks in the proposed system. We also hoped to gain inspiration for the design by asking questions, such as: is proposed interface more accurate? Does it minimize the time required to perform one task? Is it more accessible in term of functions? Is it meeting the user's expectations?

In addition, some GIS specialists suggested that the system should implement an index map and a task bar to visually inform the user about their performance. They also suggested using universal symbology for the tangible tokens, keeping the interactions uniform, minimising the steps required to perform one function and to avoid switching modes while performing one action. He said that "*for the best user experience, the system should minimize the amount of interaction as little as possible and avoid too much manipulation…otherwise the user will simply give up."* All of these insights are important and are discussed further in Chapter 6.

4.2.1.4. Cognitive work load.

The analysis shows that people, at present, are familiar with touch and hand gesture interfaces, thus the implementation of these interfaces will build on existing user experiences. Therefore, this will minimize the amount of training required to use the atlas. Furthermore, the interviews revealed that tangible interfaces need to be well designed, as it is a new and innovative method in map creation which will take time to become as popular as touch interfaces. One interesting quote stated,

> *"I believe that using too many interfaces and tokens could cause confusion in some users, but if the system is designed very well, to be simple and work properly, these issues could disappear"*

4.2.1.5. Collaborative context.

Eight interviewees believe that this technology is valuable and effective in collaborative contexts–that is, in face to face conversations. They also mentioned several benefits of the collaborative interaction, including: verifying the collected information from different users; social interfaces assure a natural interaction; excellent way to generate ideas; and they trigger peoples' memories and gauge their interests, allowing them to contribute more to the discussion process. However, two interviewees only partially agreed with the benefits of this technology in a collaboration setting, noting that this proposed tool would be valuable to some extent, but they were cautions about how successful and accurate this design would be in term of multi-user interaction. Therefore, they believe it would be challenging for this design to meet different users' perceptions, especially in a complex context like map creation.

4.2.1.6. System content.

The proposed atlas design makes use of the existing content of the Nunaliit framework and attempts to enhance its user's experiences. The new design presents a new form of interfaces that will engage cybercartographic atlas users and achieve its mission of presenting public information and interpreting rich sources of data in a digitally innovative way. All the interviewees agreed that a proposed hybrid interface is an innovative way to approach map creation, and that the new iterative generation of the Nunaliit framework provides Nunaliit users with flexible tools to present and achieve the Nunaliit framework's goals efficiently and effortlessly. Further discussion of this theme is presented in Chapter 6.

4.2.1.7. Map Navigation.

The interviews showed several interesting ways in which the maps could be navigated. For example, some people liked to navigate the interactive maps using the "zooming in and out" function to identify the preferred location on which they want to work, yet this is method is only suitable for people who are familiar with maps and landmarks.

The most interesting result shows that Navigation function should be easy to find and follow. Thus, the design should implement a tool bar, like an arc shape or half circle, to seamlessly enable visual navigation for the whole system. It can include the major system functions which the user requires to perform their desired interactions goals. By doing this, users will be focused on the tasks (map itself) by minimizing the amount of icons and tokens on the surface of the map.

In addition, navigation should consistently be in the same location on the screen; by maintaining a consistent style the users will adapt to the system more easily and interact with it more comfortably. Interviews also supported the idea of reminding the user where they are, by implementing a real-time index map and small campus directions.

4.2.1.8. Authentication process.

Most of the interviews revealed that the advantage of this system is to permit multi-user interaction, together with complete visual access, to the entire tabletop atlas screen. Yet, individual interaction, such as authentication, provides a significant design challenge. The social context of the proposed system interactions presents a real challenge, as users may feel uncomfortable entering their passwords in the presence of other users. Here is one quote taken from an interviewee who seemed concerned about the authentication process in the proposed shared system:

> *"I would like to use this technology with other users, but when it comes to logging in using personal information, I'm not as comfortable typing in my login or creating a new account with multiple people watching me. Instead, I guess you can generate a temporary access, which could be modified after completing the session. I don't want to upset the other users by trying to hide my information. Also, we are gathering to interact collaboratively, so if they felt uncomfortable by my privacy concerns they might lose interest collaborating with me in the session".*

4.2.1.9. System functionality.

The results of the interviews suggest that this hybrid interface will be an effective input/editorial tool in mapping contexts. To achieve or support this goal, the proposed system should permit several major functions, including (1) the ability to interact with the map effectively while sharing one's thoughts with other users, (2) making the interaction process as natural as possible, so as to enhance the users' engagement and enrich their interaction experiences, (3) creating new entries in the map by using different interfaces to increase the system accessibility, (4) editing previous entries to minimise errors and validate the quality of entered data, (5) the ability to directly upload/record any related audio or video files, (6) enabling screenshots and whole session recording, where the session could be played back later on (this would require user permission), (7) minimising the amount of work for the people who intend to use it, in comparison with the existing or previous techniques.

All of these functionalities were also measured in the study's usability tests, which supported what we discussed in the results of the semi-structured interviews.

4.2.1.10. Facilitator.

The interviewees all agreed on the significance of using a mediator in the proposed system to facilitate the users' interactions with the collaborative atlas. This individual could verify the users' entries, solve clashes amongst users, make the interaction session more efficient, help novice users and enhance the users' experiences in general. In addition, facilitator play a central role to assist people who are not familiar with the technology, we intended to employ a youth facilitator from the local community to facilitate the interaction of user who are not familiar with the technology and other elder people in the Canada's' north. Some interviewees stated that having facilitator might limit their ability to fully interact with the system, *"I believe having a session facilitator is a good idea, especially at the very first stage of the design, but it could lead to interruptions for other users. Instead, the system should enable different levels of function to perform most of the proposed system functionality with minimal guidance"*.

4.2.1.11. Value of the technology.

We can summarise our discussion with the ten interviewees for this particular theme with the general statement that increasing the ease of the system will increase its value. The real contribution of this technology is to support the existing Nunaliit framework and improve its main products, which are cybercartographic atlases. This new improvement keeps the Nunaliit framework up-to-date with the current technology, in terms of collaborative contexts. Other interviewees claimed that the design should use open-source software, which could accommodate different applications or domains that use the map as a means to connect with their users.

4.2.1.12. Interface preferences.

Interviewees supported the use of the three different interfaces (tangible, multi-touch and hand gesture) and their thoughts towards each one are outlined as follows:

Tangible interface

Tangible interfaces bring several advantages to the proposed system, such as: enabling users to manipulate the maps as equivalents to physical maps, and then transferring this interaction into the digital world. This would allow the user to feel in control of the system, for example, by grabbing different tokens and experiencing a direct feedback from this interaction. However, some interviewees were concerned that using a lot of tangible objects might lead to some confusion; instead they suggested optimising this interaction option with the major functions, so as to increase the accessibility of those functions and distinguish the major tasks from others.

Multi-touch interfaces

The interviewees noted that the touch interface should be the primary way to use the map, as touch technology is a universal method of interaction. Therefore, by implementing an interface that is already familiar to a wide variety of people, the design will then build on existing user experiences, which will ensure the ease of use and minimise the amount of training and time required to become familiar with the new technology.

Hand gestures

The majority of interviewees agreed that the use of hand movements is a rich interaction tool; it is also the best means to enhancing natural interactions. However, the participants introduced several critical questions, such as: which part of the hands really touches the screen, and is the system capable of capturing all of the user's movements, especially in a multi-user interaction. For example, while performing map zooming, the user can manipulate the screen in different ways: taping, using two fingers with one hand, using both hands, using all five fingers of one hand and using the whole hand with both hands.

Therefore, this interfaces needs to consider and support different hand gestures, while also adapting existing gesture technologies to leverage the current user experience and enhance the system's user-friendliness and its ease of use. Other interviewees suggest that the system design should use 3D technology to fully implement gesture interactions, which could recognise and leverage the richness of human hand movements.

4.2.1.13. Potential audiences.

The key factor to the creation of a successful design is recognizing the system's audience. This is an ongoing challenge for the Nunaliit framework, as an open-source online atlas that is open to wide-range of users. In this study, however, we focused our design to meet the needs of an average user of the cybercartographic Nunaliit atlas . The purpose of this technology is to use it as a portable input/editorial table to gather various type of information from urban environments and rural areas. Therefore, we expect that anyone could use this technology, including students, researchers, indigenous people and so forth.

During the interviews the participants insisted that the interactions should be kept as simple as possible, so that the system could easily be used by the general public. In addition, they liked the idea of having an animated help menu, which could take the users on a short tutorial when they use the system for the first time. This would assure their familiarity with the system within few minutes.

4.2.1.14. Language preferences.

The existing Nunaliit framework supports both English and French as the primary language of interactions; this system will also consider local indigenous languages, such as Inuktitut and Inuinnaqtun. However, the designer will need to gain in-depth understanding of these languages from professional linguists before they are integrated into the system. The implementation of local languages in the system interfaces will benefit the participatory researchers who are working with local indigenous communities. It will also enhance their interaction process and enable them to presents their culture in its language of origin.

4.2.1.15. Potential design challenges.

Digital tabletop displays offer many new possibilities for attracting the attention of passers-by in public settings and offer the promise of new styles of interaction. This theme opens up a wider dialogue to reveal potential design concerns that need to be taken into consideration when implementing the working system. As above-mentioned, Table 4.6 summarises all of the usability issues for the proposed hybrid interfaces. Those challenges will be addressed in the Nunaliit design guidelines in Chapter 6.

Chapter 5: Discussion

This chapter discusses the results obtained from the usability test and the semi-structured interviews, while also addressing the validity of research questions. The author interprets and discusses the findings relating to any usability concerns, as well as the participants' comments on the Nunaliit framework, design and interaction.

This section summarizes the major findings, while being careful not to overstate the results. In addition, it compares the findings of this study to those of previous studies in the field. This section reinforces the significant findings that have led us to suggest the most promising interface options. This was achieved by combining the findings of previous studies with the results taken from the present study. This combination shows the similarities and differences between the usability tests and the semi-structured interviews, on the one hand, and how the findings either confirm or cast doubt upon the previous results in this field, on the other hand; especially with respect to the diverging natures of the previous studies and those carried out in the present study.

The results of this study were based on a paper prototype, which is a valid method to evaluate a new design, especially in its initial stage. Most of the other studies, however, used a working prototype to evaluate various applications, many of which are similar in context to the present study; particularly in terms of testing the functionality of hybrid interfaces.

5.1. Overall Exploratory Thoughts

After careful observation and analysis of the 30 video records, which lasted on average between 40-70 minutes each, we compiled a significant amount of qualitative and quantitative data, which resulted in an in-depth understanding of the most appropriate interfaces to implement, the anticipation of several challenges in terms of design and practices and a strategy to ensure the ease of use of the cybercartographic nunaliit atlas. The significance of this study is that it acquires real user experiences and different viewpoints from a wide-spectrum of participants and professionals interviewees, who offered helpful insights and recommendations that contributed to the findings of the study.

With the large amount of collected data, it was necessary to perform qualitative analyses that used both the thematic and the comparative methods. These techniques were employed so as to harness the collected data and make significant connections between different perspectives, thus resulting in a meaningful organization of the data, as presented in the previous chapters.

The analysis generated from the results of the usability tests and the semi-structured interviews led to several significant findings. The first of which is that the participants found it easy to follow the tasks associated with the prototype. All of the participants answered “Agree” and “Strongly Agree”, when asked if they would use the proposed interfaces in the creating of the cybercartographic atlas using the nunaliit framework.

Other participants were not certain as to what was happening at the very beginning of the test, as a few of the participants asked for clarification. This did not surprise the author, as this was observed during their recorded interactions with the mocked up paper prototype. We noticed a level of uncertainty while certain participants were running through the tests, whereas, we have witnessed enjoyment and satisfaction in other users, who effortlessly and quickly understood the testing process, when they began performing the given tasks.

From this study, we note that the design of the testing prototype should provide the user with more visual feedback to increase testing accuracy and ensure that the participants performed the proposed paper prototype of the new interfaces accurately. As demonstrated in the literature concerning usability, it is acceptable, and even recommended, to start testing new products using paper prototypes. Since this study sought to evaluate a novel approach to the atlas interface in this study, it was recommended that we use a low fidelity prototype in the early stage of the design. In addition, emphasis was given to uncover wide-ranging perceptions and the capabilities of the proposed hybrid interfaces using this paper atlas prototype.

The evaluator gained more insight into some of the participants' experiences during the discussions that occurred after the tests were completed, which helped us to understand and analyse the participants' interactions with the prototype more accurately. For instance, one particular participant admitted that he has a very little experience with tangible interfaces, especially their use in an interactive mapping context. This explains the hesitation and confusion he demonstrated when using the prototype during the test, and ultimately resulted in his request for an explanation of the system, when the test session had concluded.

5.2. Answering the Research Questions

This study carried out a holistic analysis of natural hybrid interfaces (touch-based, gesture and tangible interfaces) as novel interaction tool that has the potential to promote a new form of collaborative tabletop interface using the Nunaliit framework to create cybercartographic atlases. As a way to investigate these claims, the author utilised a paper prototype to evaluate several possible concepts of hybrid interaction and their direct impact on the Nunaliit framework.

The results and analysis of the data from the study have answered the research questions positively with slight differences on participants' preferences of the proposed three hybrid interfaces, which are: To what extent are hybrid interaction interfaces useful in enhancing collaborative user interaction with cybercartographic atlases? Can these interfaces improve the usefulness, ease of use, or enhance an atlas user's experience while viewing, adding or editing map information?

The study results confirmed and answered the research questions, which is achieved by dividing the discussion into three major categories that reflect the three proposed interfaces (tangible, touch-based and hand gesture). Then, we conclude by shedding light onto some crucial concerns regarding the implementation of this novel interaction with the cybercartographic Nunaliit atlas.

5.3. Tangible Interfaces

A quantitative analysis of the results from the usability testing demonstrates that three quarters of the participants were willing to use tangible interface as collaborative mapping tool in a large surface tabletop. They noted that tangible interfaces ensured the ease of use, as it felt very natural to control the map while adding/editing information to the proposed system. Interestingly, 80% of the participants disagreed with the statement that the tangible interface was tiring and tedious. As a result, these outcomes support the research question that asks whether a tangible interface will enhance the ease of use and the usefulness of the Nunaliit framework in a collaborative mapping context.

The qualitative findings for both the usability tests and the semi-structured interviews confirmed that using tangible interface is a useful new approach that should be integrated into the proposed cybercartographic Nunaliit atlas, and they were enthusiastic to see the system once it is ready for actual use. Both of the experimental methods show that a tangible interface offers several advantages to the proposed system, such as enabling users to manipulate the maps in the same way as physical maps and then transferring this interaction into the digital world, where the user can obtain direct feedback from their interaction.

In comparison, a number of participants showed some concerns regarding the use of a tangible interface in terms of accuracy, suitability, mobility and affordability. In addition, some interviewees noted that using a lot of tangible objects might cause some confusion. Instead, they suggested optimising the tangible interface implementation to be used as alternative interaction option for the major functions, so as to increase the system functionality, accessibility and to differentiate the most important tasks in the cybercartographic Nunaliit atlas framework.

These results are supported by findings in the previous studies, as Marshall (2007) found that tangible interfaces support face-to-face collaborative work, permitting multiple users to interact with the system while collaborating with each other.

5.4. Touch-Based Interfaces

Interviewees and participants both indicated that touch-based interfaces should be the primary interface used in the Nunaliit framework. Touch-based interfaces have become a widespread method of interaction, and the general public is familiar with most touch devices. Therefore, implementing this option will benefit the proposed system, as the design will build on existing user experiences, ensuring the ease of use and minimising the amount of training or learning time required to familiarize the user with the new technology. This supported by Buxton's (2008) argument that multi-touch technology has been present for decades, as Apple products made this technology famous through their use of multi-touch interfaces in products such as the iPhone, iPad and iPod.

The present study reveals that implementing this popular interface in the cybercartographic Nunaliit framework atlas will be a significant development within this framework, and mapping in general. The users showed their familiarity with touch technology in small-sized devices and some of them had already used it with large screens; therefore, they believed that multi-touch technology is capable of supporting multi-user interaction on large screens. An earlier study by Wobbrock, Morris, and Wilson (2009) came to the same conclusion, arguing that multi-touch technology for small screens could be applied to a large display. This has in turn influenced the growth of gesture technology for tabletop surfaces, while also enhancing user acceptance of such gestures.

Su, Lee and Lee (2009) showed that multi-touch interfaces have grown in popularity over the last few years, not only because of their well-known implementation in mobile phones, but also on account of the benefits to using this technology. For example, when compared with other interfaces, multi-touch technology permits users to directly interact with the application by using their fingers as an input tool. This advantage was noted by the present study, as touch interfaces provide users with a strong feeling of control over their interactions. Another important feature of this interaction is its ability to increase the ease of access of the system to a wider range of users.

Furthermore, a multi-touch interface permits simultaneous interaction in collaborative contexts, such as the current c Nunaliit framework.

5.5. Hand Gesture Interfaces

The results of the study reveal that the hand gesture interface is very rich interaction tool. It is also the best practice to enhance natural interaction, as it is complementary to the multi-touch interface, thus making it favourable within the proposed system.

Observation and video record analyses revealed various interaction patterns when using the gesture interface. Participants showed that hand gestures are natural interaction methods, as every individual uses hand gestures regularly to perform different daily activities. Thus, the idea of implementing natural hand gestures to control the Nunaliit framework when interacting with cybercartographic atlases seems very attractive. Moreover, half of the participants immediately started using their fingers and various hand gestures when interacting with the proposed prototype map. One reason for this may be that the proposed prototype includes various interface elements, which permit or require different sorts of gesture.

The experiments in the study introduced several critical questions, such as: which part of the hands are actually touching the screen and is the system capable of capturing all of the user movements, especially in multi-user interactions?. For example, users can perform the map zooming function in several different ways, including tapping, using two fingers with one hand, using two fingers on both hands, using all five fingers from one hand, using the entire hand with both hands.

This study focuses specifically on surface gesture technology that only uses two dimensions. Our aim was to keep this system as user-friendly as possible and as simple as possible, therefore we skipped the three dimensional concepts at this stage, as the target user of our cybercartographic atlases is the general public. Moreover, we intend to use this technology as a portable atlas to conduct participatory research in Canada's north with elderly and indigenous people. A touch-based gesture interface will offer a new movement trajectory for the cybercartographic atlases, which will allow users to interact directly using their fingers and hands on the interactive collaborative surface.

The aforementioned results show how gestures enhance the natural interaction, especially when participants felt free to perform different tasks in the prototype, such as: panning, rotating and touching the map using various gestures, such as: two fingers, whole hand, two hands, etc. Participants and interviewees also stated that this interaction will be more appealing and very natural in the working system.

This finding was tested on a similar working prototype, conducted at the Vancouver Aquarium, to examine how visitors interact with a large interactive table exhibit using multi-touch gestures (Hinrichs and Carpendale, 2011). They investigated various factors that influenced the choice and use of multi-touch gestures on large horizontal displays in a walk-up-and-use exhibition space. They found that a whole selection of gestures may be natural for any given intended action and that the choice of these gestures is influenced by their interaction context. Their research supports the observations in the present study, that is, that different individuals will use various alternative gestures for the same action depending on the interaction context, their previous experiences and the general purpose of their interaction.

5.6. Discussion of Major Findings

As a part of the observations and analysis of this study, we described fifteen overarching themes that emerged from a detailed thematic and comparative analysis of the video recordings of the interviews and usability tests. In the following sections, however, we are only going to discuss few key examples from these findings.

5.6.1. System ease of use

As mentioned earlier in the literature review, there has been a wide-spectrum of research conducted on horizontal, direct-touch tabletops over the last two decades. These studies prove that there is an increasing number of interactive, multi-touch and tangible interfaces that are being created to support tabletop group activity and collaboration in various domains, such as schools (Cao et al., 2010), museums (Horn et al, 2012; Hornecker, 2008), , seminar rooms and study labs (Shaer et al, 2010). In addition, this technology became familiar amongst the general public after the production of Microsoft's Surface and, more recently, Microsoft's Surface Hub (Microsoft, 2014), and Jeff Han's multi-touch table (Han, 2006).

Accordingly, this study opens a new opportunity to use tabletop technology in a mapping domain and build on existing popular and useful modalities. This will ensure the appropriate functionality and enhance the ease of use of this application, which will be available to a wide-spectrum of potential users. The present study shows that the proposed hybrid interfaces offer a seamless interaction process that will provide a successful user experience. This will be achieved by focusing on several designs rules, such as: minimizing the numbers of steps required to perform a function, providing shortcuts or alternative ways to interact and optimizing the tangible tokens for the major tasks.

5.6.2. Multi-user support

One of the most evident practical challenges uncovered in this exploratory study is the design of a large display collaborative atlas that supports multi-user interactions, who are interacting simultaneously. There are several values of distinguishing between the users in the context of cybercartographic atlases such as; it is very significant to know who entered the information into the atlas in order to verify their entry, also it is essential in our work to give some well-known users in the northern communities full credits for their contribution, also increasing the credibility of all of cybercartographic atlases. Thus, the proposed system must be able to distinguish between users and concurrently identify their individual interactions as quickly as possible in order to keep them engaged. According to the previous studies in this field, no definite solution exists to support simultaneously multi-user interactions for various interfaces and multi-touch technologies.

Notwithstanding the potential value of using interactive tabletop technology to facilitate collaborative work, most tabletop hardware cannot directly differentiate users from multi-touch inputs, with the notable exception of the DiamondTouch (Dietz & Leigh, 2001). The DiamondTouch functionality relies on the use of multiple antennas to distinguish between users, as each antenna is hooked up to a capacitive receiver. The method is limited, however, to a very specific tabletop structure. It also cannot differentiate between individual characteristics of each user, such as fingerprints; thus, it required initialisation, which limits the mobility of the table itself.

As collaborative multi-touch applications often do not allocate specific zones for each user, the distinction between individual users would allow further enhancements to improve the user experience. To solve this issue, an attempt was made by Dohse et al. (2008) to augment a multi-touch tabletop setup with hand tracking by mounting an additional camera above the table to distinguish between users. Although the technology is promising, the approach only works when users stand on opposite sides of a tabletop. However, the proposed study uses the existing reactable, which is compact and all of the functionalities are hidden under the system itself.

A recent study has provided a potential solution to enhance the available tabletop hardware in order to accommodate multi-user interactions. In their paper, Clayphan et al. (2008) discuss a plug-in system that adds touch identification to a conventional tabletop. They evaluated the proposed solution under a number of testing conditions, including scalability (number of users), activity density and multi-touch gestures. They claim that the plug-in touch system could add user differentiation and tracking to the interactive tabletop hardware that is currently available. Their work also goes beyond previous work on multi-user identifications by exploring a touch identification system that can be affordably added to a wide-range of existing tabletop hardware technologies. Both the touch identification system and the test evaluation set are freely available for use by its designers.[6]

[6] http://chai.it.usyd.edu.au/Projects/DataMiningForTabletop

5.6.3. Favourite interface

This study has considered all of the aforementioned usability rules and principles throughout the entire process, from the design of the study's evaluation tasks, to conducting the experiments and the analysis of the results, so as to measure the compatibility of the Nunaliit framework with these standards.

The evaluation of the usability tests, questionnaires and semi-structure interviews reveal that the participants generally had a positive reaction towards using the proposed interfaces (tangible, touch and hand gesture) as useful tools to be implemented in the cybercartographic Nunaliit atlas. The touch-based interface proved to be the most favourable interface in most areas of assessment, such as: ease of use, natural performance and accuracy, and most participants believed that touch-based interaction will be an invaluable interface in map creation. The second most favourable option is the hand gesture interface, which was close in result to the touch-based interface, as participants believed that most of the actions in these interfaces required both their hands and fingers.

The results concerning the tangible interface were similar to the previous options, although there were slight differences in terms of the general perception of the participants. They show that a tangible interface requires greater efforts to make it intuitive and thereby a reasonable interaction option in a collaborative mapping context. These results supported the research statement, which states that using multiple or hybrid interaction methods will benefits the Nunaliit Framework used to create cybercartographic atlases by enhancing its ease of use, increasing the system's accessibility and offering more natural ways to interact with and manipulate the atlas in interactive maps.

6. Chapter: Novel User Interface Guidelines for the Nunaliit Framework

This chapter offers a discussion of the new user interface guidelines for the Nunaliit framework and provides design recommendations with which to integrate the hybrid interfaces (touch-based, tangible and hand gestures) within the Nunaliit framework.

In this section, we shed some light on the current version of the Nunaliit framework, so as to position this novel approach within the ongoing development of the Nunaliit framework. We also aim to provide concrete theoretical evidence based on the present exploration study, which will be used to build a new iterative version of the Nunaliit framework. This new version will be called the *collaborative Nunaliit framework mapping tool*.

In addition, the usability guidelines and recommendations from this study will be used to encourage other new updates of the current Nunaliit framework, which is still in use, to further enhance the existing an open source approach for online cybercartographic atlases.

Throughout the study's usability testing and semi-structured interviews, we used some of the existing Nunaliit framework interfaces to simulate the proposed paper prototype, which we then used as a connecting focus to perform the usability tasks. Moreover, we received substantial feedback from the participants in the study regarding the existing Nunaliit framework interfaces.

This chapter is divided into two major sections: the first section discusses the functionality of the existing Nunaliit framework and introduces some related recommendations for the online version of the Nunaliit framework. The second section explores the collaborative Nunaliit framework with an emphasis on providing concrete guidelines and consideration, which will in the implementation of this novel hybrid interface. In addition, the study findings provide useful design information from which the Nunaliit designers and development team can obtain a concreate idea of how to create this novel hybrid interface and build a fully functioning collaborative Nunaliit framework. This novel technology will be a portable input/editorial tool that can be used to create the cybercartographic atlases. Thereby, we will offer the atlas users a functioning system that is easy to use, well-organized, operational, valuable and able to enhance its user experience.

6.1. Existing Nunaliit framework functionality

This section discusses the various functions and interface design aspects of the existing Nunaliit framework. This evaluation serves as a complementary step towards achieving a more usable and user-friendly interface in all of the Nunaliit framework products. The outcome of the recommendations can be implemented in both the online Nunaliit framework and the new *collaborative Nunaliit framework mapping tools*, where these new tools will utilize the existing framework functions and create several new functions; in particular, the use of the three distinct interfaces to arm the new Nunaliit framework with various interaction techniques. We also dedicate a separate section to a discussion of potential implementation considerations of the novel hybrid interfaces within the collaborative cybercartographic Nunaliit atlas.

6.1.1. Atlas main page

As discussed above, the main products of the Nunaliit framework are the cybercartographic atlases. Atlas home pages are the face of the Geographic and

Cartographic Research Centre (GCRC) where various users decide to interact with the Nunaliit framework by using its cybercartographic atlas around the world. The current Nunaliit framework was built upon a comprehensive usability test that was conducted as early as 2003, which proved its validity over the last decade. In fact, the plethora of interface technologies, which now arms users with new experiences, created a demand to make some reviews and keep up with the new technologies and substantial user experiences.

When asking participants about the main page, they found it useful and easy to navigate requiring only needing a few prompts. Thus, we can conclude that the Atlas home page needs to have a balance between presenting the range of map icons and making the map easy to use, so as to ensure that the majority of users can effortlessly embark on atlas tasks.

6.1.2. Login/create new account

The login is located at the top right of the main page– when users click on it, they get a login pop-up that allows them to create a new user account. The study participants liked the idea of keeping the login as simple as possible, where they would not need to fill out a long form in order to login; the existing framework has already successfully addressed this issue. We also discussed the option of using existing accounts like Facebook or Google+ to login. In this way, they would not be required to memorise new login details, thus keeping the login process as simple as possible.

6.1.3. Search option

The study shows that seventeen out of twenty participants noted that the search option in the existing Nunaliit framework could be better designed. Participants were asked to find a precise location or some landmarks using this function, but they could not; they realised that it was only possible to search for information within the previous atlas entries. Therefore, we suggest linking the atlases to interactive servers, like Google maps, where user can search for different points of interest. This function will enhance the ease of use of the atlases and make them useful in other capacities, creating an easy way to navigate the atlas via the search option. Also, other interviewees suggested improving the search functionality by using a filter bubble search, in which the atlas user would be given several options to optimise their search.

6.1.4. Help menu

When designing a new system, it is beneficial to offer helpful information throughout this system. Yet, atlas users that operate the map less frequently usually do not have the time to search through a help menu. Also, the Nunaliit framework user does not require a list of topics, but will simply want to know how to perform map tasks. Therefore, it is recommended that the designers analyse each part of the Nunaliit framework and identify the areas in which users may need additional help, as there are various atlases, some of which might require an optimized help function. In this part, we focused more on the appearance and functionality of the help menu, so as to provide the Nunaliit framework with a better design in general.

After the observation and interviewing process, we concluded that the help function should be as simple as possible, which will be achieved by implementing what we call a task-based help menu. This required us to identify the major tasks, such as navigation, add points, edits, etc.; then they are implemented as questions: how to navigate the map? How to add features to the map? How to edit a previous entry? In addition, the help function should appear clearly on the tool bar of the atlas interface in order to ensure that it is accessible with a single click.

Interestingly, in the new collaborative interfaces, the design of the help function is going to be intuitive. Since we are going to implement tangible interfaces, we can make an interactive token for the help menu, thus, when the user needs help, they can place the token on the surface of the map to open a general help menu. This token will also be paired together wirelessly with other tokens on the system. In this case, this *help token* could provide help to any function of the system easily by just tapping the item or function with which users required help. For example, if users want to use the function *Add new feature to the map* and they might not sure how to perform the *Add* function, they can just place or tap the *help* token on the *Add token* and then the system will show a shortcut help instructions for how to add a new information to the map.

6.1.5. Add/edit map features

This function is the most important task in the Nunaliit framework; it is the point at which users start their interaction with map after being logged in. Therefore, additional care should be taken to present this function in an intuitive way. The user study showed that this function should not be integrated with the map; it needs to be distinguished in the tool bar. Participants were also confused by the term "*Add";* instead, they suggested using the term "*new entry" or "create."* When we asked the participants to elaborate on this comment, they stated that the term "add" implies the ability to add more information to a previous entry.

6.1.6. Navigation

Navigation is a significant component of the Nunaliit framework and it is useful in terms of enabling the user to find information and to view maps through the various cybercartographic atlases. Therefore, well-designed navigation tools encourage the atlas users to explore a particular area of the atlas, which they might otherwise have skipped.

In this study, we found that there is a need to design the interfaces in a way that enables users to navigate the map and the entire application by using the interfaces themselves. To achieve this goal, the Nunaliit Framework development team needs to keep the focus on the major tasks of the atlases and let the users navigate through the system using the minimal steps required to perform one action; in other words, we must enable some shortcuts to perform the major tasks. For instance, users noted that they would like to see some landmarks, reference points and an interactive campus, which rotated concurrently with map rotation; all of which would ensure the ease of use of the map and system navigation.

6.1.7. Forms and data entry

The Nunaliit framework enables users to enter additional details about their newly added features or edit the previous entry using Form Fill, For example, there are three major forms in which to add more information, specifically adding points, lines and polygons. These component need to be well-designed in order to provide access to its rich functionality, while requiring a minimum amount of input from the user. Each form should be concise and clearly worded so that the user has an explicit idea of what they need to do when making an entry. It may be useful to add a drop down menu from which a user can make a selection. For example, all Nunaliit forms ask the user to type the date.

This function could be made easier if it incorporated an autofill calendar from which to choose the date; it saves the user time and also avoids the issue of the different formats for writing the date.

The Nunaliit framework uses a multimedia approach to enable users to interact in several different ways with the atlases. One of these multimedia approaches is the addition of audio files to the system which the current Nunaliit framework, allows users to upload their audio. Since our aim is to record stories in audio or video format, the Nunaliit framework should support a live recording, where users can speak and record any information that is directly related to a map feature, without creating a recording that is separately uploaded to the system. Participants in the study noted that this feature would keep Nunaliit users engaged, allowing the system to record their voice while they concurrently interact with the map. Other users suggested that the system include a replay function for the recording, which would enable the user to edit it or choose the most relevant recording to be added permanently to the map.

6.1.8. Credibility

The Nunaliit framework makes it possible to gather different spatial and temporal information to represents various aspects of peoples' relationships with their environment particularly valuing the traditional knowledge of indigenous people. As a result, cybercartographic atlases have successfully addressed their initial goals, that is, providing rich, accurate and well-presented material. Moreover, our study showed that it is crucial to focus on enhancing the atlas' credibility and increase the user's trust in the content and the organisation behind it. We suggest adding a verification stamp, which could be displayed in the map beside any information that is entered —people providing the information have to give their consent; this suggestion can increase the rigor of the cybercartographic atlases, give users credit for valuable information and provide trustworthy materials for other researchers that are interested in carrying out similar research. However, this process needs to be further investigated for the ethical and copyright issues involved, as well as public preferences regarding the use of personal identifies within the cybercartographic atlases.

6.2. New Collaborative Nunaliit Framework

After reviewing the existing Nunaliit framework, we move to a discussion of the current hybrid interfaces, specifically dealing with the guidelines pertaining to each of the interfaces that we are going to implement and any general thoughts about the system as a whole. Therefore, we have divided this section into four groups, which include: tangible interface guidelines, touch-based interface guidelines, hand gesture guidelines and concluding with a review of the most pressing issues relating to the entire Nunaliit framework design.

6.2.1. Tangible-interfaces guidelines

As technology continues to grow and develop, it has become possible to turn almost any object into an interactive interface. This study explores the needs of potential users and attempts to understand their perceptions, with the aim of creating the metaphors essential to improving the current interactions of the cybercartographic Nunaliit framework.

In previous chapters, participants offered different views regarding the potential use of tangible interfaces as input tools that could enrich the collaborative interaction enhance the ease of use and increase the accessibility of the proposed system to a wide-spectrum of potential users.

As with any new design process, however, the implementation of tangible interfaces into the cybercartographic Nunaliit atlas has its own challenges, especially on account of the fact that the Nunaliit framework uses a spatial context (map) as a connecting point between the users and the software. This kind of complex information format requires the designer to take additional care of the system requirements and ask important questions, such as: what are benefits of implementing tangible interfaces into the collaborative Nunaliit framework? Are there special considerations regarding tangible interactions that need to be taken into account? What happens when implanting tangible interfaces with other interfaces, such as touch-based and hand gesture?

After reviewing the participatory research results and consulting previous scholarship, we came up with a few recommendations and thoughts that will assist the designer and developer in implementing this system effectively. Table 6.1 provides a detailed list of the tangible interfaces' usability issues and the recommended solutions.

Table 6.1 Tangible Interfaces Guidelines

Tangible interface issues/concerns	Suggested solution
Too many tokens on the map The tokens might get lost	Optimize tokens for the major functions
How can multi-users perform interactions and does every user require a separate set of tangible tokens?	We suggest using different sets of tangible tokens for each user, or all tokens could be used by various users but they would need to touch their ID to pair the used token with their ID. This will enable the system to recognise who is doing what.
The user requires training before using it	A short animation video could identify first time users of the potential of this function Map facilitator can go over them in less than 2 minutes
Allocate tangible interface for the major tasks	Collaborative multi-users

Not sure where to place the tangible token on the map	This comment comes from novice users, they understand its usefulness, but they were not sure where to place them.
Some participants removed the token before completing the required action	System should save their interaction automatically or when this error happens, user will receive a feedback message to inform them about this action.
Not suitable for certain tasks (add precise location)	We addressed this concern for optimising tangible tokens for the major tasks. Tangible tokens will be associated with zooming in/out to enable user to identify the precise location for their entry.

6.2.1.1. Purpose of using tangible interfaces.

The study revealed that in order to obtain better results, the tangible interface should be optimised for the major application tasks, such as adding features, editing features, recording stories, etc. not all of the functions on the system, however, require a tangible interface. Too many tangible tokens on the surface could cause confusion; especially in multi-user contexts where every user is required to use their own tokens to manipulate the map. Instead, tangible items should be used only for the most important functions. This is important for several reasons: (1) distinguishing the most significant tasks so as to draw the user's attention; (2) increasing the system accessibility for some users (*i.e.* elderly) who may find this option easier to use, while also guaranteeing that the major goals are not skipped, since it will be available in different interface formats;(3) the system aims to capture user interaction on major points like telling a story or revealing various opinions towards a particular place. Therefore optimizing this tangible interface for such a tasks will support face-to-face collaborative activities, and permit multiple users to interact with the system while collaborating with each other. Thus, this optimization will help users to perform these tasks better.

6.2.1.2. Integrating tangible items with the map or leaving them as a physical objects and free to use.

One-quarter of the usability test participants believe that tangible interfaces should be integrated into the system like visible icons. When questioned further, they stated that physical objects might get lost or mistakenly taken by some user. Furthermore, having all of the icons built in will make them easier to carry and users will able to find them all in one place. At that time, I notice there is a misunderstanding of the tangible interaction concept, then when I explained the tangible interfaces functionality those users realized that the power of tangle is to keep them as physical items on the map.

The other three-quarters of the participants and 100% of interviewees rejected the idea of integrating the tangible objects, saying: (1) there is no point to using a tangible interface, if it is going to be integrated into the system; it is no longer a tangible interface, it merely becomes a fancy way to display an iconic format that is actually part of the touch interface; (2) when integrated into the system, you terminate the natural function and the feeling of moving those objects around; the sensation of grabbing and passing them to other users is lost; (3) tangible interfaces are an alternative option to manipulating and interacting with the map; some user will prefer to use them as a first option of interaction, therefore, integrating them will maximize the accessibility of the system for people who described the tangible objects as their favourite interaction option.

6.2.1.3. Tangible token pairing.

The present study focused specifically on the user interactions required to move objects over the large surface of the interactive maps, but it is also important to consider the larger technical context in which these actions are performed. One interviewee, who specialises in wireless networks, suggested scaling up the application to enable various users to use unlimited tangible tokens. To make their interactions easier, tangible tokens or object could be connected wirelessly to one user's identification token by using tracking system or a Bluetooth, and any time a user wants to use this token, they can simply couple it with their ID symbol and the system will recognise that this user is the one manipulating the system; every user could simultaneously do the same.

We would re-configure the proposed system so that it is consistently prepared to support cross-device interaction. This would allow the users to focus on the interaction itself and enable them to add files or media from their own devises and upload it directly into the system. Also building a system that enables pairing devices might also help resolve the authentication concerns, where user could login to the system using their own devices. These alternative pairing uses require further study in order to gain a better understanding of the most appropriate cross-device pairing methods and how it should be accordingly designed.

6.2.2. Touch-based interface guidelines.

The study revealed that the touch-based interface is one of the most promising interfaces that can be used in the new collaborative Nunaliit framework. As previously mentioned, this exploratory study and previous research confirmed that implementing a novel interface, based on existing familiar technology, will increase user acceptance of this new implementation and leverage the rich user experiences, thus contributing to the enhancement of the collaborative Nunaliit framework's efficiency, particularly in terms of ensuring its ease of use, minimising the cognitive workload and increasing the system's learnability. Therefore, we suggest learning from similar implementation patterns that have used touch-based interfaces in various domain applications.

A certain level of ability is required in order to use touch screens and users can either find the screen buttons too sensitive or not sufficiently responsive. The study uncovered some potential usability concerns, for which we have made several theoretical recommendations so as to address them appropriately, as shown in Table 6.2.

Table 6.2: Touch-Based Interface Considerations

Touch interface issues/concerns	**Suggested solution**
Interruptions by other users	Implementing an efficient multi-user identification system which recognises every possible interaction and ignore unintended touches.
Does this application support special needs users?	The proposed system has not tested this group, but it would be valuable to explore this concern further.
Who are the users?	The proposed system will be open to the general public; therefore the design should be kept as simple and intuitive as possible.
The deeper zooming might result in a loss of text.	Keep the zooming in/out manageable and keep this feature associated with the system readability.
The system could be tricky for a novice user	Implement an animated tutorial to help novice users familiarise themselves with the system interaction.
Not quite sure what touch pattern will be used to manipulate the map	The system should offer particular patterns for accepting and handling input and for providing feedback to users. For example Apple has identified several simple and intuitive patterns specialized for a multi-touch interface.
Add/edit map feature is not clear enough when using touch interface	Some people may not like to use one particular interface, so using three distinct interfaces enable the user to choose from three distinct interfaces.

Table 6. 1: Touch-Based Interface Considerations

6.2.3. Hand gesture guidelines.

Testing hand gestures using paper prototypes is challenging, as users cannot observe direct feedback from their interaction. However, this study is still a valid method to uncover some general hand gesture patterns which reflected the natural interactions or responses of the participants. We have identified several hand surface gestures by observing the various video records. We found that these patterns are inspired by existing touch device technology. For example, participants used one hand with two fingers to zoom in and out on the map; two five fingers from one hands; or two fingers from both hands. Other participants preferred to use a particular hand (right or left hand).

We recommend leveraging the current hand gestures used in existing technology and apply them to this framework, so as to ensure the usability of these gestures and minimize the amount of training needed to use them. Moreover, the working system should recognize these various hand gestures effectively and we expect that there will be several challenging issues when the system is handling gestures from multiple users. Therefore this area needs to be investigated very carefully to ensure that the system is capable of identifying the hand gestures of various users. Throughout this study we have identified few concerns in regard to using hand gestures in the implementation process, as shown in Table 6.3.

Table 6.3 Hand Gesture Interface Considerations

Hand gesture interface issues/concerns	Suggested solution
The different ways of using hands might be confusing	Offer training /Need a facilitator
Some people do not like to use both hands, but in this system two hands might be necessary	The system should be able to recognize different user interaction patterns
Good for three dimensional application	Using a hand to spin or rotate the interface might cause an interruption by another user
Hand gesture are hidden features	Identifying the system's hand gesture patterns educate users about the potential of this interface
Inability to undo the hand interaction	Implement "undo hand gesture" or enable this feature somewhere on the system's main page.

6.2.4. General Usability Guidelines and Standards

Guidelines and standards for ensuring good usability of interactive systems have seen great advancements over the past several years. They range from the low to high-level guidelines (or heuristics) proposed by Nielsen and Shneiderman, (Nielsen 1995; Shneiderman and Plaisant 2005), as shown in Tables 6.4 and 6.5. These guidelines were useful and were thus considered in the present chapter.

Table 6.4 Nielsen's usability heuristics (Neilsen, 1995)

principles for interaction design	**Recommended solation**
1. Visibility of system status	The system should always keep users informed about what is going on, through appropriate feedback within reasonable time.
2. Match between system and the real world	The system should speak the users' language, with words, phrases and concepts familiar to the user, rather than system-oriented terms. Follow real-world conventions, making information appear in a natural and logical order.
3. User control and freedom	Users often choose system functions by mistake and will need a clearly marked "emergency exit" to leave the unwanted state without having to go Through an extended dialogue. Support undo and redo
4. Consistency and standards	Users should not have to wonder whether different words, situations, or actions mean the same thing. Follow platform conventions
5. Error prevention	Even better than good error messages is a careful design which prevents a problem from occurring in the first place. Either eliminate error-prone conditions or check for them and present users with a confirmation option before they commit to the action.
6. Recognition rather than recall	Minimize the user's memory load by making objects, actions, and options visible. The user should not have to remember information from one part of the dialogue to another. Instructions for use of the system should be visible or easily retrievable whenever appropriate.
7. Flexibility and efficiency of use	Accelerators -- unseen by the novice user -- may often speed up the interaction for the expert user such that the system can cater to both inexperienced and experienced users. Allow users to tailor frequent actions.
8. Aesthetic and minimalist design	Dialogues should not contain information which is irrelevant or rarely needed. Every extra unit of information in a dialogue competes with the relevant units of information and diminishes their relative visibility.
9. Help users recognize, diagnose, and recover from	Error messages should be expressed in plain language (no codes), precisely Indicate the problem, and constructively

errors	suggest a solution.
10. Help and documentation	Even though it is better if the system can be used without documentation, it May be necessary to provide help and documentation. Any such information should be easy to search, focused on the user's task, list concrete steps to be steps to be carried out, and not be too large.

Table 6.5 Shneiderman's Eight Golden Principles of Good Interface Design (Shneiderman and Plaisant, 2004)

principles for interaction design	Recommended solation
1. Strive for consistency	Consistent sequences of actions should be required in similar situations; identical terminology should be used in prompts, menus, and help screens; and consistent commands should be employed throughout.
2. Enable frequent users to use shortcuts	As the frequency of use increases, so do the user's desires to reduce the number of interactions and to increase the pace of interaction. Abbreviations, function keys, hidden commands, and macro facilities are very helpful to an expert user
3. Offer informative feedback	For every operator action, there should be some system feedback. For frequent and minor actions, the response can be modest, while for infrequent and major actions, the response should be more substantial.
4. Design dialogue to yield closure	Sequences of actions should be organized into groups with a beginning, middle, and end. The informative feedback at the completion of a group of actions gives the operators the satisfaction of accomplishment, a sense of relief, the signal to drop contingency plans and options from their minds, and an indication that the way is clear to prepare for the next group of actions.
5. Offer simple error handling	As much as possible, design the system so the user cannot make a serious error. If an error is made, the system should be able to detect the error and offer simple, comprehensible mechanisms for handling the error.
6. Permit easy reversal of actions	This feature relieves anxiety, since the user knows that errors can be undone; it thus encourages exploration of unfamiliar options. The units of reversibility may be a single action, a data entry, or a complete group of actions.
7. Support internal locus of control	Experienced operators strongly desire the sense that they are in charge of the system and that the system responds to their actions. Design the system to make users the initiators of actions rather than the responders.
8. Reduce short-term memory load	The limitation of human information processing in short-term memory requires that displays be kept simple, multiple page displays be consolidated, window-motion frequency be reduced, and sufficient training time be allotted for codes, mnemonics, and

sequences of actions.

6.2.5. The entire collaborative Nunaliit framework design perspectives.

In any research of this kind, the system development and implementation imposes certain challenges, most notably in the ability of this system to enable natural interactions, touch recognition, identifying different user interactions and much more. We explored some of these challenges by trying to connect them with previous research in the field, so as to provide a better understanding of how a developer could address them, while also creating new opportunities for other researchers to investigate them. Here, we mention again a few examples of the Nunaliit framework design functions, which we previously identified in Chapter 4 (Table 4.6). This table offers a brief description of fifteen overarching themes that emerged from a detailed thematic and comparative analysis of the video recoded interviews. The themes generated from these analyses highlight a wide range of evaluation areas that could be useful to consider when implementing the collaborative Nunaliit framework.

6.2.5.1. Natural interaction design.

As the technology develops, new studies on the qualitative aspects of tabletop interaction appear in scholarship. Several attempts have been made to assure that the natural interaction occurs on a large, shared screen. For example, Scott et al. (2003) offer a comprehensive design direction for constructing digital large display systems. In their study, the authors stress the central question: how can we support and facilitate a natural way of interaction for multi-users interacting with a tabletop system. To address this question, they determined that designed system should support several functions, such as: (1) Natural interpersonal interactions; (2) smooth transitions between activities; (3)

movement between individual and collaborative work; (4) the use of physical objects in combination with the tabletop; (5) permit shared access to physical and digital objects; (6) appropriate physical arrangements of the users' space; and (8) real-time or simultaneous user actions.

The findings from the present study reveal that the majority of the participants in the usability test and 100% of the interviewees agreed with those initial guidelines, especially in terms of assuring the natural interaction of the system. In addition, they believe that engaging a user's body parts (e.g. fingers, one hand and two hands) and other input tools, like tangible tokens or a stylus, in the proposed system will enhance the user's natural interactions and affect the system's ease of use.

6.2.5.2. Distinguishing user identity.

The results of the study demonstrate that the ability of the system to recognize a user's identity is essential to its overall success. Also, authenticating the user entries is very crucial function in the Nunaliit framework, and to give our users credits for their contributions. Thus, this system should support multi-user interactions simultaneously. All of the interviewees believe that solving this issue will be the key to successfully achieving a real collaborative interaction in the proposed hybrid interfaces within the Nunaliit framework.

Several studies also discussed user identification as an essential feature to consider when providing personalized interactions, personalization of the interface and secure access to data in collaborative interfaces (Schmidt, Chong, and Gellersen, 2010; Ryall et al., 2005. In a recent review of tabletop literature, Bellucci et al. (2014) claims that there is no widely accepted or developed technique that would allow user identification for surface interactions. They explore some previous attempts in this regards, such as DiamondTouch. Dietz and Leigh (2001) associated touch to users, as a result of enabling user differentiation; however, the system cannot disclose any information about a user's identity. In DiamondTouch, touches occur by means of capacitive coupling and, therefore, the system can only recognize that someone seated on a particular chair is touching the surface. Nevertheless, it lacks practicality as it requires the whole session must be set up ahead of time. It also requires user to stay in their designated seat at all times during of interaction, which leads to unnatural interaction and diminished engagement.

Recently, several efforts have been made to recognize user identity, such as using biometric authentication modalities based on hand contours or employing personal devices, such as smartphones, to recognize a user's virtual identity. Here, users can log into the system using their own device (Schmidt, Chong, and Gellersen, 2010). Other attempts were made by Marquardt et al. (2011), who made use of fiduciary tagged gloves, but this was not a real resolution, it just provided a tool or toolkit to explore and highlight potential benefits of user and hand part ID.

Hayashi, Maas, and Hong (2014) carried out innovative research that seamlessly integrated natural user identification with gesture-based interfaces. This system introduced a way to identify users by a two-second hand waving gesture that is captured by a Microsoft Kinect. The proposed body-based user identification system thus presents a new method for user identification, which is based on the body length and a hand-waving gesture. They evaluated the proposed system by conducting two lab studies and one field study, consisting of 8,640 examples from 75 total users. Their results prove that gestures offer a possible tool by which we can identify user interactions. This, however, requires more detailed investigations as well as probable customization to suit the particular needs of a system such as ours.

6.2.5.3. Touch recognition.

Another factor discussed by the participants was the unintended interactions, that is, what happens when a user accidently touches something while another user is interacting with system. They were concerned that this would interrupt the current interaction or that the system would be focused or locked onto that particular interaction. This concern was addressed in previous scholarship, most notably Esenther and Ryall (2006), who refer to the precise recognition of intentional and unintentional contact points as a problem that is inherent to the use of multi-touch sensing. This concern could be crucial, especially if our proposed system makes use of tangible tokens which could accidently be hit on the interactive display by some user.

Therefore, the implemented system should be capable of recognizing unintended touches. Bellucci et al. (2014) discuss that the recognition of unintentional interaction requires a cabaple hardware and software system that could track various simultaneous touches and then assign a context to each possible touching with respect to the current interaction. by assigning this contextual information accompanied by a correct specification of interaction, the system then will be able to filter the interaction and keep only the intentional interaction.

6.2.4.4. Interface orientation.

The study results showed that the orientation of the interface could be an issue in a collaborative interaction environment, where users are located at various points around the circular tabletop. At a glance, this could be both challenging and promising for group interactions. On the one hand, some participants were concerned about how they could interact appropriately with the map when the interface is oriented in the opposite direction. On the other hand, this could be a motivating factor that engages users throughout the interaction by continuously rotating the map and passing objects between each other.

We suggest implementing a rotation button on each side of the table, which could rotate the map 360 degrees. This would allow any user to easily rotate the map and encounter the interface, while encouraging the users to communicate with each other whenever they want to turn the map. Implementing a map-controlled orientation would smooth the collaborative interaction process. This suggestion need to be investigated further in the future research.

Previous studies supported our discussion regarding the importance of maintaining individual and multi-user workspaces through the appropriate orientation of objects, whereby different user can read the interfaces from their various positions around the table. For example, Shen, Vernier, Forlines, and Ringel (2004) implemented a toolkit called DiamondSpin, which enabled the authors to design new tabletop interaction metaphors, such as: rotating the entire tabletop, rotating all the documents within the system, the passing metaphor that integrates push and rotate into one motion, as well as laying out documents around the perimeter of the tabletop. All of which permit arbitrary document positioning and orientation on a tabletop surface.

6.2.4.5. System windows.

The new system makes use of a circle shape as a natural metaphor to facilitate multi-user gatherings around an interactive table, in which every user has an equal opportunity to simultaneously interact with the system. While this system used a circle shape as its preferred design, our study showed that we need to maintain this consistency throughout our design. Therefore, any interfaces or windows within this system should be a circle, or at least a half circle, to keep the users engaged in this circle metaphor.

The new design proposes to implement the touch interface toolbar as a flexible arc bar, where users will rotate it concurrently with map rotation. Within this toolbar, the system functions will be shown as icons so as to present the system functions in as a familiar symbol or note, which is clear enough to understand the functionality at glance, and distinguishable from other icons on the screen. One can argue, however, that designing self-explanatory icons might be challenging, as users have different perceptions about those symbols. The interviewees suggested showing the function name of the icons, or once a user taps on the icon, a small text will appear and briefly explain its meaning (short labels under the icons).

6.2.4.6. Visual feedback.

Despite the fact that the system is interactive and enables direct manipulation so that users can see and track their interaction process, the system should also offer useful tools to enrich the user's capability of controlling the system and keeps them informed about their interaction process. For example, using an index map will assure that user is aware of the location in which they are working and if they zoomed in and out they can navigate through the map more effectively. Also, when implementing the zooming in/out function, it might be useful to have a small percentage bar on the edge of the screen to maintain the manageability of this function.

Another good example of using visual feedback is the creation of an option on the screen which prompts the user to take a short animated tutorial at the start of their session. This intimation could be interactive as well, taking the user through some simple steps, while keeping them engaged and curious to know more about the system, as well as educating the user about the potential applications of this system.

6.2.4.7. Assuaging users' concerns about the system's ease of use.

After reviewing all of the considerations and recommendations, we can conclude our discussion in this section by insisting that all of the aforementioned functionalities are being brought together in order to assure the user of the system's ease of use. In addition, the following points provide a brief summary of the findings that were extracted from our exploratory study:

- Providing users with different alternatives for interaction
- Keep the design simple so that it's easier to perform and remember

- Keep the help function handy and concise
- Optimize the major tasks (aims of the system)
- Using a friendly circle metaphor
- Add some directions to the tangible token to enable users to direct the interface
- Implement a physical button for each user that permits them to redirect the interface and rotate it as quickly as possible to encounter the interface from their position
- Minimize the number of steps required to perform a function
- Provide shortcuts or alternative ways to interact and optimizing the tangible tokens for the major tasks

7. Chapter: Conclusion and Future Study

7.1. Summary

In the last twenty years, we have observed notable developments in interactive tabletops research both in academic and industrial modalities (ITS, 2013). Additionally, large interactive tabletops have increased in popularity and are progressively being used in public domains, such as museums, offices, shopping malls and various city locations (Ardito, Buono, Costabile, and Desolda, 2015). The aim of this study was to explore a novel interactive approach of using a multi-touch gestural and tangible interface in the Nunaliit framework to create maps in shared contexts. This collaborative Nunaliit framework system supports various map interaction processes, such as viewing, editing and adding map information.

Cybercartography theory aims to present spatial and temporal information in a multimodal approach by using the Nunaliit framework's practical application to produce various cybercartographic atlases. Therefore, there is an ongoing need to keep up-to-date with the latest technology that would enable users to interact directly with the system, using multiple senses and intuitive ways to gather and present information so as to produce their own maps. The Nunaliit framework was built carefully using a user-centred design approach to address the ongoing needs of its users. Moreover, since its creation fifteen years ago, the Nunaliit framework has evolved through an iterative development process. As a result, this study establishes a concrete transitional step toward producing a cutting-edge technology that leverages various hybrid natural interfaces to make the collaborative Nunaliit framework.

This study was motivated by a real need and desire to meet the ongoing Nunaliit framework developments, which required conducting several investigations to accurately address this alterations process and build a fully functioning intuitive collaborative Nunaliit framework. Therefore, this study is a small step towards implementing the aforementioned cybercartographic theory goals in a multi-modal collaborative Nunaliit framework that enable users to interact with its atlases in very intuitive way.

The primary aim of this study was to investigate the potential of tabletop natural user interfaces tools for improving the Nunaliit Cybercartographic Atlas Framework. Therefore, this study undertook a comprehensive analysis of natural hybrid interfaces, including touch-based, gestures and tangible interfaces, as a human-computer interaction methods that have the real potential to facilitate a concrete approach to the design of a novel collaborative tabletop interface with Nunaliit cybercartographic atlases.

7.2. Research Objectives

Chapter 1 outlined the research questions of this study, namely: to what extent are hybrid interaction interfaces useful in enhancing collaborative user interaction with cybercartographic atlases? Can these interfaces improve their usefulness, ease of use, or enhance an atlas user's experience while viewing, adding or editing map information? We also examined the designed interactions' effectiveness in supporting the existing Nunaliit framework.

These objectives were fulfilled by using several distinct approaches; first, we performed a literature review (Chapter2), examining various considerations in digital tabletop application design, the nature of the cybercartographic theory and practices and the manner in which it is evolving overtime. This evolution was primarily achieved through the production of an updatable framework to transfer various cybercartographic concepts and present them in their major format, which are the cybercartographic atlases. Then, we found a promising connection between cybercartographic theory and different aspects of the hybrid interfaces, the latter of which would be a vital theatrical and practical technology to fulfil the full potential of the cybercartographic atlas' major elements (Taylor, 2005; Taylor, 2014). We also conducted a short review of several usability design guidelines that would effectively address the study's prototype design and would efficiently manage the users in the study.

Chapter 3 outlines the methodology of the study to assure the validity of study design and accuracy of its results. A paper prototype was produced for the study, which was used to test different aspects of the hybrid interfaces by using several tasks and scenarios within the usability testing methods. It was also utilized as a connecting focus in the interviews. The study ran a usability test in order to gauge the experiences of various users by using a paper prototype and conducting semi-structured interviews; the goal of which was to evaluate several different possible concepts of hybrid interaction.

This primarily study used a qualitative approach to investigate the research questions and realize the goals of the project. As mentioned in Chapter 3, we limited the use of quantitative approaches to the collection of some descriptive data concerning the study participants, as well as measurements of user satisfaction and their perceptions towards the proposed hybrid collaborative atlas.

Semi-structured Interviews and usability testing both showed that participants generally held positive reactions towards all three of the hybrid interfaces (tangible, touch and hand gesture) as a useful tools to be implemented in the cybercartographic Nunaliit atlas. In the assessment, the touch-based interface was the most favourable, as participants were more willing to use the touch interface as a first option of interaction with the collaborative Nunaliit framework.

The second most favourable option was the hand gesture interface, which had similar results to those of the touch-based interface. Here, participants believed that most of the actions performed in those interfaces required both of their hands and fingers. Additionally, the hand gesture interface is very rich interaction tool that could to enhance natural interaction and complement the multi-touch interface, thus making it favourable within the proposed system.

The analysis of the results also confirmed that tangible interfaces are useful and intuitive methods of interaction and will be valuable to the Nunaliit framework. The majority of the participant and interviewees also proclaimed their enthusiasm to see the system once it is ready for actual use. Moreover, our experiments revealed that tangible interfaces offer several unique benefits to the Nunaliit framework, such as allowing users to manipulate maps in the same way as physical maps; the product of which then conveyed into the digital world, where the user can attain direct feedback from their interaction.

We used a thematic analysis to systematically identify and describe features of the qualitative data that would inform the design of the new interface generation for the

Nunaliit framework. Fifteen overarching themes emerged from a detailed thematic and comparative analysis of the recoded video tapes of the interviews. The themes generated from these analyses highlight a wide range of assessment areas of the proposed system functionalities, as summarized in Chapter 4.

7.3. Research Contribution

The study made several contributions to the ongoing research of the Nunaliit framework, all of which are outlined below

Examining a novel hybrid interface within the Nunaliit framework

The qualitative results of our observational study indicate that, of the three interfaces; touch-based interfaces was more powerful, less physically tiring, and better supported the Nunaliit framework (ease of use, map creation, offering the user several options to perform the system functionalities). The three interfaces were also capable of navigating the framework in an intuitive way.

Confirming the real need and value of introducing this novel interaction into the Nunaliit framework

Employing this novel approach in the Nunaliit framework within the context of its cybercartographic atlases will introduce an original user interface for digital mapping, while also permitting users to manipulate maps collaboratively in real-time interactions. Moreover, this new interface will advance the visualization of the spatial and temporal geographic information, establish a new collaborative approach to map creation and leverage the technical and design aspects from the HCI field.

Considerations for the design of the hybrid interfaces into the Nunaliit framework

These considerations include: guidelines and recommendations concerning the functionality of the existing Nunaliit framework which will be invaluable to inspiration of new updates for the current Nunaliit framework, which still in use, to produce cybercartographic atlases. In addition, we explored the new collaborative Nunaliit framework with an emphasis on providing concrete guidelines and considerations which will be essential when implementing this novel interaction approach. Also, there is a need to provide holistic, informative design knowledge, so that Nunaliit designers and developers can obtain a concrete understanding of the various possible ways to implement this novel hybrid interfaces in a completely functioning collaborative Nunaliit framework.

Providing portable tools of the new collaborative Nunaliit framework

The GCRC team rely heavily on participatory studies to collect trustworthy spatial and temporal information from various locations Canada-wide. Therefore, the new technology must support this central function by offering a portable input/editorial tools with which to create the cybercartographic atlases. We must provide the atlas users with a functioning system that is easy to use, well-organized, operational, valuable and able to enhance its user's experience.

7.4. Study Limitations

As with any research of this kind, employing this novel approach in mapping context is relatively original; also it requires a careful design of the system requirements in order to develop an efficient functional application. All of these factors imposed certain limitations, most notably in the effectiveness of the digital tabletop's multi-user recognition and other aspects related to the compatibility of this new technology to address the goals of the Nunaliit framework, in general, and mapping needs, in particular. One limitation of this study was that the twenty participants in the usability evaluation had varying degrees of familiarity with some of the new interfaces, such as the tangible interface. For example, I found that most of the participants preferred the touch interface as the first option when performing the usability tasks. This result was likely driven by the fact that the majority of the participants were familiar with touch modalities. Therefore, the previous familiarity of the interface had it impact in the user's opinion regarding the implementation of these proposed interfaces in the Nunaliit framework.

Another limitation concerns the testing of the framework with individuals that are not familiar with technology. This concern needs to be addressed in a separate study, so as to learn more about how novice users perform during the testing session and how their particular needs can be met. This point is essential since the new collaborative Nunaliit framework will be used by some native elder users who are not familiar with the technology. In this study, we strive to ensure the ease of use of the new collaborative Nunaliit framework; a typical user should have little difficulty working with the system, although we also suggest having a well-trained facilitator on hand to assist those who are less technologically inclined at the beginning of the system development process, until we are able to more thoroughly investigate the needs of this particular group and address them accordingly.

One interesting challenge was uncovered when we discussed the functionality of the proposed system shape – that is, the circular shape. Even though, the circular shape has several advantages, as discussed in Chapter 5, concerns arose in regards to map rotation, particularly for multiple users. The map rotation is necessary, as every user must encounter the system interfaces in order to read the map content effectively. One proposed solution is to only rotate the map labels, which would enable the users to read them easily from their designated positions around the collaborative table. However, the ability to rotate the whole map is essential for enabling all users to add or edit different features directly into the map, without having to shift their positions around the table.

Finally, although the usability results are generally in favour of using touch-based interaction in the new collaborative nunaliit framework, the outcomes need to be interpreted with care, the touch-based interaction also likely benefit from its familiarity amongst users (i.e., an increased familiarity in new touch-based device technologies). Further experiments are required which incorporate different user experiences and the testing of all three interfaces (tangible, touch and hand gestures) in the fully functioning system; only such measures will demonstrate whether the user preferences remain the same.

7.5. Direction for Future Work

By introducing the early explorations of a novel research theme that uses a collaborative tabletop with hybrid user interfaces in mapping creation, with its entire emphasis on the Nunaliit framework, this study has only begun to touch upon several concerns which are promising for forthcoming research. Thus, this study offers a number of opportunities for further investigation.

Firstly, the study has focused on using hybrid user interfaces (tangible, touch-based and hand gesture) as a novel approach for the Nunaliit framework, which has its roots in several forerunning applications in different domains, but not explicitly in a collaborative cartographic context. We look forward to exploring the impact of this new generation of the fully functioning collaborative Nunaliit framework on enhancing the process of gathering and presenting various forms of spatial and temporal geographic information, and through which users can interact seamlessly with different atlases. Another direction for future exploration is the evaluation of this system with users who are not technologically inclined, so as to see whether this proposed technology is intuitive enough to accommodate this type of user group. For instance, we need to evaluate this proposed system with elders from indigenous communities.

Secondly, the participants identified that the tangible interfaces proposed in this study could effectively support the functionality of the Nunaliit framework, although noting that not all of the system functions should be supported by tangible interfaces. Additional functionality of the Nunaliit framework might be explored in the future, particularly whether tangible token can be used to add a precise geographic location, and whether tangible interfaces can be used simultaneously by multiple users without interruption between them.

Thirdly, we investigated whether the hybrid interfaces enhanced the Nunaliit framework's ease of use. The results of our study confirmed that this novel technology will be very efficient and valuable in map creation. We recommend further investigation that would explore the actual use of the cybercartographic atlases, specifically identifying those who will actually use the atlases. This challenging was identified as well earlier within the existing design of the Nunaliit framework. (Taylor, et al. 2014). It is essential to know your audience, when embarking on a user-centred design, so as to effectively address their needs.

Finally, we uncovered a real need to investigate several technical issues, particularly those that would ensure that the system is capable of identifying the hand gestures of different users. For example, there are several hand gestures that could be implemented in the Nunaliit framework to facilitate major functions,; those gesture patterns need to be recognized individually and concurrently within multi-users interactions. Also, each user will differ in their hand gestures, the size of their hands and fingers size and the hand with which they use the system (right or left).

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Appendices

A. Appendix: Study Consent Form

Title: Investigating the Potential of Tabletop Natural User Interfaces Tools in Improving the Nunaliit Cybercartographic Atlas Framework
Date of ethics clearance: To be determined by the REB
Ethics clearance for the collection of data expires: To be determined by the REB

Emerging multi-touch gestural and tangible interaction techniques (hybrid interaction) have the potential to enhance collaboration and discovery. However, they have limitations when manipulating intensive spatial data sets. Our goal is to define a novel interaction technique for multi-touch gestural and tangible interfaces in shared mapping contexts, in which the subsequent map allows for creating, reviewing, editing and adding information through the tabletop collaborative atlas. Therefore, we would like to learn about the perceptions that user's hold regarding these technologies and, specifically, we will evaluate some possible interactions using a paper prototype in order to verify the best hybrid interaction options in collaborative map creation.

The researcher for this study is **Omar Bani-Taha**, a graduate student working under the supervision of **Dr. Fraser Taylor** in the department of Human Computer Interaction at Carleton University.

Participation in this study takes approximately one hour and is rewarded with $10 for general testing portion of the individual study. While expert participants in the group study will spend around two hours and will receive a certificate of appreciation along with some refreshments during the focus group. There are no known personal or physical risks associated with this study. If you are uncomfortable discussing the topic of applying hybrid interaction in map creation, we recommend that you do not participate in this study. You have the right to withdraw from the study at any time, and for any reason. You can withdraw by asking us to leave the study prototype evaluation at any time before completing it. If you withdraw from the study, all information you provide will be immediately destroyed. In addition, be aware that video recording will capture only the participants' hands and fingers movements during their interaction with the testing prototype materials. There is no face capturing in our recorded video, and participants have the right to check the recorded material once they complete the study task.

All research data will be encrypted and password protected on Carleton University servers. Research data will only be accessible by the researcher **Omar-Bani-Taha** and the research supervisor **Dr. Fraser Taylor**. Once the project is completed, all research data will be kept and potentially used for future comparisons with other research projects on this same topic. This project was reviewed by the Carleton University Research Ethics Board, which provided clearance to carry out the research. Should you have questions or concerns related to your involvement in this research, please contact:

By signing this form, you consent to participate in the research study as described above.

Participant name & Signature: ____________________ Date: ____________________

B. Appendix: E-mail (Letter of Invitation)

Title: Investigating the Potential of Tabletop Natural User Interfaces Tools in Improving the Nunaliit Cybercartographic Atlas Framework
Date of ethics clearance: To be determined by the REB
Ethics Clearance for the Collection of Data Expires: To be determined by the REB
Dear Sir or Madam,
My name is Omar Bani-Taha and I am a Master's student in the department of Human Computer Interaction at Carleton University. I am working on a research project under the direction of **Dr. Fraser Taylor.**
I am writing to invite you to participate in a study that assesses the potential use of hybrid interfaces in map creation. This study aims to evaluate a novel interaction technique for multi-touch gestural and tangible interfaces in map creation.
This study involves an approximately one hour usability study that will take place in a mutually convenient, safe location. With your consent, interviews will be audio and video-recorded — be aware that the video recording will capture only the participants' hands and finger movements during their interaction with the testing prototype materials; there is no face capturing in our recorded video. We will transcribe the audio- video recording and once I defend my thesis, the audio and video recordings will be destroyed.
You will have the right to end your participation in the study at any time, and for any reason. If you choose to withdraw, all the information you provide will be destroyed. Participation in this study takes approximately one hour and we offer the participants $10 as a token of our appreciation for general testing portion of the individual study. While participants in the focus group study will devote up to two hours and they will received a certificate of appreciation and some refreshments. No other compensation will be provided.
All research data, including audio-recordings and any notes will be encrypted and password-protected. Any hard copies of data (including any handwritten notes or USB keys) will be kept in a locked cabinet at Carleton University. Research data will only be accessible to the researcher Omar-Bani-Taha and the research supervisor Dr. Fraser Taylor.
This project was reviewed by the Carleton University Research Ethics Board, which provided clearance to carry out the research. Should you have questions or concerns related to your involvement in this research, please contact:
Sincerely,
Omar Bani-Taha
School of Information Technology/
HCI Department
Carleton University

C. Appendix: Focus Group Themes

Welcome the Group/Describe Discussion Workflow

Good morning and welcome. Thank you for taking the time to join our discussion, which centres on an investigation of the potential impact of employing Hybrid interfaces (tangible and touch-based gestural interfaces) into collaborative atlas map creation. My name is Amos Hays, and I will serve as the facilitator for today's focus group discussion. Assisting me is Omar Bani-Taha. The purpose of today's discussion is to get information from you concerning the benefits or limitations of employing hybrid interaction technology in the creation of collaborative Nunaliit atlases. You were invited because you have professional experience in user experience, interfaces development and design, as well as geomatics and cartographic mapping.

There is no right or wrong answer to the questions that I am about to ask. We expect that you will have different points of view. Please feel free to share your point of view, even if it differs from what others have said. If you want to follow up on something that someone has said, you want to agree, disagree, or give an example, feel free to do that as well. Do not feel like you have to respond to me all the time. Feel free to have a conversation with each other about these questions. I am here to ask questions, listen and make sure everyone has the chance to share. We are interested in hearing from each of you. So if you are talking a lot, I may ask you to give others a chance. On the other hand, if you are not saying much, I may call on you. We just want to make sure we hear from all of you. Feel free to get up and get more refreshments if you would like. Amos and I will take notes to help us remember what is said. We are also recording the session because we do not want to miss any of your comments. We have name tags here in front of us today, but no names will be included in any of the reports. Let's begin by having each person in the room tell us their name and area of expertise. (Adapted from Krueger and Casey, 2000)[7]

Study purpose

Emerging multi-touch gestural and tangible interaction techniques (hybrid interactions) have the potential to enhance collaboration and discovery. However, it might have some limitations when manipulating intensive spatial data sets. Our goal is to define a novel interaction technique for multi-touch gestural and tangible interfaces in a shared mapping context, in which the subsequent map allows for creating, reviewing, editing and adding information through the tabletop collaborative atlas Therefore, we would like to learn about the perceptions that user's hold regarding these technologies and, specifically, we will evaluate some possible interactions using a paper prototype in order to verify the best hybrid interaction options in collaborative map creation. **Discussion themes:**

1. **Evaluating the proposed hybrid interaction technology for making the collaborative Nunaliit atlas:**
   - How extensively could interactive tabletops technologies be used in map creation?
   - What are the benefits of using this technology in map creation?

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[7] Krueger, Richard A. and Mary Anne Casey (2000). Focus Groups: A Practical Guide for Applied Research. 3rd Edition. Thousand Oaks, CA: Sage Publications.

- What features are most important for collaborative use? Especially for elderly users?
- What features make tabletops better than standard computer interfaces?

2. Assessing the ease of use for the proposed hybrid interactive Nunaliit atlas:
- What is your overall impression of using a collaborative atlas in map creation?
- What are your suggestions for improving the use of interactive Nunaliit atlas, including design, information and functionality?
- Are there any special considerations we need to be aware of, to ensure the atlas' ease of use?
- What is your opinion about the following statement? We suggest that the interactive collaborative Nunaliit atlas users will require less cognitively challenging when creating maps through the use of hybrid interactions (tangible, touch-based and gestural) in a collaborative tabletop atlas.

3. Estimating Atlas effectiveness

- How is efficient this novel interfaces will be used as an input/editorial tool for map creation?
- How successful will the interactive Nunaliit collaborative atlas be in capturing the narratives of people?
- How important is this novel approach in forming a new era of mapping creation interaction?

4. Underpinning the significance of using tangible interfaces in mapping creation

- To what extent will the interactive Nunaliit atlas engage users, and enable them to focus on adding and manipulating their favourite map information?
- What are the benefits of using tangible interfaces in collaborative mapping creation?
- What are the constraints of using such a technology?

5. General comments or recommendations towards implementing interactive Nunaliit collaborative atlas

Please feel free to add information or argue any other ideas.

Closing discussion

Thank the participants for their precious time and for participating in this research, we appreciate their insightful opinions which will enrich and add great value to our study.

D. Appendix: Questionnaire

General Questions

1. What is your age in years?
2. What is your sex?
3. What is the highest level of education /current level of study?
4. Have you participated in a usability test in the past six months?

Computer Expertise

1. How many hours do you use a computer daily?
2. What computer platform do you normally use? [E.g. Mac, Windows XP, etc.]
3. Have you used touch devices before? Please specify?
4. Please rate on the following scale your willingness to use new technology.[1-5 Likert]
5. Please rate on the following scale how knowledgeable you are about technology in general. [1-5 Likert]

Participant's performance and satisfaction about hybrid interaction options

Please rate your experience using the following interaction options: [Likert scale 1-5]

Evaluation question	**Tangible objects**	**Multi touch**	**Hand Gestures**
Using tangible objects as a mean of interaction was: *[1 very difficult - 5 very easy]*			
Performing this interaction felt: *[1 unnatural - 5 very natural]*			
Starting this technology on a table top surface required *[1 little motion, 3 right amount of motion – 5 too much motion]*			
The action cause by this interaction was *[1 too slow, 3 just right, 5 too fast]*			
Performing this gesture was *[1 not tiring - 5 tiring/tedious]*			
The given information for the following interaction was [1 not accurate - 5 accurate]			
I am willing to use this technology for map creation if it is available *[1 strongly agree, 3 neither agree or disagree - 5strongly agree]*			
I believe this technology will be useful to interact with interactive maps in collaborative contexts? [1 not useful - 5 very useful]			
This technology will enhance the ease of use for map creation *[1 strongly agree, 3 neither agree or disagree - 5strongly agree]*			
How well do these interaction options work on map			

creation *[1 poor – 5 excellent]*			

Comments about tangible object interactions:

Comments about multi-touch interactions:

Comments about hand gestures interactions:

Other Comments or recommendations,

E. Appendix Semi-Structured Interview Questions

Purpose of Study

Emerging multi-touch, gestural and tangible interaction techniques (hybrid interactions) have the potential to enhance collaboration and discovery. However, they might have limitations when manipulating intensive spatial data sets. Our goal is to define a novel interaction technique for multi-touch, gestural and tangible interfaces in a shared mapping context, which support a variety of map functions, including creating, reviewing, editing and adding information through the interactive tabletop collaborative atlas. Therefore, we would like to study the perceptions that user's hold regarding these technologies. Specifically, we are evaluating possible interaction options that have been gathered from our usability test.

Note: ask the interviewees to sign the study consent form before starting the interview.

Discussion questions: The flowing is an area of assessment to evaluate the system functionality. The interviewer will use them as guide to manage the progress of the interview.

6. **Evaluating the proposed hybrid interaction technology as an input adding/editing tool in the Nunaliit Framework:**
   - How extensively could interactive tabletops technologies be used in map creation?
   - What are the benefits of using this technology in map creation?
   - What features are most important for collaborative use? Especially for Elderly users?
   - What features make tabletops better than standard computer interfaces?
7. **Assessing the ease of use of the proposed technology:**

   - What is your overall impression of using these mixed interfaces in collaborative map creation?

- What are your suggestions for improving the use of the interactive Nunaliit atlas, including design, contents and functionality?
- Are there any special considerations of which we need to be aware to assure the atlas' ease of use?
- What is your opinion of the following statement?

We suggest that the users of the interactive collaborative Nunaliit atlas will require a lesser cognitive load when creating maps by using the hybrid interactions (tangible, touch-based and gestural) in a collaborative tabletop atlas.

8. **Valuing atlas effectiveness**
   - How useful will this technology be in terms of an efficient and accurate input/editorial tool for map creation?
   - To what extent will the interactive cybercartographic collaborative atlas be successful in capturing people narratives?
   - How important will this novel approach be in developing a new era of map creation?
9. **Underpinning the significance of using different interfaces in map creation/preferred interface**
   - How important will the tangible interfaces be in engaging users, and enabling them to add and manipulate their favorite map information?
   - What are the benefits of using tangible interfaces in collaborative mapping sessions?
   - What are the constraints of using such a technology?

Closing discussion

Thank the participants for their time and participation in this research. We appreciate your insightful opinions, which will enrich and add great value to our study.