

**BRIDGING SIGHT AND INSIGHT: VISUALIZATION IN ACTION
AMONG DIGITAL HUMANISTS**

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Submitted to the Graduate Faculty of
the School of Computing and Information in partial fulfillment
of the requirements for the degree of

Doctor of Philosophy

University of Pittsburgh

2022

UNIVERSITY OF PITTSBURGH
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University of Pittsburgh, 2022

Emerging from the 1950s, Digital Humanities (DH) has gradually developed into an interdisciplinary research field between different research methods and conventions. As increasing numbers of scholars entered the DH landscape from various knowledge domains, scholarly discussions have concerned the connotations and extensions of DH without achieving agreement. However, these theoretical discussions failed to provide either empirical evidence to support their claims or sufficient insight into the shape of DH. In this dissertation, I aim to explore the current dynamics of digital humanities as a field from an empirical perspective, and particularly through the lens of inscriptions. Inscriptions have been widely used in science and technology studies to illustrate the disciplinarity of fields and as a vehicle to mobilize scientific communication.

In DH research, visual inscriptions (e.g., visualizations and graphs) have been increasingly applied in both research output and process, creating unprecedented opportunities to use them as a critical indicator to examine the cross-field collaborations among DH scholars and the field's evolution. More specifically, I take a Latourian approach to investigate how digital humanists, broadly defined as any researchers or practitioners engaging in DH work, leverage inscriptions as “immutable mobiles” to produce, transfer, and communicate humanities knowledge, both in research outputs and during the research process. I apply a sequential, explanatory mixed-methods design, quantitatively examining the use patterns of inscriptions in DH journal articles from 2011 to 2020, before proceeding to the underlying, implicit decision-making processes and practices of visualization among digital humanists of various domains, using semi-structured interviews.

This dissertation contributes to scholarship in digital humanities, visualization, and science and technology studies. First, this dissertation offers one of the first empirical studies of inscription use in DH. The findings of the dissertation suggest a gradual evolution of DH

into an empirical, data-driven, and formalized field, which, in the long run, contributes to a better understanding of the current dynamics as well as the future directions of DH as a field. Second, this dissertation develops a working taxonomy of inscriptions commonly used in DH research, contributing to visualization scholarship from the perspective of an under-evaluated research context and potentially accelerating visual data literacy among DH communities. Finally, this dissertation provides a basis for further cross-field, comparative research on inscription use, which has been a classic theme of discussion in science and technology studies that can also potentially contribute to research on scholarly communication and collaboration.

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To Mom and Dad, with love

Preface

It takes a village to write a dissertation, and I am grateful to have my own unique and supportive village throughout my Ph.D. journey. I would like to give special thanks to my advisors and dissertation committee. Professor Sheila Corral took me in as her doctoral student in 2017 and has since then offered me continuous advice and guidance for my work, research, and career, even after her retirement. My co-advisors, Dr. Ruth Mostern and Dr. Kip Currier, have given me invaluable feedback on my dissertation with their knowledge and expertise in digital humanities and information research and have supported me through the major Ph.D. milestones with unfailing encouragement and advice. I am also particularly thankful to Dr. Daqing He, who joined my dissertation committee during a time of hardship in my doctoral study and generously opened the door for me to his lab and group meetings, where I have learnt a lot. Without all my advisors and their kindness, support, and guidance, I could not have imagined such a fulfilling Ph.D. career.

I am also lucky enough to have many mentors who supported me over the ups and downs of my Ph.D. study. I am not sure if I would ever have this rewarding career in library and information science if I had not met Haihui Zhang back in 2014, who first introduced me to the work of library science and archives. I might not have even come to the United States if it was not for Dr. Cecile Sun, who believed in me and accepted me as her student in Chinese literature. Although I am now on a quite different academic trajectory, I am forever grateful for Dr. Sun's continuous encouragement, caring messages, and enthusiastic support. I also want to thank Dr. Lingfei Wu for introducing me to a new scholarship of the science of science in my doctoral study, for the opportunity to collaborate, as well as for the career development advice.

In addition, my Ph.D. journey would not have been completed without the support from the SCI community. I must thank the ICDS department for providing the Teaching Assistantship over the course of my study, which has helped me tremendously to navigate my potential to be a teacher and educator. I also want to thank all the ICDS faculty for their guidance and support, Debbie Day and the whole SCI administration for their assistance with paperwork, grants, registration, and everything, and the entire ICDS Ph.D. cohort for

being amazing colleagues and friends.

I am also grateful to extend my supporting “village” into a broader intellectual and professional community. The completion of my dissertation benefited from the invaluable experience and knowledge my participants shared with me during interviews, and I cannot miss this opportunity to express my gratitude to them for taking the time during this critical time of the pandemic to participate in my study and generously share their work with me. I am aware that many sparkles in this work are indebted to their wisdom. Thanks to Kai Li and Fanghui Xiao as well, for collaborating with me on certain parts of the dissertation work and offering me their critical feedback.

The initial idea for this project came from my unique experiences with the LEADS-4-NDP fellowship program in 2019. I want to extend my gratitude to Dr. Jane Greenberg and the faculty at Drexel University’s College of Computing & Informatics for granting me this invaluable opportunity to develop my work. In addition, the completion of this dissertation also benefited from the generous financial support from the following institutions: Pitt Cyber Accelerator Grant from the University of Pittsburgh Institute for Cyber Law, Policy, and Security; the Eugene Garfield Doctoral Dissertation Fellowship from Beta Phi Mu Honor Society; and the Doctoral Dissertation Proposal Scholarship from the Association for Information Science and Technology.

Finally, I must give my most heartfelt thanks to my friends and families who have continued to inspire me and created endearing memories of my life in Pittsburgh: To Sunny, Ning, Yu, Tianni, and Danchen, for hotpots, board games, and trips; to Xiao Yu, for laughs; to Yulia, for cocktails and New Orleans; to Wan Li, for statistics; to Haochuan, for programming; to Judith, for conversations; to Andras, for all the fun and lovely time, for travel, food, and bears; to Klara and Andras, for heartwarming cheers; to mom, for being my best role model all the time; to dad, grandparents, and all my family, for care, love, and unconditional support. I look forward to having all of you there with me for my new adventures.

1.0 Introduction

1.1 Background

1.1.1 Rose Diagram and Nightingale's Insight

The journey started with an insight: Back in the 1850s, Florence Nightingale, a nurse serving in the British Army during the Crimean War, discovered that the most common reason for casualty in the army were not battle wounds, but rather, the epidemic disease, illness, and infection that often happened in hospitals. And therefore, improving sanitation practices at hospitals would be able to save thousands of soldiers' lives. One important decision that Nightingale had to make after this realization was how to communicate this insight to the decision maker of the time, Queen Victoria, and persuade the Queen to follow her recommendation to improve sanitation practices at hospitals.

Nightingale, in this case, could have multiple options. For example, she could write a brief letter to the Queen and try to convince the Queen with her reasoning and arguments. Alternatively, Nightingale could also submit a detailed report with tables and data demonstrating the arguments and claims. Although these methods may be the most fashionable of the time, they might not be the most effective in this case. The first option suffers from the lack of data, which may reduce the credibility of Nightingale's argument. The second option, on the other hand, presents a sufficient volume of data, but is not an efficient method to deliver the insight to this particular audience.

Faced with this situation, Nightingale chose a method that was truly revolutionary and that no one had ever done before. She created a new form of visual graph, which was later coined as the "rose diagram" and marked one of the earliest visualizations in history (Figure 1). As demonstrated in Figure 1, this graph directly compares the mortality caused by infection and battle wounds from 1854 to 1856 in a visually striking manner. With this novel graph, Nightingale successfully convinced the Queen to follow her recommendations, which modernized the sanitation practices in British hospitals in the 19th century.

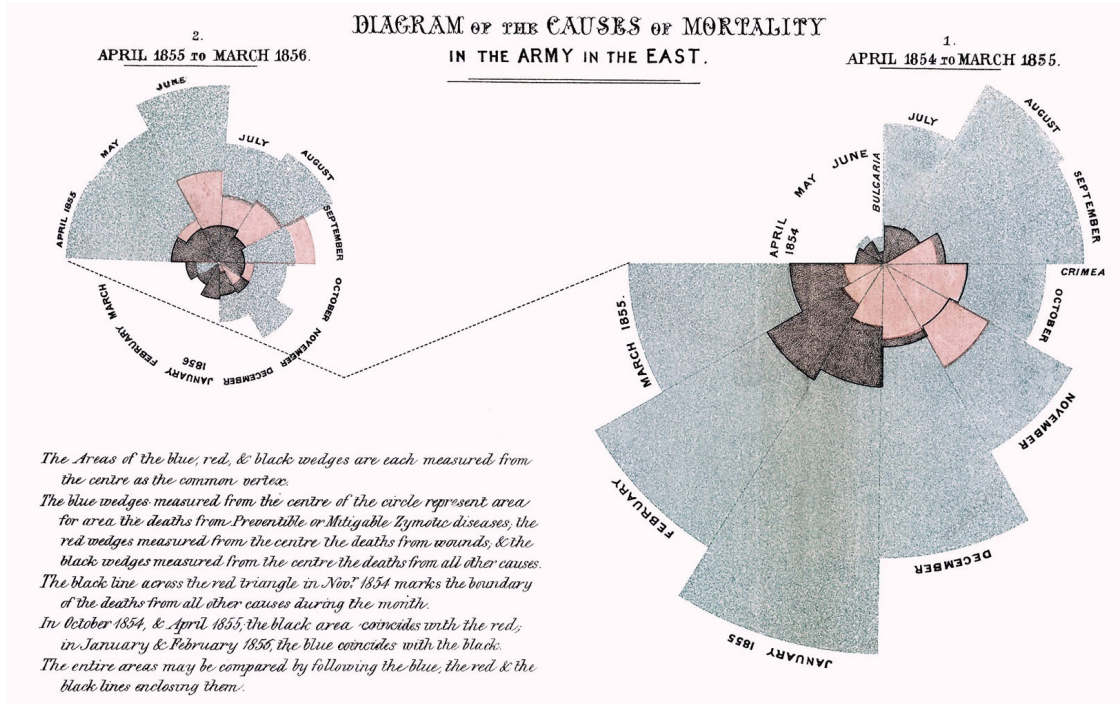


Figure 1: Diagram of the Causes of Mortality in the Army of the East, 1858.

Nightingale's case demonstrates the sheer power of seeing and also illustrates the dynamics between sight and insight: The visuals are created based on the insight and discoveries; however, the effectiveness of the visuals will also largely determine the way the insight is perceived among audiences and communities. In addition, Nightingale's case also raised multiple questions. For instance, (1) why did Nightingale have to develop an "instrument," in this case, a specific form of inscriptions, and use it as a tool to communicate to the decision maker? What is the unique nature of inscriptions? (2) Why did Nightingale choose a visual graph over tables, which were a more commonly used method of communication during that period of time? How different are the functions of inscriptions of various forms and types? (3) Finally, if Nightingale was speaking to a different group of audience, such as other statisticians or nurses, would she choose a different method and communication tool? In other words, how is inscription use affected by specific contexts, needs, and communities?

In this dissertation, I explore these questions related to the concept and use of inscriptions and particularly examine them in the specific context of digital humanities research.

The urgency and value of this dissertation study are grounded in the unique nature and functionality of inscriptions in research, and its potential contribution to illustrating the current dynamics as well as the actual shape of digital humanities (DH) as a field. Defined as the “material signs and artifacts...embodied in some medium” (Roth & McGinn, 1998), inscriptions function as immutable mobiles in research and can be a critical index to examine specific characteristics of a field or a discipline (Cleveland, 1984; Smith, Best, Stubbs, Johnston, & Archibald, 2000; Arsenault, Smith, & Beauchamp, 2006). As digital humanists suffer to understand the identities of digital humanities as a field as well as its future development, a study of inscription practices offers a valuable perspective to explore the variety of research conventions in the field, the behind-the-scene communities driving the evolution of the field, and how the communication and collaboration among these communities shape the future of DH.

1.1.2 Identity Crisis of Digital Humanities as an Interdisciplinary Field

Emerging from the “humanities computing” around the 1950s, digital humanities have gradually developed into an interdisciplinary research field with various debates and issues worth in-depth exploration (Schreibman, Siemens, & Unsworth, 2004, 2016). One of the enduring concerns in the field has been how to define digital humanities, regarding which scholars are yet to reach an agreement. A large volume of scholarship, including manifestos, monographs, and articles has approached this question from aspects such as the scope of DH, the implications of the “digital,” and how DH differs from the humanities convention (Schreibman et al., 2004, 2016; Burdick, Drucker, Lunenfeld, Presner, & Jeffrey, 2012; Gold, 2012).

Among the various debates and controversies in the scholarly attempts to portray the identities of DH, one widely acknowledged attempt is the “Big Tent DH.” The notion of “Big Tent DH” (Svensson, 2013) was raised at the DH 2011 Conference to demonstrate the increasing diversity of the subjects, disciplines, and topics that can be included under the umbrella of DH (Figure 2). As shown in Figure 2, in addition to the traditional humanities disciplines and fields, the “Big Tent DH” embraces an increasing number of new areas of

inquiry such as e-Performance, new media studies, cultural studies, and library science, as well as a series of new methods and forms of knowledge production practices such as big data and visualization.

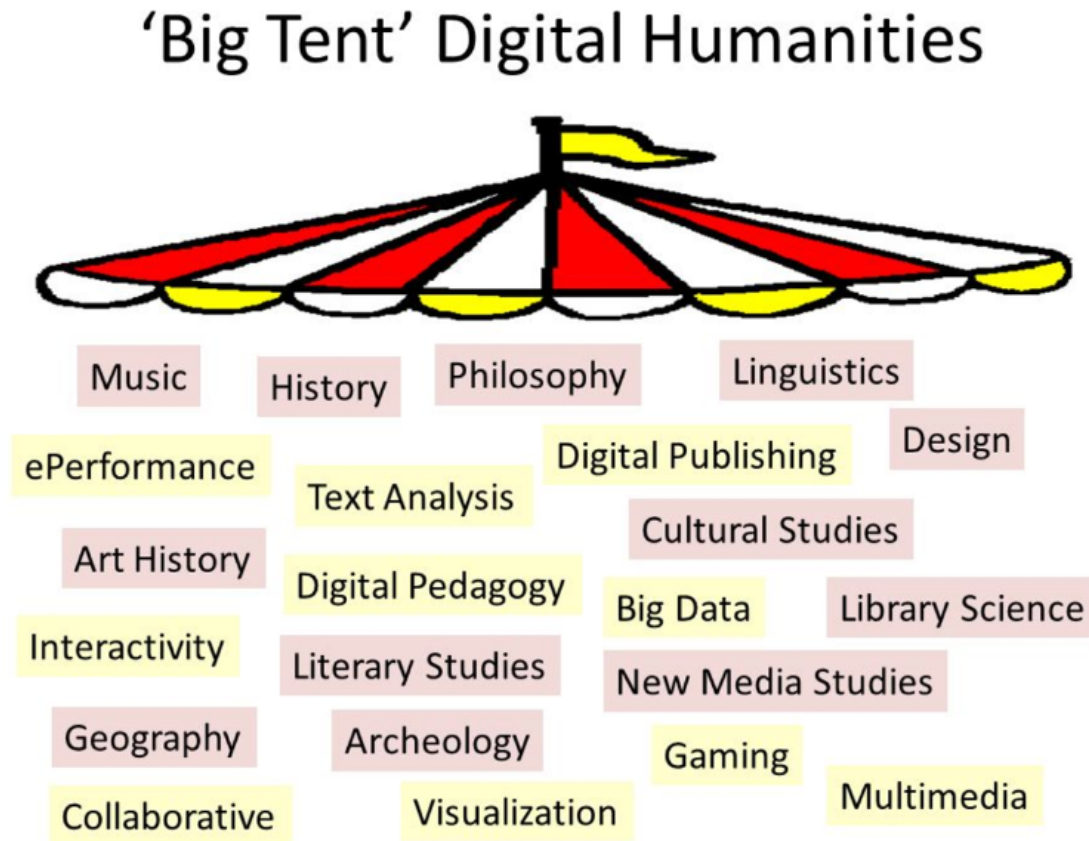


Figure 2: The “Big Tent” Digital Humanities (<https://slideplayer.com/slide/8272334/>)

Despite the valuable, conceptual discussions of the identity of DH, there has been a lack of empirical examination that can actually demonstrate, both qualitatively and quantitatively, the current dynamics within the field, as well as how the field is evolving. Questions such as *who are leading this interdisciplinary field?* and *how do different research communities and forms of research practices shape the field dynamics and scholarly interaction?* are crucial to understand DH as a field, but can only be answered with empirical data and analyses. To potentially answer these questions, I offer an empirical exploration in this dissertation of the

dynamics of the digital humanities field, focusing on one empirical lens, i.e., the inscriptions.

1.2 Key Concepts

Three concepts are essential to understand the discussions in this dissertation: inscription, visualization, and digital humanist. In this section, I elaborate on the notions of these three concepts so as to demonstrate the scope of this dissertation. Questions to be answered include: What are inscriptions? How do they refer to different objects in different contexts? How does inscription differ from visualization? What does it mean to be a “digital humanist,” and more specifically, within the context of this dissertation?

1.2.1 Inscription

The notion of an inscription was first raised as a general term to refer to the map-drawing process in science and scientific practices (Latour, 1990). Related to this notion, scientific instruments that “provide a visual display of any sort in a scientific text” are described as “inscription devices.” This perspective on inscriptions illustrates the need to “follow scientists and engineers” in laboratories and during the scientific knowledge production process (Latour, 1987).

In addition to this definition from the procedural perspective, inscriptions are also commonly defined as “material signs and artifacts of scientific production embodied in some medium” (Roth & McGinn, 1998). In scientific research contexts, they are traces of scientific research production embodied in materials and consist of a broad spectrum of non-verbal forms, including but not limited to all sorts of information visualizations, tables, diagrams, and equations. Arsenault et al. (2006) established a taxonomy of inscriptions based on scientific research literature, which includes three major categories, i.e., graphs, non-graph illustrations (NGI), and non-visual inscriptions (NVI). Graphs refer to figures that are created based on and represent empirical and quantitative data. Graphs can also be used interchangeably with charts and visualizations. NGIs are visual representations that are

not necessarily created based on empirical, quantitative data but are still frequently used in research literature to demonstrate a research object or procedure. NVIs, by contrast, are non-visual which essentially include tables and equations in Arsenault et al.’s (2006) classification scheme.

Inscriptions play a fundamental role in the construction and communication of scientific knowledge. All the inscriptions in sciences function as “immutable mobiles,” meaning that they can retain their meaning and information regardless of contexts or communities (Latour, 1990). This nature of the inscriptions in general account for their ability to deliver scientific discoveries and arguments across contexts (e.g., in journal articles, at conferences, or on social media). In addition to this essential role, inscriptions can also tremendously increase the persuasiveness of scientific literature (Suchman, 1990) and have enormous value in science education (Dimopoulos, Koulaidis, & Sklaveniti, 2003; Evagorou, Erduran, & Mäntylä, 2015). However, inscriptions in many other research contexts refer to different artifacts and objects. For example, in the humanities research context, the term “inscription” often refers to the embodied information in artifacts such as engraving or epigraphs (Bodel, 2001).

1.2.2 Visualization

But the discussion of inscriptions as a form of non-verbal rhetorical instruments in the humanities is not a new phenomenon. The large body of scholarship in cartography is one early example that has been closely related to humanities disciplines (Jessop, 2006). Building upon the long tradition of cartography, humanities research has developed a strong focus on visual languages (in their words, visualizations), rather than other forms of inscriptions such as tables or equations, to represent humanities data and knowledge. More specifically, with the evolution of information technologies and computational methods, computer-assisted visualizations started to receive widespread recognition in digital humanities in the 2000s, when new visualization techniques were developed and applied to facilitate the distant reading of texts (Moretti, 2005; Sinclair, 2003).

Generally speaking, visualization can take various meanings. The Merriam-Webster Dictionary defines visualization as the “formation of mental visual images or the act or process

of interpreting visual terms or of putting into visible form.” A Latourian notion of visualization defines visualization as one particular form of inscriptions, which are created based upon and also to reflect and represent empirical and quantitative data. In other words, the visualization defined in the context of this dissertation can also be used interchangeably with charts and graphs in Arsenault et al.’s (2006) framework. Thinking from this perspective, does a screenshot or a photograph count as visualization? Photographic representations have been widely used in sciences to communicate existence of natural phenomena and facts (Bartalesi, Meghini, Metilli, Tavoni, & Andriani, 2018; Huang et al., 2020). Despite their equally important function and value in supporting claims and arguments in research, such visual representations are not created based on quantitative and empirical data, and therefore, are not regarded as visualizations under a Latourian scientific inscription framework. This understanding of visualizations is also widely adopted across research and context, especially with the increasing application of computational methods in research (Bol, 2020; E. Tufte, 2001; Rauber, Fadel, Falcão, & Telea, 2017).

Visualization is also a crucial concept in the digital humanities research context. The notion of “humanistic visualization” demonstrates the need to create visual representations that fit the specific needs of humanistic inquiries and humanities research (Drucker, 2011). Similarly, researchers have also raised different principles and ideas for a quality “humanistic visualization,” which, in some occasions, contradict the data abstraction and simplification principles of visualization in general (Manovich, 2011; Hinrichs, Forlini, & Moynihan, 2019; Woolgar, 1990). Visualizations in the humanities research context have strong overlaps with the connotations of “inscriptions” in the STS context, although they refer to not only graphs and charts but also photographs, images, or illustrations (Münster & Terras, 2020).

1.2.3 Summary of Inscription and Visualization

Figure 3 summarizes the connotations of inscription and visualization and highlights the conceptual differences between the two terms. The concept “inscription” used for this dissertation takes the definition in the science and technology studies research context. More specifically, this concept contains three characteristics: First, it refers to the evidential arti-

facts and objects used in research outputs to communicate knowledge and claims, including both visual (e.g., graphs and charts) and non-visual evidences (e.g., tables, equations). Second, all inscriptions are “immutable mobiles,” which have the ability to move across contexts while maintaining the same meaning and information. Finally, inscription has a more specific application context and demonstrates a strong tradition in science and technology studies.

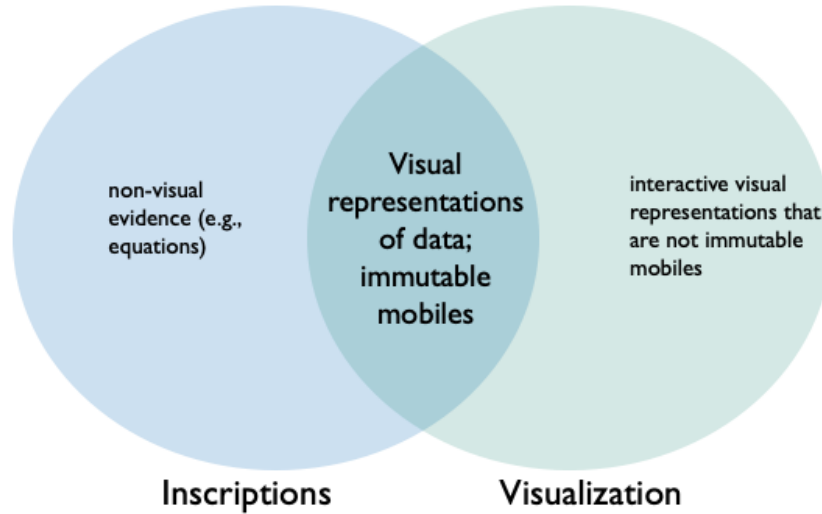


Figure 3: Conceptual Differences between Inscription and Visualization

Comparatively, visualization has somewhat different connotations, despite a strong overlap with inscriptions. Visualization contains visual data representations that function as immutable mobiles, which overlap with connotations of inscription. However, in addition to the overlap, visualization also includes *interactive* visual representations that are not “immutable.” Such interactive visualizations are widely applied in contexts such as digital humanities or cultural analytics. In addition to the conceptual differences, the two terms also differ in their application contexts. Particularly, compared with inscriptions that have a strong STS emphasis, visualization has broader application contexts. These differences are partially attributed to different research and disciplinary traditions and conventions. As this dissertation aims to be an interdisciplinary one that bridges multiple fields of research and discipline, *I use both terms in this dissertation, given specific contexts of discussion.*

For example, inscription is more widely used in Study 1, as it is a more accurate term to capture all types of artifacts and materials included in the analysis. The identification and classification of inscriptions used in the digital humanities scholarship in the dissertation was established based on Arsenault et al.’s (2006) framework, which includes graphs, non-graph illustrations (NGI), and non-visual inscriptions (NVI), along with their respective sub-categories. Building upon this scientific inscription framework, I collaborated with another researcher to identify new and unique categories of inscriptions used in DH, and as a result, added multiple sub-categories such as simulations (under NGI), text (under NVI), and code (under NVI). Specific definitions for each of the identified categories are presented in Section 5.1.1. It was worth noting that certain types of materials were not included as inscriptions based on the critical discussions between my collaborator and I according to the definition of the concept. Quotation was one such example. Quotations were not included as a form of inscriptions in this study, because (1) functionally, they are not “immutable” in the sense that they can usually be appropriated when incorporated in a new publication text, and (2) visually, they are usually included in the narrative flow of an article and not presented distinguishably from other narrative text. Poems, when presented in their entirety and separate from other narrative, however, were considered to be a form of inscription because they are functionally “immutable” and visually distinguishable. These examples demonstrate that the identification of inscriptions in this study was subject to critical judgment, which is potentially an important part of knowledge classification and organization. Visualization, by contrast, is frequently used in Study 2, particularly in my semi-structured interviews with DH researchers and practitioners. This is because (1) visualization is a better term to describe interactive visual representations that are frequently implemented in DH interfaces and projects, and (2) it is a term that has been more accepted and embraced in DH scholarship and research context.

1.2.4 Digital Humanist

Accompanied with the “Big Tent DH” notion and the ambiguity in the research identities of the DH field came the discussions of the DH workforce that concern one central question:

“What does a digital humanist entail?” Alvarado (2012) defined a digital humanist as someone who (1) aims to develop the deep domain knowledge of the traditional humanist, (2) learns a wide variety of technologies and programming languages, and (3) critically situates the technologies as cultural artifacts “participating in the production of social and cognitive structures.” This definition of the “digital humanist” requires a scholar to be proficient in both technical skills and humanities knowledge, which, admittedly, is hard to achieve and limits the involvement of scholars from various domains in digital humanities research. Ramsay (2011), by contrast, argued that a scholar can be called a digital humanist as long as they can build something with digital methods (e.g., applying existing tools or modifying existing codes). This definition embraced a much broader reading of the “digital,” emphasizing the gradual transition of a humanities scholar into a digital humanist. By this definition, a digital humanist is primarily a humanist, who received strong humanities training. Neither of the definitions, however, captures the diverse research communities involved in DH research and reflects the true workforce landscape in the DH field (Jänicke, 2016).

To address these issues, more recent works apply empirical methods to analyze the community structure of DH (Wang, 2018; Weingart & Eichmann-Kalwara, 2017). Such empirical studies take a more bottom-up approach and demonstrates a more inclusive understanding of “digital humanists,” which includes any researchers or practitioners currently working on, or have published on, DH related projects and studies, regardless of their professional training backgrounds or affiliated institutions. This is the definition of “digital humanists” that I am adopting in this dissertation. This broader, inclusive definition of “digital humanists” enables an *empirical examination* of the *relations* between various research communities with the DH field.

1.3 Problem Statement and Thesis

With the increasing application of inscriptions (or visualization) in digital humanities research, scholars have started to discuss the principles and ideals for quality visualizations

(Münster & Terras, 2020). However, most of such discussions have remained conceptual and emphasized a hypothetical notion of “*humanistic visualization*” (Drucker, 2011; Manovich, 2011). This notion suggests that visualizations in digital humanities studies should adopt different sets of design principles and be used distinctly from the general information visualization due to the intrinsic interpretative nature of humanities data and inquiries. Yet, little research has offered empirical evidence to support this general claim or provided insight into the *status quo* of DH inscriptions. How are inscriptions actually used in DH research outputs, particularly in journal publications? And how do digital humanists apply inscriptions and work with inscription devices in their work? These questions are crucial to answer to build a comprehensive understanding of inscription use and practices in the digital humanities field, and in the long term, to further inform the understanding of the research identities of DH as a field.

In this dissertation project, I contend that an empirical examination can add to and illustrate the conceptual discussion of the “humanistic visualization” in DH and build a foundation for further inscription analyses in both DH and beyond. In addition, such an empirical investigation into the inscription use and practice can also offer a meaningful lens to observe the current dynamics as well as the future directions of digital humanities as a field. Bruno Latour (1987), in his classic text titled *Science in Action*, contended that to study what the modern science entails, one should look to the day-to-day practices at scientific labs. This suggests that any individual interested in understanding sciences should move the focus from the “cold, stable products” to the “warm, unstable productions.” Illustrating a series of scenes at a scientific laboratory where an imagined “dissenter” meets the scientists at work and debates over the scientific arguments *in the making*, Latour (1987) discussed the importance of revealing the “black box” of science by following and investigating scientists’ everyday work and scientific practices: to discover how scientific facts are constructed in labs, embodied and transformed by “immutable mobiles” such as inscriptions, and then disseminated, disputed over, revised, and accepted among scientists and the general public as knowledge. Latour’s theory shed light on how the interactions among actors (i.e., communities), their practices, and the mediating artifacts can successfully connect and forge the understanding of a field. The proposed ethnographic approach and rules of

method in the text also demonstrate viable ways of achieving theoretical understandings of science. Building on Latour’s conceptualization, scholars in science and technology studies have also empirically tested the power of inscriptions in revealing disciplinary traits in sciences (Cleveland, 1984; Smith et al., 2000; Smith, Best, Stubbs, Archibald, & Roberson-Nay, 2002; Arsenault et al., 2006).

In this study, I adopt a Latourian lens to look into how digital humanists, broadly defined as any researcher or practitioner engaging in DH work, apply and work with inscriptions in their work, with empirical analytical methods. More specifically, I investigate how digital humanists from various knowledge domains (1) leverage inscriptions as a form of “immutable mobiles” (Latour, 1990) to present findings and support argumentation in research outputs (in this case, DH journal articles) and (2) work with inscriptions in their research processes. Following a two-phase, sequential mixed-methods design, I use a combination of qualitative and quantitative methods to address multiple research questions with regard to inscription *use* and *practice*, such as “how are inscriptions used across time and community?”, “what are the commonly used types of inscriptions and what are their narrative functions?”, and “what does it mean to be a quality visualization in research practices?”

This dissertation sets out the first step to empirically explore the shifting and ambiguous research identities of DH. Inscriptions, with their increasing significance and scale of application in DH scholarship (Flanders & Jannidis, 2019; Schreibman et al., 2016), serve as a promising lens and perspective to examine current research communities in DH and their work dynamics, so as to reflect on the gradual changes of the DH field.

1.4 Motivation

I am first and primarily motivated to conduct this dissertation study by the two problems identified in the problem statement: (1) First, the lack of empirical investigation into the current use and practice of inscriptions in DH research; and (2) second, the existing need for a change of perspective in examining the complex connotations and research identities of digital humanities as a field. In this dissertation, I aim to bridge these two research problems

and discuss the current community structure, work dynamics, and even future directions of the DH field through an empirical perspective of inscription use and practices.

In addition to the research problems that highlight the value and potential of this dissertation project, I am also motivated to adopt an *empirical* approach because of the abundance and availability of DH data, both in terms of DH publications, authorship, as well as the variety of inscriptions used in DH scholarship. The development of infrastructures, such as the databases and Application Programming Interfaces (APIs), also allow me to retrieve massive bibliographic data about DH scholarship and empirically code and analyze the inscription use in those datasets. In addition to the volume of publication data, the emergence of DH departments, centers, and institutions around the world offers an invaluable opportunity to recruit DH researchers and practitioners for interviews and explore how they work with inscriptions in their research processes.

Last but not least, this dissertation project is also inspired by my personal passion for research in multiple areas such as digital humanities, visualization, and science and technology studies. My dissertation aims to offer an interdisciplinary study that connects, and contributes to, each of these areas with new insight and perspectives. Previous research experiences with visualization of manuscripts, oral histories, and digitized archives also convinced me of the value of understanding how scholars work with visual technologies to enhance representation of, and interaction with, cultural data in the digital age. By connecting multiple research areas and practical insight earned from professional experiences, this dissertation addresses a new and also under-explored topic, which can potentially help us explore the “soul” of digital humanities as a field.

1.5 Roadmap

This dissertation follows an IMRAD structure that is commonly used for scientific research writing, which presents the study with a sequence of sections including introduction, methods, results, and discussion (Nair & Nair, 2014). According to Meadows (1985, 1998), “IMRAD is a result of that evolutionary process” that responded to the exponential growth

of scientific information since the 1940s and 1950s. This modular structure offers several benefits: it “helps the author to organize ideas and remember critical elements; it makes easier for the editor and the reviewer to evaluate manuscripts; and it improves the efficiency of the scientist to locate specific information without going through the entire paper” (Meadows, 1998; Sollaci & Pereira, 2004).

In the following chapters, I start with a review of the existing literature that is relevant to this dissertation project, including topics such as inscriptions in science and technology studies, controversies and debates over research identities of DH, and visualization research and “humanistic visualization” (Chapter 2). Review of the existing literature demonstrates the need and novelty for this dissertation project to bridge the research gap, by understanding DH research identities through an empirical study of inscription use and practices among digital humanists. Building upon the scholarship of multiple research areas, in Chapter 3, I discuss the conceptual framework and Latour’s (1987, 1990) theory of “immutable mobiles” that I use to guide the sequential, mixed-methods design of the dissertation project and the research questions involved. Following the overall research design, I illustrate the data and specific methods used for each study in Chapter 4, before proceeding to present and discuss the results and their implications (Chapters 5 and 6). Due to practical concerns related to the COVID-19 pandemic period, as illustrated in detail in Chapter 4, the results from this dissertation project provide more implications for *inscription use* in DH journal articles, which is the first stage of the Latourian framework, rather than *inscription practices*, as demonstrated in its second stage. In addition, the results presented in this dissertation are edited based on three published articles in 2021 (Ma & Li, 2022; Ma & Xiao, 2021; Ma, Li, & He, 2021). In the final chapter (Chapter 7), I conclude the dissertation with a discussion of its major contributions, limitations, and multiple directions of future work.

2.0 Literature Review

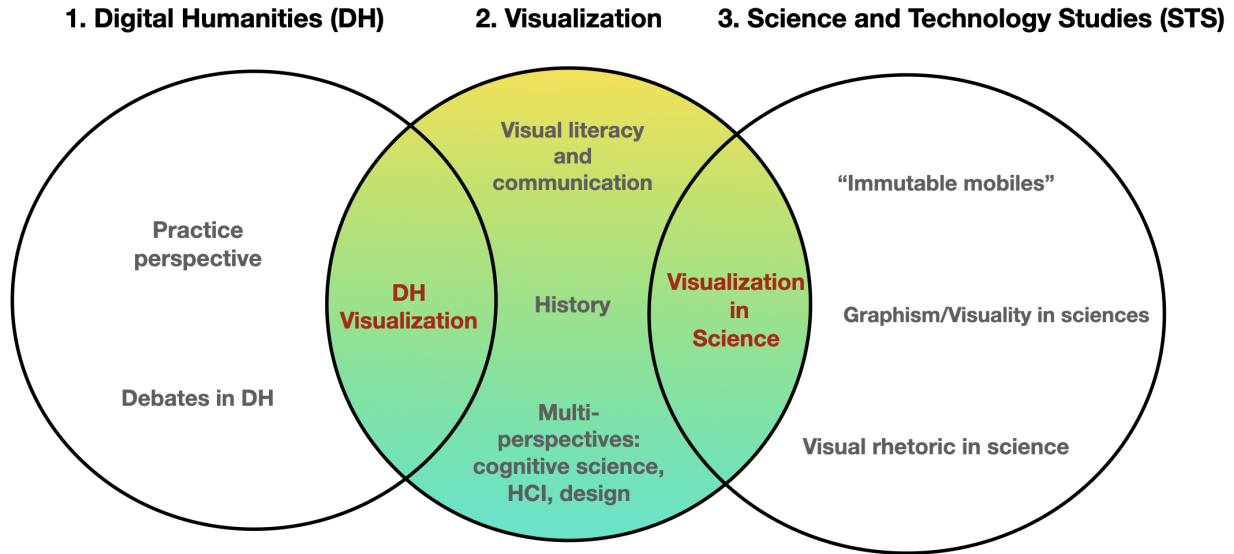


Figure 4: Literature Map

In this chapter, I review the various streams of scholarly work related to this dissertation project. Figure 4 is a literature map that demonstrates the major components and themes of the reviewed work, along with how they relate. The literature review consists of three sections: (1) the digital humanities field with its essential debates and the recent research from the lens of practice, (2) visualization research with a brief history, studies from multiple perspectives, discussions on DH visualization, and the work from an LIS perspective; and (3) the science and technology studies (STS) on visualization, with a review on Latour’s (1990) theory of the “immutable mobiles,” the *visuality* thesis, and visual rhetoric in scientific communication. All the three sections of the scholarly literature inform this dissertation study in various aspects. The first section on the debates in the DH field and the discussions of DH practices (rather than theories), offers a background of discussion for this dissertation study as well as a support for the problem statement. The second section is dedicated to review visualization research from various perspectives and disciplines, which aims to

highlight the potential value of the dissertation study and its impact on visualization studies. The third section reviews scholarly work in the science and technology studies (STS) as they relate to scientific visualization, which informs the conceptualization and design of this dissertation work.

2.1 Digital Humanities: The Humanities, Controversies, and Practices

2.1.1 The Humanities Tradition

Discussion of digital humanities cannot avoid a brief engagement with the humanities traditions that has a very long history. Study of “the humanities” had its origin in the Antiquity, where “humanistic activities” took a variety forms such as “a ritual, a consequence of philosophy, and sometimes a political instrument” (Bod, 2013). Such humanistic activities shaped the basis for the humanities inquires in terms of the principles and the underlying logic (Bod, 2013). It was during the Renaissance Period that the actual term “humanities” derived from the Latin expression *studia humanitatis*, which implied the study or education that befitted a cultivated man. In the 15th century, the *studia humanitatis* became a course of studies comprised of “grammar, poetry, rhetoric, history, and moral philosophy,” things deemed essential for the Renaissance humanism and its ideal for a cultivated, sophisticated man – a “humanist.” It was constructed and used against the theological stance and studies of its time, and particularly emphasized and valued the secular. Since the 19th century, the humanities have been generally regarded as a group of disciplines that investigate the “expressions of the human mind” (Bod, 2013). According to Bod (2013), such expressions include language, music, art, literature, theatre, and poetry; and therefore, philology, linguistics, musicology, art history, literary studies, and theatre studies all belong to the field of “the humanities. A more pragmatic definition claims that the humanities are the disciplines that are taught and studied at humanities faculties, from which perspective the contemporary fields of inquiry such as media or film studies can often times be included in the humanities as well (Bod, 2013). In addition to the multiple definitions, another perspective

treats “the humanities” from its major functions. According to Bod (2013):

“[The humanities] have a memory function by keeping alive the works from the past and the present, often through collections. They have an educational function by teaching these works to new generations. They also have a critical function by interpreting these works for the public at large. In addition to all this, the humanities have a research function by asking questions and posing hypotheses regarding humanistic artefacts. While often intertwined, these functions have not been equally prominent in all historical periods.”

In the information age, the humanities tradition has started to take new forms. Bod (2013) identified three trends of change in the humanities: (1) the cognitive approach to examining humanistic materials, which proved to be beneficial to the development of new criticism and interpretation perspectives in disciplines such as literary studies and art history; (2) the digital, computational approach to humanistic materials that has led to new comparisons and methods of analysis as well as new questions which have never been asked before; and (3) the integration of supra-disciplinary methods from sciences and social studies that promotes the adoption of new forms of thinking, inquiries, and techniques within the humanities research. Among the three emerging approaches, the rise of the digital and computational methods has been one of the essential catalysts for the development of what we call today as “digital humanities” research.

2.1.2 Debates and Controversies in Digital Humanities

The earliest attempt in what we call digital humanities today may date back to 1949 when Father Roberto Busa persuaded IBM to offer technical and financial support for the mechanized creation of concordance to the works of St. Thomas Aquinas (Jones, 2014). During the 1950s and 1960s, the use of computation in linguistics and literary studies gained recognition, new centers (e.g., Center for Literary and Linguistic Computing at Cambridge) were established, and dedicated journals (e.g., *Computers and the Humanities*) were published, establishing the field that was then called “humanities computing” and now known as the “digital humanities” (Antonijević, 2015). With the development of digitization and the building of digital infrastructures, the first wave of DH emerged with a focus on creat-

ing ways of more effective engagement with computation and technologies (Burdick et al., 2012), such as electronic text resources or databases. The “digital” in this early phase, took a specific and clear emphasis on digital resources and computer programs. Since the late 1990s, the “digital” has taken more complex connotations and forms such as creating “visualizations, geospatial representations, simulated spaces, and network analyses of complex systems” (Burdick et al., 2012), extending from the mere task of building infrastructures and becoming more integrated into humanities research analyses. In addition to the increasing complexity of the digital engagement, new disciplines and areas of studies such as the film and media studies, have entered the digital humanities scene as well. Such an expansion in the disciplinary landscape, as a result, has broaden the extension of digital humanities while generating new problems and controversies, particularly in terms of the identities of digital humanities and the relationships between the “digital” and the “humanities.”

Typical controversies in the field have been identified in the literature, such as what counts as digital humanities and what does not; who is in and who is out; whether the digital humanities is about making or theorizing, computation or communication, practice or politics; and what are the roles of the “digital” in “digital humanities” (Svensson, 2010, 2013; Liu, 2013; Ramsay & Rockwell, 2012; Spiro, 2012). An exhaustive discussion of every problem and controversy in the DH field would be beyond the scope of this work. In this section, I highlight a few issues and discussions as they relate to the above debates.

One of such issues is how to treat the “digital” in digital humanities. In terms of the roles of technologies in DH, two prevalent arguments exist. One argument focuses on the transformation of scholarly practices brought by technologies and the opportunities they offer for scholars to embrace both the challenges and the promise of the digital age (Gold, 2012). Another assumption, however, has more negatively portrayed the digitalization of humanities scholarship as the “transmission of alien disciplinary genes from other paradigms of knowledge” (Liu, 2013), demonstrating the destructive impacts of technologies on the humanities identities. Both prevailing claims, however, do not have an empirical support or elaboration and do not quite resolve the long-standing controversies over the digital humanities identities. A more neutral stance on this issue considers the change of degree in digital engagement from the “humanities computing” to the “digital humanities.” According

to Svensson (2010, 2012), “technology or tool-related methodology often serves an instrumental function” in humanities computing, while in the digital humanities, the interrelation between the two can be discussed in more diverse terms – such as the digital or technology as “tool, study object, medium, laboratory, or activist venue.” This claim presents a more dynamic, ever-changing picture of the digital humanities field, where the digital technologies do not only intervene but also deeply shape the landscape of digital humanities.

As a matter of fact, despite the multitude of scholarly attempts since the inception of digital humanities, no consensus on the scope and definition of digital humanities has been achieved. Scholarly work tackles this issue from various perspectives: On one hand, some researchers tried to define DH based on the disciplinary proximity of the field, namely, to which “traditional” humanities discipline is DH most aligned? Works from this perspective have focused on the disciplines of literary and linguistics studies and the related textual data and materials (Fitzpatrick, 2012; Svensson, 2012). However, the major problem with this way of conceptualization is that it can no longer capture the diversity of the disciplinary landscape that may constitute the field of DH. By contrast, another group of scholars take a more inclusive approach to define DH. The “Big Tent DH” idea is one such example. The term “Big Tent DH” was proposed as the theme of the Digital Humanities 2011 conference at Stanford University (Svensson, 2012, 2015). The Call for Papers (CFP) for the conference demonstrated the connotations of the term:

“Proposals might, for example, relate to the following aspects of digital humanities: research issues, including data mining, information design and modelling, software studies, and humanities research enabled through the digital medium; computer- based research and computer applications in literary, linguistic, cultural and historical studies, including electronic literature, public humanities, and interdisciplinary aspects of modern scholarship. Some examples might be text analysis, corpora, corpus linguistics, language processing, language learning, and endangered languages; the digital arts, architecture, music, film, theater, new media, and related areas; the creation and curation of humanities digital resources; the role of digital humanities in academic curricula” (Alliance of Digital Humanities Organizations, 2010).

As demonstrated in the CFP, the “Big Tent DH” is inclusive in two senses: on one hand,

it covers not just the traditional humanities subjects; and on the other, the terms suggests a higher level of digital involvement in humanities studies. The Big Tent DH aims to embrace all that can be related to DH and increase the interdisciplinary and collaborative dialogue among various subjects, methods, and conventions of research. Extending from this concept, Svensson (2012) argued that digital humanities can be a “trading zone and meeting place,” where certain qualities of DH such as the “commitment to interdisciplinary work and deep collaboration” attract individuals both inside and outside of the “tent” who has an interest in DH to become a part of the field. Methodologies, as shown in the CFP excerpt above, also tend to be as inclusive as possible to encourage participation in the field. To further illustrate the inclusiveness of the “Big Tent DH” and highlight its recent trends, Weingart and Eichmann-Kalwara (2017) analyzed the topical, regional, and authorial aspects of the “Big Tent” based on a large corpus of ADHO conference abstracts, demonstrating a continuous increase in DH participation, a shift from project-based topics to principle-based ones, a dramatic increase in the introduction of new authors, and the presumably increasing scale and depth of collaboration measured by the rate of co-authorship.

Although the “Big Tent DH” idea has offered numerous possibilities for DH, it is also a compromise strategy that scholars developed to grasp and cope with the actual complexity and ambiguity of the field. Such a disappointment has also been demonstrated in articles where scholars claimed that there is no such thing as digital humanities, acknowledging the difficulty in defining the field as a consistent set of theoretical concerns, disciplines, or methods (G. Hall, 2012; Alvarado, 2012). As a matter of fact, the debates in the digital humanities have never been stopped and the ongoing book project on *Debates in the Digital Humanities* is one strong evidence (Gold, 2012; Gold & Klein, 2016, 2019). Such a situation has encouraged and will continue to encourage discussions from various perspectives.

2.1.3 Empirical Inquiry of the Digital Humanities Field and Community of Practice

Considering the difficulties in defining the scope and identities of DH, some scholars have shifted their focus from theoretical discussions to DH *practices*. Kirschenbaum et al.’s (2012)

discussion of what the English department is doing with digital humanities is one example on specific disciplinary communities actually practicing DH. Liu (2013) advocated for an anthropological approach to studying the DH field. As Liu illustrated, “an ethnographer of the field, indeed, might take a page from Claude Lévi-Strauss and chart the current digital humanities as something like a grid of affiliations and differences between neighboring tribes;” and such a grid of affiliations and differences can embody the boundary and extension of the DH field. Extending from Liu’s (2013) idea, Antonijevic (2015) presented a data ethnography of DH, broadly covering aspects such as the digital workflows, disciplinary (re)orientations, and the organizational patterns and mechanisms in supporting DH work. With a more specific yet in-depth focus, Warwick’s (2012) book *Digital Humanities in Practice* highlights a number of DH activities at the University College London Center for Digital Humanities (UCLDH), demonstrating an institutional community’s effort to participate in DH work. By means of case studies and examples of various types of practices such as the development of digital resources, open access image processing, 3D recording, text encoding and scholarly digital editions, Warwick’s (2012) volume presents a constellation of works that took a more practical, empirical approach to the question of what digital humanities may be – rather than should be, so as to provide a better understanding of the field.

Other miscellaneous works on DH practices have also looked at issues such as (1) how a specific discipline such as the literary studies developed digital and computational methods (e.g., distant reading, text mining) for handling texts (Moretti, 2013; Wilkens, 2012; Manovich, 2016; Gavin, Jennings, Kersey, & Pasanek, 2019); (2) how institutionalized practices, e.g., practices in DH centers, libraries, and academic departments, impact DH work (Fraistat, 2012; Kirschenbaum, 2012; Fraistat, 2019; Smiley, 2019); (3) how the labor market, career development, and scholarship evaluation systems influence the knowledge production in DH (Flanders, 2012b; Edmond, 2019); and (4) how new forms of digital publishing have transformed the DH research presentation and sharing (Fyfe, 2012; Stauffer, 2019).

The discussion with focus on DH practices and communities has generated meaningful results on grasping the overall landscape of the field, as what it actually is. But there is still a lot that can be done, particularly in terms of the specific, emerging communities of practices and their impacts on the field of DH. Visualization is such a practice that has the potential

to portray the landscape of communities within DH and therefore facilitates a better understanding of the field. To my best knowledge, there has not been a comprehensive study that adopts a community of practice perspective to examine visualization as the major connecting point, despite the recent increase in the scholarly attention to DH visualizations. Questions such as (1) what do digital humanists seek out of visualizations, (2) what are actually being done in DH visualization, and (3) how might visualizations function and impact the field of DH, have not been systematically investigated. As I will discuss more in the next section on visualization in this chapter, the multitude of discussions among digital humanists has focused on what is a quality *humanistic visualization* in theory (Drucker, 2011; Manovich, 2011; Meirelles, 2019; Drucker, 2015; Sinclair & Rockwell, 2016). Only a small number of previous research studies have taken an empirical approach and the majority of them have focused on either a specific discipline or project, which did not yield sufficient insights into the roles of visualization in DH work (Jänicke, Franzini, Cheema, & Scheuermann, 2015).

2.1.4 Multilingual Digital Humanities: The Case of East Asian DH

Most of the literature discussed above has a European and Western focus. However, digital humanities by no means remain only in the English-language scholarship. Multilingual DH, or global DH, has become an emerging practice in digital humanities across the world and demonstrates the global and international diversity of the field (Crompton, Lane, & Siemens, 2016; Spence & Brandao, 2021). Many departments and schools offering digital humanities curricula would designate a course to global or multilingual DH, as exemplified by the DH curricula at University College London or the University of Pennsylvania. Among the multilingual DH scholarship, East Asian DH focuses on materials and literature in East Asian languages, particularly Chinese, Japanese, and Korean, and arises both in Asia and with the development of East Asian studies and East Asian librarianship in the United States since the 1950s. East Asian DH serves as a case to discuss multilingual DH in this section, which is an important aspect of DH in general. More specifically, this section discusses East Asian DH from the perspectives of topics, approaches, communities, and resources.

Major analytical approaches to East Asian DH focus on, for instance, textual analysis,

GIS and spatial analysis, social network analysis, and visualization. Literary and philology scholars demonstrated the use of tools and search interfaces to better analyze texts. For example, Sturgeon (2019) introduced “a toolset designed to make a core set of key text mining functions accessible to a much wider audience of scholars working with Chinese texts” which were implemented in the *Chinese Text Project* (an online digital library of over 30,000 pre-modern Chinese texts) and perform textual analysis tasks such as “collation of term frequencies and collocations, identification of user-defined patterns of word usage, detection of text reuse, and investigation of authorial style using principal component analysis.” Working with data is also an important topic in East Asian DH, particularly in discussion of text analysis. Vierthaler (2016) discussed the use of bibliographic records and metadata “on more than thirty-four thousand volumes of late imperial Chinese literary works printed between 1550 and 1799 procured from the Online Computer Library Center’s WorldCat database” to analyze the changes in book productions in late imperial China. The research cases provided more integrated view of how individual scholars can adopt DH thinking and redesign their research (especially in terms of research questions and methods) utilizing digital methods and existing technologies.

Social network analysis (SNA) has been widely used in historical analysis and the study of history. At the Digital Expo of the Annual Meeting of the Association for Asian Studies (AAS) in 2019, multiple speakers presented studies on SNA, such as the *Japanese Biographical Database* developed by Sophia University in Japan and the *Authorship of Chinese Women’s Periodicals* database by Academia Sinica in Taiwan. Speakers also illustrated how SNA can be performed with the digital resources, using examples from their research (Association for Asian Studies, 2019). For example, the Japan Biographical Database (JBDB) provides “biographical information on Japanese historical figures and their personal, social, and political networks,” and allows users to search all entries “by date, kinship, non-kinship relations, social status and profession, and other filters as well as visualize networks of interest in a dedicated visualization component.” Created by the Institute of Modern History at Academia Sinica, the database of Authorship of Chinese Women’s Periodicals (ACWP) aims to “record women’s biographical entries in modern China in a structured way, which allows users to systematically process data.” Chinese Buddhism scholar Marcus

Bingenheimer also discussed the use of SNA in Chinese Buddhist history research, introducing “some datasets recording the social connections of Chinese Buddhists (100 CE-1900 CE)” that can be used within Gephi for visualization and analysis (Association for Asian Studies, 2019).

Geographical Information System (GIS) and spatial analysis is another important aspect of examination in East Asian DH research. Applications such as the WorldMap from Harvard University and the LoGaRT local gazetteer research tool developed by the Max Planck Institute for the History of Science in Germany represent the new developments of GIS (Blier & Bol, 2016; Guan et al., 2012; S.-P. Chen, Hammond, Gerritsen, Wu, & Zhang, 2020). Similar with the design and use of other forms of digital tools, GIS and spatial analysis aim to tackle resources that cannot be competently processed through the manual labor, and therefore, can assist with the discovery of new research perspectives and problems.

In addition to textual analysis, SNA, and geo-spatial analysis, visualization and the use of visual technologies also serve an important role in facilitating East Asian DH. Visualization has been a theme at multiple Digital Expos at AAS. Typical themes include “virtual heritage,” use of virtual reality (VR) and augmented reality (AR) technologies, simulations, and 3D modelling to recreate scenes for educational and research purposes. For example, at the 2019 Digital Expo, Ellen Sebring presented a case titled “March on Beijing 1900,” which reenacted the “ten-day march on Beijing by troops of the Eight-Nation Alliance in August 1900” using VR and relevant historical resources. The use of VR and digital tools to build a digital archive and collection provides a different way of “seeing” that is digitally mediated and generated an interactive environment for deep observations and conversations among the public (Association for Asian Studies, 2019). Utilized in studies of visual cultures, archaeology, and art history, it seems to be a rather new area of research in East Asian DH and very few articles have been published in this area, as similarly suggested by visualization literature in digital humanities research.

Moving beyond such topics and analytical approaches mentioned earlier, Vierthaler’s (2020) article on “Digital Humanities and East Asian Studies” provides a broader overview of the East Asian DH field and discusses more related aspects and issues. For example, the efforts on corpus building and text digitization, image processing, and dealing with East

Asian materials beyond CJK (Chinese, Japanese, Korean) languages (e.g., Manchu, Tibetan, Tangut). Such aspects are significant areas to facilitate the development of East Asian DH.

In addition to the efforts made by Asian studies scholars from the perspective of digital research and analysis, other communities of research and practice have also contributed to the development of East Asian DH. East Asian Studies librarians are one important community. Since the late 1990s and early 2000s, East Asian libraries in the U.S. have started to initiate and maintain digitization and DH-related projects, as the strategy to cope with the digital trends. More specifically, librarians have contributed to East Asian DH from three major perspectives, if not more:

(1) From the perspective of collection development, East Asian libraries are expanding their e-resources by building overseas partnership with libraries, publishers, and book vendors in East Asia. Cho and Yi (2012) discussed the ways in which CJK librarians build eBook collections at their libraries, which involves active collaborations with vendors and publishing companies in East Asian countries. For example, the majority of Chinese eBook resources are purchased from Apabi and Superstar; most Korean e-resources are from KSI, Nurimedia, and Kyobo; and finally, while Japanese studies do not actually have a passion for eBooks, Japanese Studies sometimes purchase eBooks from JapanKnowledge database or NetLibrary by Kinokuniya via EBSCO. Cho and Yi (2012) also argued that East Asian libraries should collaborate to build eBook collections together, so as to cope with the challenge of budget cuts and to better satisfy patrons' needs.

(2) Cataloging and technical services has proved to be another area of library expertise that positively support East Asian DH endeavors. Committee on Technical Processing (CTP) is part of Council on East Asian Libraries (CEAL) that is specifically dedicated to providing cataloging and technical services related to East Asian librarianship; every year during the CEAL pre-conference on AAS, CTP has special workshop that provides updates on cataloging advancements, discusses emerging issues in technical services, and offers cataloging training for East Asian materials. In the newly published article in the *Journal of East Asian Libraries*, Chou (2018) illustrated CTP's vision for emerging technical service for DH: "keep CTP and CEAL members synchronized with ... digital humanities; and compile digital humanities / digital scholarship resources and plan training sessions in the

near future.” Besides, the CTP also emphasized the communication and collaboration with related groups to establish CJK data standards and best practices, especially the metadata creation of digitization projects (Chou, 2018), in order to address the increasingly important technical challenges for East Asian library communities.

(3) While facilitating the development of East Asian DH by their own means, East Asian Libraries are also trying to develop deeper collaborations with East Asian DH research communities. This is reflected, on one hand, in libraries’ efforts to build global partnerships with East Asian countries and introduce valuable Asian-language collections. On the other hand, it is also reflected in librarians’ initiatives in creating new DH projects with cross-domain, and even international collaborations. For the second aspect, there have been numerous projects and cases that benefited from the creativity of information professionals at cultural heritage institutions and in-depth cross-field collaboration: For example, the Memory Project at Duke University (Zhou, 2019), the Chinese NGO Web Archiving Project at Stanford University (Xue, Yang, & Long, 2019), the CR/10 project and the ongoing Chinese Village Gazetteer Project at the University of Pittsburgh (Ward, 2018; Ma, 2022). This non-exhaustive list of projects demonstrate contributions in two ways: On one hand, the projects made accessible the materials that scholars would otherwise remain unaware of; and on the other, they generated more machine-readable, interactive resources which provide infrastructural support for East Asian research.

Similar to DH scholarship in the English-language literature, multilingual DH also faces various challenges. Data and infrastructural construction has remained as one of the central challenges, not only for DH research in general, but also for East Asian DH, especially given its specific need to work with non-western languages. Additionally, collaboration, and in the case of East Asian DH, international collaboration, is another challenge to address in order to accelerate the development of the field. Finally, from the perspective of visualization and inscription in particular, some questions also emerge: Do inscription practices change across countries, cultures, and societies? For example, are inscriptions and visualizations used differently between English-language DH and East Asian DH? Why or why not? Do audiences and researchers of various countries perceive and read inscriptions differently, and do they have different visual literacy levels and proficiency? Such questions have not been

addressed sufficiently in the current literature and would deserve future research for more in-depth exploration. But just as multilingual DH has informed digital humanities research in general, a cross-cultural and cross-societal perspective to analyze inscriptions may also create new insight into visualization and DH fields.

2.2 Research on Visualization

2.2.1 A Brief History of Visualization

Visual devices have been utilized for centuries to reveal data patterns, communicate complex ideas, and to tell stories (Figure 5). The earliest visual representations of knowledge can date back to at least the 16th century, where the study of astronomy developed and the “techniques and instruments for precise observation and measurement of physical quantities, and geographic and celestial position were well-developed” (Friendly, 2008). During this period of time, the earliest forms of visualizations arose in geometric diagrams, in “tables of the positions of stars and other celestial bodies,” as well as in the map making for navigation and exploration (Friendly, 2008). Statistical graphics, however, only originated from the emergence of statistical techniques and thinking in the 18th century and prospered during the first half of the 19th century, the period Friendly (2008) called the “Golden Age.” In this Golden Age, pioneers such as William Playfair, Charles Joseph Minard, Francis Galton, and John Snow, (1) invented new statistical graphic forms such as the line graph, pie chart, scatterplot, and thematic or data maps that are still widely used today, (2) developed groundbreaking ideas and analytical techniques (e.g., Galton’s idea of correlation and regression), and also (3) led the application of visualizations into various fields of inquiry, including the scientific discovery and measurement, historical storytelling, or the public welfare and health (Friendly & Denis, 2005; Friendly, 2008, 2002; E. Tufte, 2001).

The Golden Age of statistical graphics also witnessed the beginning of the systematic appreciation, study, and evaluation of visualizations from various perspectives. Few influential results include: the emergence of data graphics theories and evaluation standards,

and the examination of the roles of visual representations in scientific knowledge production and communication (M. Lynch & Woolgar, 1990b; E. Tufte, 2001). Tufte (2001) traced the use of statistical graphics to at least 1750 - 1800 and proposed metrics for evaluating quality statistical visualizations such as excellence, integrity, and sophistication. Beyond the standard metrics, Tufte (2001) also proposed a certain number of data graphic theories for quantitative data representations, namely the principles for quality graphical design that are still widely appreciated today, including the data-ink, chartjunk, data density, and small multiples.

The development of visual techniques and methods led to the wide-ranging practice of visualization in scientific inquiries and the use of them in scientific research outcomes. And this trend inspired sociologists, philosophers, and rhetoricians of sciences to further look beyond the visual forms *per se* and examine visualizations in domain contexts, which means particularly the complex relationships between visuals and the production and communication of scientific knowledge. Bruno Latour (1990), the leading sociologist and philosopher of science during the 20th century, pioneered on an idea that visual representations of data function as “immutable mobiles” in sciences that transformed the discovery and research processes usually only visible in the laboratory context into validated and widely recognized scientific facts. The central role of visual displays in sciences, also named as the *visuality* or *graphism* of science, was applied to examine the disciplinary traits within sciences, such as identifying the *scientificity* of disciplines (Arsenault et al., 2006; Judelman, 2004; Richards, 2003; Rudwick, 1976; Smith et al., 2002). Following this line of inquiry, scholars also discussed the rhetorical functions of visualizations in scientific publications with specific disciplinary cases (Graves, 2014; Richards, 2003; Rudwick, 1976).

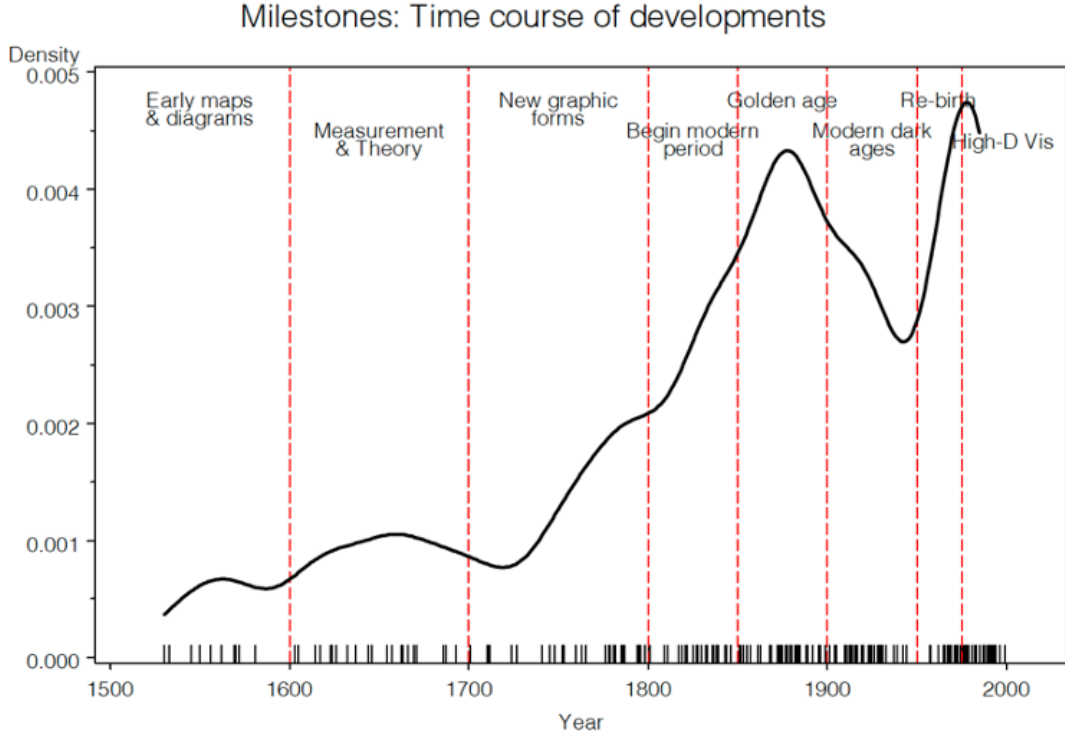


Figure 5: Time Distribution of Milestones in the History of Data Visualization (Friendly, 2008).

2.2.2 Visualization Research from an Information Science Perspective

During the 1980s, with the development of computer graphics programs and the first annual IEEE Conference on Visualization held in 1990, the field of “information visualization” has emerged and continued to be an important stream of study in various domains (Bailey & Pregill, 2014). Recent work has approached the topic of visualization from various perspectives, such as that of cognitive science, data and digital visual literacy, as well as the human-information interaction (HII), addressing issues such as memorability, aesthetics, functionality, or users’ perception of visualizations (Borkin et al., 2016, 2013; Judelman, 2004; Börner, Bueckle, & Ginda, 2019). Numerous conferences and journals dedicated to computer graphics and visualization research have been established, such as the *IEEE Transaction on Visualization and Computer Graphics*, *Information Visualization Journal*, *IEEE*

Symposium on Visual Analytics Science and Technology (VAST), and IEEE VIS Conferences, highlighting multi-perspective studies with the focus on visualization. A browse of the articles published in such visualization-focused resources revealed certain aspects of research, with a few examples for each aspect. (1) One main area of research on visualization focuses on visualization technologies and methods development (Zhang, Schultz, Lawonn, Eisemann, & Vilanova, 2016; Rauber et al., 2017). (2) The second stream of research studies users' interaction with visualizations, including how different groups of users make sense of and work with visualizations, as well as different roles and tasks of interaction in visualizations (Yi, Kang, Stasko, & Jacko, 2007; S. Lee et al., 2016; Gramazio, Schloss, & Laidlaw, 2014). (3) In addition, from a cognitive science and human perception perspective, characteristics of visualizations and their impacts on human visual processing capacity have also been researched widely in the literature, such as what kinds of visualizations are more memorable, how does the visualization size or grouping influence user performances, and etc. (Tory & Moller, 2004; Yost & North, 2006; Healey & Enns, 2012; Borkin et al., 2013, 2016). (4) Eventually, a number of scholarly works focus on the design aspect of visualization, discussing the aesthetics, effectiveness, and quality of design (Gramazio et al., 2014; Wood, Kachkaev, & Dykes, 2019). These studies provide valuable references for this dissertation work in terms of the variance of perspectives to analyze visualization (e.g., visualization technologies, user needs of visualization among specific communities).

2.2.3 Visual Literacy

Another scholarly perspective to look at visualization is information literacy and visual literacy. This is also a topic that library and information science research has been actively engaged with. Association of College & Research Libraries' (2010) *Information Literacy Competency Standards for Higher Education* is a typical example of an information literacy framework. The *Framework* identified six frames, which include: 1) authority is constructed and contextual; 2) information creation as a process; 3) information has value; 4) research as inquiry; 5) scholarship as conversation; and 6) searching as strategic exploration. The *Framework* also has various implementation guidelines for different specific areas, and the

Visual Literacy Competency Standards for Higher Education is one of them (Association of College & Research Libraries, 2011). According to the *Visual literacy Competency Standards*, a “visually literate” individual should be able to: 1) determine the nature and extent of the visual materials needed; 2) find and access needed images and visual media effectively and efficiently; 3) interpret and analyze the meanings of images and visual media, 4) evaluate images and their sources; 5) use images and visual media effectively; 6) design and create meaningful images and visual media; and 7) understand the ethical, legal, social, and economic issues surrounding the creation and use of images and visual media, and access and use the visual materials ethically (Association of College & Research Libraries, 2011).

Digital visual literacy (DVL), with a narrower focus on visual literacy in the current digital trend, emphasizes “the ability both to create and to understand certain types of information [and] visual materials created with a computer” (Spalter & van Dam, 2008). With the emergence of computer graphics around the 1960s and its subsequent, widening use in various industries, it becomes increasingly necessary for the general public and non-visual professionals to develop sufficient literacy to leverage the power of visual knowledge and information representations (Spalter & van Dam, 2008). Börner et al. (2019) used the term DVL to refer to “data visual literacy,” demonstrating a more particular emphasis on the visualization of data instead of the visual media. According to Börner et al. (2019), DVL aims to “promote better communication and collaboration, empower users to understand their world, build individual self-efficacy, and improve decision-making in businesses and governments.” Synthesizing the enormous scholarly literature on DVL over the last five decades along with their own research, Börner et al. (2019) proposed a revised data visual literacy framework (DVL-FW) as shown in Figure 6.

The framework shows the seven core types of the revised DVL-FW theory, including insight needs, data scales, analyses, visualizations, graphic symbols, graphic variables, and interactions. According to Börner et al. (2019), the identified elements within each type were “derived from an extensive literature review and refined using feedback gained from constructing and interpreting data visualizations for the 100 + client projects in an Information Visualization massive open online course (IVMOOC).” For instance, “insight needs” refer to the basic task types to design effective visualizations for communication and/or

exploration. “Analyses” contains necessary steps before visualization, such as the statistical, topical, and geospatial analyses. In addition to the six categories that can be applied to almost all kinds of visual representations, the “interaction” category highlights essential elements during the process of working with interactive visual forms (e.g., visualizations displayed on websites for browsing and interaction). Börner et al.’s (2019) DVL-FW is the most recent, comprehensive, and quality analytical framework of visualization, which provides further analytical insights and basis for this dissertation study.

Insight needs	Data scales	Analyses	Visualizations	Graphic symbols	Graphic variables	Interactions
Categorize/cluster	Nominal	Statistical	Table	Geometric symbols	Spatial	Zoom
Order, rank, sort	Ordinal	Temporal	Chart	Point	Position	Search and locate
Distributions (also outliers)	Interval	Geospatial	Graph	Line	Retinal	Filter
Comparisons	Ratio	Topical	Map	Area	Form	Details on demand
Trends (process and time)		Relational	Tree	Surface	Color	History
Geospatial			Network	Volume	Optics	Extract
Compositions (also of text)				Linguistic symbols	Motion	Link and brush
Correlations/relationships				Text		Projection
				Numerals		Distortion
				Punctuation marks		
				Pictorial symbols		
				Images		
				Icons		
				Statistical glyphs		

Figure 6: Typology of the DVL-FW (Börner et al., 2019).

2.2.4 Humanistic Visualization in Digital Humanities

Visualization in the digital humanities sits at the intersection of the DH scholarship and that of the visualization; and as a result, scholars from both sides have engaged in the discussion. According to Bailey and Pregill (2014), “twenty-first-century humanities scholars find themselves in the midst of a visualization renaissance of sorts with information analysis and visualization literacy recognized as fundamental skills in the academy.” In the area of literary studies where the term “humanities computing” originated, the use of visualizations for interpretation and analysis has been advocated and then widely discussed since the 2000s when Moretti (2005) published his influential work titled *Graphs, Maps, Trees: Abstract Models for a Literary History*. A massive number of projects and tools

for visualizing humanities inquiries and knowledge have been developed, covering various types of humanities data and analyses including the spatial visualization (Jessop, 2008; Theibault, 2012), temporal visualization (Drucker, 2011; Posner, 2015), textual visualization (Jänicke et al., 2015; Sinclair & Rockwell, 2016; Moretti, 2005), and 3D visualizations (Foni, Papagiannakis, & Magnenat-Thalmann, 2010). In this section, I am not going to review each of them in details as the purpose of this study is neither to develop new visualization techniques for the humanities research nor to discuss the evolution of a specific type of DH analyses. Rather, I focus on two relevant themes in DH visualization: (1) the nature of *data* in the humanities research context, and (2) the charged discussions of the values of DH visualization and principles of *humanistic visualization*.

2.2.4.1 Nature of Data in the Humanities Context Floridi (2010) defined *data* at its most basic level as “the absence of uniformity, whether in the real world or in some symbolic system.” However, the notion of data has remained relatively foreign in humanities research. As illustrated by Schöch (2013), “most of [the] colleagues in literary and cultural studies would not necessarily speak of their objects of study as data. If you ask them what it is they are studying, they would rather speak of books, paintings and movies; of drama and crime fiction, of still lives and action painting; of German expressionist movies and romantic comedy. . . . Maybe they would talk about what they are studying as texts, images, and sounds. But rarely would they consider their objects of study to be data.” However, the mass digitization of cultural and humanities materials has introduced new occasions, as therefore unique challenges, for scholars working with cultural materials in humanities-oriented research. From another perspective, this quote also aptly captures the unique characteristics of data in the humanities research context, which has been explored and discussed in existing scholarship.

For instance, Borgman (2010) in her work *Scholarship in the Digital Age* discussed the unique characteristics of humanities data compared with those in scientific research contexts. Unlike natural or social scientists whose data usually come from experimental observations and are clearly different from “publications,” humanities data are “innumerable” and their boundaries with publications are “fuzzy” (Borgman, 2010). On one hand, “publications

and other documents are essential sources of data to humanists: Newspapers, unpublished correspondence, diaries, manuscripts, and photographs are among the most heavily used sources by academic historians, for example. They are analyzed for facts, evidence, themes, and interpretations.” On the other, “almost any document, physical artifact, or record of human activity can be used to study culture. Humanities scholars value new approaches, and recognizing something as a source of data (e.g., high school yearbooks, cookbooks, or wear patterns in the floors of public places) can be an act of scholarship” (Borgman, 2010).

Humanities data are also distinctive from scientific data due to their “dispersion and separation from context”: “Cultural artifacts are bought and sold, looted in wars, and relocated to museums and private collections. International agreements on the repatriation of cultural objects now prevent many items from being exported, but items that were exported decades or centuries ago are unlikely to be returned to their original sites. Those who hold cultural artifacts create the records that describe them, and thus the records also are dispersed” (Borgman, 2010; Geser & Pereira, 2004).

In addition to the unique forms and characteristics, humanities data are also distinct in terms of their value- and interpretation- laden nature. Drucker (2011) highlighted this aspect with the notion of *capta*. Compared with the widely known concept of data, which refers to “things given” in Latin, *capta* is a *given*, which captures the interpretive nature of humanities inquiries. As discussed in more detail in the following section, this understanding of humanities data supports Drucker’s theories of a “humanistic visualization,” which has also been shared and developed by other scholars in the field.

2.2.4.2 Principles of Humanistic Visualization One important theme of discussion in the emerging scholarship on DH visualization has focused on what is the value of visualization in digital humanities research, and what a “humanistic visualization” *should* look at and *hypothetically* be different from visualization in general (e.g., scientific visualization or information visualization). Jessop (2008) argued that visualization should be a scholarly activity in the digital humanities, not simply a technique or a tool, which means that they are highly interwoven into humanities inquiries and interpretation. Such embedded visualizations, according to Jessop (2008), constitute the concept of “humanistic visualiza-

tion.” The media studies and visualization scholar Manovich (2011) raised the concept of “direct visualization,” a method that “creates new visual representations from the actual visual media objects or their parts,” without any *reduction*. Compared with the principles favored by prevalent theories of information visualization (e.g., E. Tufte, 2001), this new form of visualization, as Manovich (2011) argued, values complexity and the preservation of original forms of the humanities data, which may better serve the purpose of humanistic inquiries. Drucker (2011), in her essay titled “Humanities Approaches to Graphical Display,” argued that all visual displays act as a sort of “intellectual Trojan horse,” a vehicle that always bears certain hidden, underlying assumptions of the data. For humanities data, as she claimed, it is even more the case. To potentially solve this inherent issue in the humanities graphical display, she raised the concept of *capta* to acknowledge the “situated, partial, and constitutive character” of humanities inquiries and knowledge production. Extending from Drucker’s (2011) line of argument, a number of scholars have also claimed that “problems of bias, interpretation, subjectivity, and ambiguity must be taught alongside problems of scientific rigor, decomposition, and algebra” for the humanities, and it is crucial to create visualizations that are “reflective and critical” (Champion, 2016; A. Bradley et al., 2018; Dörk, Feng, Collins, & Carpendale, 2013).

In addition to the theoretical proposal of a “humanistic visualization,” scholars have discussed, also *theoretically*, the ways to model and create humanistic visualizations. Jänicke (2016) created a collaborative, cross-field visualization model, where both the humanities scholars and visualization scholars would contribute to the DH project. Hinrichs et al. (2019), building upon Jessop’s (2008) call, leveraged a critical design approach and modelled visualization in DH as a “sandcastling” process. As Hinrichs et al. (2019) demonstrated, sandcastle is “a provocative yet productive perspective that reclaims sand as a versatile medium, ... for weaving critical thinking throughout the visualization design process, and for forging a productive space for curiosity-driven, cross-disciplinary research.” Different from the notion of a sandbox that is widely used in computer science and software design to refer to a “safe yet constrained” environment of experiment, “sandcastling” is “a metaphor for mindset, a methodology, and a praxis” integrated into practices (Hinrichs et al., 2019). Berg et al. (2018) offered a different but interesting perspective on modeling DH visualiza-

tion. As they argued, humanities research suffers from the intrinsic problem of lacking the “ground truths;” and therefore, the value of visualization in DH lies essentially in the promotion of the trust, transparency, and accessibility of the research. However, this is not to say that DH visualizations should be “objective;” rather, it means that visualization in DH research should “make interpretive bias and subjectivity explicit” (van den Berg et al., 2018). This discussion points to another important issue in conceptualizing DH visualization, which is *uncertainty*. Although uncertainty has always remained an important issue to consider in statistical graphs and information visualization (Cairo, 2019; Cheshire & Uberti, 2021), it is becoming increasingly important when it comes to visualize humanities and cultural data. A relatively similar work has proposed a framework to model and address the issue of uncertainty in DH visualizations (Therón Sánchez, Benito Santos, Santamaría Vicente, & Losada Gómez, 2019). These discussions, however, do not exhaust all the dimensions and aspects about visualizing humanities data. As visual technologies are applied to analyze large-scale cultural data from various contexts and of various forms, issues such as visualization *scale*, *quality*, and *complexity* will also become significant elements in visual design, just as illustrated by Lupi’s (2017) graph (Figure 7).

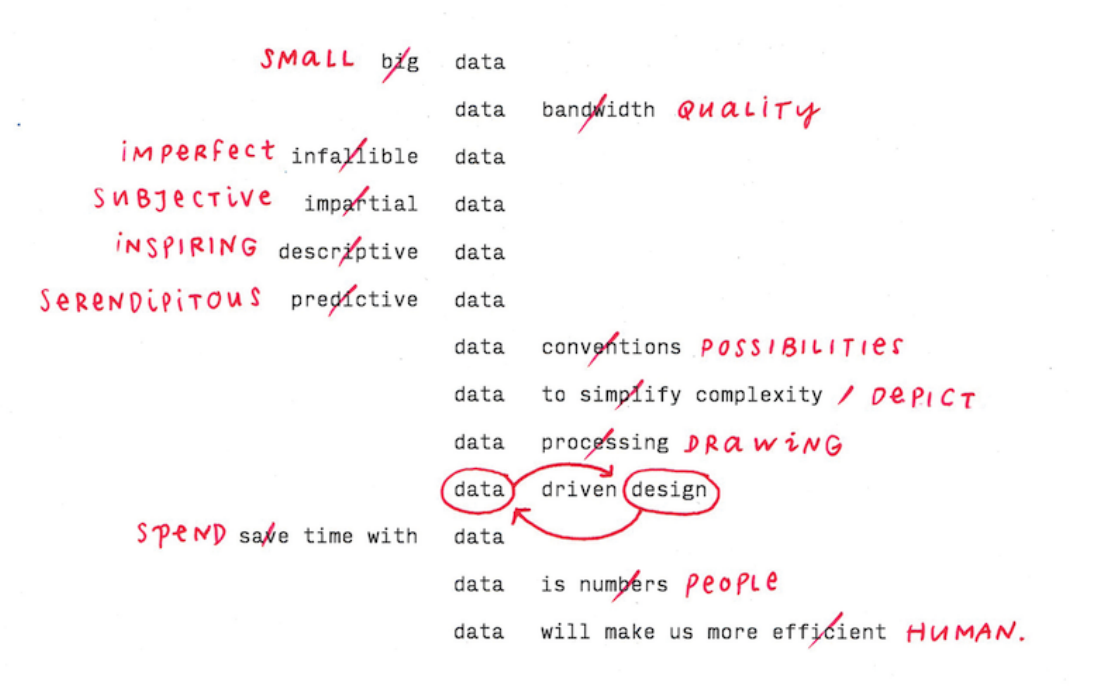


Figure 7: Data Humanism (Lupi, 2017)

2.2.4.3 Promises and Challenges Despite the valuable insights offered by the numerous theoretical discussions, scholarly literature in this respect shows only the *hypothetical potential* of visualization in DH, rather than its *current reality*. With the recent increase in the scale of specialized workshops (e.g., VIS4DH), conferences (e.g., DH conferences), publications with focus on DH visualization (e.g., Jänicke et al., 2015), there has come an unprecedented opportunity to grasp the visualization in DH as an area of research in a comprehensive, empirical manner. This research opportunity has started to attract scholarly attention. Jänicke et al.’s (2015) state-of-the-art report on textual data visualization techniques demonstrated an early attempt to provide an overview of the DH visualization with empirical analyses. Their 5-year extensive work analyzing papers published in both representative DH and visualization journals classified textual data visualization techniques based on their support for either close reading or distant reading. Analyzing the abstracts published at the DH conferences from 2004 to 2015, Weingart and Eichmann-Kalwara (2017) identified visualization as one of the most rapidly increasing field of research in DH, among

textual analysis, natural language processing, semantic analysis, and media studies.

In a very recent work, Munster and Terras (2020) proposed a concept of “visual digital humanities” that encompasses “the computational supported research on complex visual information to treat research questions and interests from the humanities.” According to their definition, a range of analyses can be included: image analysis, perception-based techniques (e.g., the visuospatial analysis of architectural objects), spatial modelling (e.g., 3D reconstruction of historical architecture), and visualization (e.g., sketching for visuospatial reasoning). Using the methods of survey and interview, the authors analyzed: (1) the academic backgrounds of scholars in visual digital humanities, why they entered the visual digital humanities field, how did they learn the relevant methods and tools; (2) research topics and research methods, how to implement those methods in visual digital humanities research; and (3) finally, the “state of establishment” of the field, scholars’ preference for engaging in smaller, rather than bigger, collaborative communities. Aiming to provide an overview for primers in DH visualization, Benito-Santos et al. (2020) adopted a data-driven approach to analyze 1,900 journal articles, which resulted in a preliminary mapping of the DH visualization in terms of its citation patterns and the most prominent authors.

Such recent attempts suggest both an epistemic and a methodological change in examination of DH visualization. It calls for the examination of visualization as a *field* or *area of research* within DH, not just the specific research perspective or tools applied to disciplinary inquires (e.g., textual analysis or spatial analysis). It aims to seek commonalities, rather than specificity, within the DH that bridges various research communities. Methodologically, recent work on DH visualization demonstrates the potential and feasibility of an empirical, ethnographic approach to facilitating an in-depth look into DH visualization *in action*, rather than *in theory*. My dissertation work aims to build upon this epistemic and methodological change in DH visualization research, applying empirical approaches to analyze how digital humanists of various communities leverage visual techniques in both the final research presentations and the ongoing, collaborative scholarship making process.

2.2.5 Library and Information Science Perspective on DH and Visualization

Libraries and more broadly the GLAM (galleries, libraries, archives, museums) sectors have been an important actor in digital humanities research since its early developments in the 2000s. Sula (2013) emphasized that libraries are well positioned to contribute to digital humanities. He demonstrated that “a search for digital humanities within library and information science (LIS) literature reveals a steady increase in publications since 2005 ... [and that] publications on digital humanities have nearly doubled in 2012.” Several themes from LIS perspective have been discussed in the literature. For example, from the perspective of infrastructure development, many digital humanities centers are housed in close proximity to libraries; and libraries serve as an important provider for the humanities-based information and information technologies (Svensson, 2010). Via DH centers, libraries and information science professionals may contribute to the DH development in “building digital collection and associated tools, ... and serving as a repository,” “offering training, serving as an information portal, and providing technology solutions,” and “offering structural or research experimentation services” (Svensson, 2010). By surveying the relevant paper abstracts in the Library, Information Science and Technology Abstracts (LISTA) database, Sula (2013) also identified five most prominent topics in LIS engagement, which consists of arts and humanities librarianship, digital infrastructure, knowledge production and collaboration, digital scholarship, and research communities. Furthering this line of research, Poremski (2017) provided an overview of the skillsets of DH librarians and their engagement in the DH field. In addition to the technological and infrastructural support, Poremski (2017) identified outreach, project management, and teaching as the most prevalent activities among DH librarianship. Cassella (2017) investigated the dynamics between academic libraries and digital humanities and summarized three levels of partnership between them, which are (1) the spatial level, including the physical sharing of space, staff, and equipment, (2) the service-oriented level, including the services and tools developed by academic libraries to support DH research, and (3) the professional level, including the skills and expertise gained by academic librarians in collaborative digital humanities projects. Closely related to the three levels of partnership, the LIS engagement in DH can also be demonstrated through

the efforts to improvement information literacy among DH scholars.

Libraries' engagement in visualization exemplifies such an effort. Chen (2017) analyzed the driving forces for libraries to engage in information visualization: (1) the changing nature of the library collection in conjunction with the rapid changes in technology; (2) the ability enabled by visualization to increase the library's value to its end users; and (3) the increase in the number of e-resources. One area where libraries have contributed to the visualization scholarship is the development of core visualization skills, which can serve as a leading force for the improvement in information literacy. Within the context of digital humanities, Chen (2019) examines how digital humanities scholars apply information visualization techniques and how academic librarians support the emerging trend. By analyzing the LibGuides and typical DH journals, Chen (2019) offered a set of best practices for academic librarians aiming to provide assistance for DH scholars in their visualization practices. Braun (2019) further proposed an approach to DH visualization via the *ACRL Framework for Information Literacy in Higher Education*, which "encourages critical engagement with data, the tools we use to interrogate them, and the visualizations we design to represent them." Particularly, he examined how a collection of "critical dichotomies" (e.g., reduction and holism) can be mapped to a subset of the core information literacy competencies identified in the *Framework* and how the *Framework* can guide the critical interpretation and design of humanities visualizations among researchers, students, and even lay users.

2.3 A Science and Technology Studies Perspective on Knowledge Representation and Visualization

In this section, I review the literature on visualization in science and technology studies (STS), which informs the theoretical and methodological foundations for this dissertation work. A STS treatment of scientific visualizations has looked into the roles of representation in scientific practices. As Lynch and Woolgar (1990a) indicated, STS scholars started to show interest in representation studies around the 1970s, and topics under discussions included "how scientists construct models, enact experimental runs, design and interpret data

displays, report upon methods and findings, and assign credits for discoveries.” Tibbetts (1990) proposed three aspects to investigate the problem of representation, which are the representational devices (RD), the ontological status of the represented objects (RO), and the *mapping* of the relationships between RD and RO. As a few scholars have argued, while both realist and constructivist approaches can be “mutually at work in the design and utilization of RD in scientific contexts” (Tibbetts, 1990), the RD-RO relationships are always, by essence, “socially constructed” and discipline-situated (Suchman, 1990; Barnes, 1977). Concurrent to the *sociological turn* in the investigation of scientific representations was the *rhetorical turn* in the examination of how languages, images, or gestures “spoke for science” and facilitated the creation, diffusion, and transformation of scientific knowledge (Latour & Woolgar, 1986; Bazerman, 1981). Instead of treating objectivity as the essence of the modern sciences, the rhetorical turn acknowledged the power of narrative and representational devices in establishing and communicating scientific knowledge.

2.3.1 The Latourian Notion of Inscriptions, the *Immutable Mobiles*, and the *Visuality* Thesis

One significant contribution to the representation studies during their early phase of development came from Bruno Latour (1990), with the theory of *inscriptions* and *immutable mobiles*. In his classic essay “Drawing things together,” Latour (1990) defined inscriptions as the end products of scientific, laboratory instruments, which were “combinable, superimposable, and could be integrated as figures” in scientific articles. The essence of an inscription, according to Latour (1990), is simultaneously its inherent immutability and its ability in mobilization. It means that on one hand, an inscription (e.g., such as a statistical graph, diagram, or table) possesses what Ivins (1973) called the trait of “optical consistency,” where its internal properties cannot be easily modified after the inscription is produced (i.e., the immutability). However, the immutable inscriptions can embody the scientific reasoning process and practices, enable the communication of laboratory observations and discoveries, persuade the general audiences and dissenters, and eventually mobilize the traces of laboratory practices into widely accepted scientific knowledge. In addition to the *mobility*

and *immutability* properties, inscriptions also have the following advantages: they can be easily reproduced, scaled, reshuffled, or recombined with other inscriptions, so as to be further incorporated into written scientific texts. Essentially with such properties, inscriptions function as a rhetorical device bridging the mental and the material, *drawing* laboratory traces into visible sciences (Latour, 1990). The “drawing up” process was also elaborated as an “evidence-fixation” procedure, where the sense data obtained from experiments were transformed into the persuasive evidence (Amann & Cetina, 1990).

The importance of Latourian inscriptions in sciences has also been surveyed with empirical methods, which led to the thesis of *visuality (or graphism)*. The *visuality* thesis contended that the use of scientific graphs can delineate the hierarchy of sciences, particularly in terms of the *hardness* of scientific disciplines (Smith et al., 2000). Cleveland (1984) first tested this hypothesis with seven scientific disciplines, which included the chemistry, physics, biology, medicine, psychology, economics, and sociology. For the analysis, he selected four journals from each discipline and randomly sampled 50 articles from each journal. The study found that the perceived hardness of a scientific discipline among the general public is positively correlated with the “fractional graph area” (FGA) of the disciplinary journals, the proportion of the total page area in articles devoted to graphs. The perceived “hard” natural sciences journals tended to have higher FGAs than the perceived “soft” social science journals. Arsenault et al. (2006) built upon this line of inquiry to establish a taxonomy of all Latourian inscriptions used in sciences, and performed Cleveland’s (1984) analysis on all types of inscriptions. Their research demonstrated that non-visual inscriptions such as tables or equations do not have the same effects on the hierarchy of sciences as graphs, and further reinforced the *visuality* thesis. Although the discussions of scientific hierarchy (i.e., “hard sciences” vs. “soft sciences”) have been gradually dismissed and may no longer remain attractive in the current time, these earlier studies empirically tested and supported Latour’s claim on the central roles of inscriptions in building and communicating scientific facts. Moreover, these studies have demonstrated that visualization can be an effective metrics in evaluating the overall development and major characteristics of a research field.

2.3.2 How Does the Mobilization Happen? Rhetorical Perspectives and Analyses

Now that visualizations matter as a rhetorical device in scientific knowledge production and communication, how did they actually function in the mobilization process and produce meaning? Historians and rhetoricians of sciences have extensively engaged in this line of inquiry from the perspective of visual rhetoric, and the discussions on the narrative functions of inscriptions, especially the various forms of visual representations, have been genre- and discipline- based. In addition, scholars also approached the inquiry from three perspectives: (1) How do different *visual forms* produce meaning? (2) How do *visual compositions* produce meaning? And (3), how do *visual-verbal interactions* produce meaning?

With a case study of geology, Rudwick (1976) discussed the importance of using visual languages in sciences. He argued that despite the long-time neglect, visual language was similar to any other linguistic skills and needed to be learned and practiced. With specific visualization examples from geology, Rudwick (1976) identified the important components of a geological visual language, which included geological maps, geological sections (e.g., traverse sections), and geological landscapes (e.g., artistic and realist rendering of the natural topology). These components assisted geologists in presenting and communicating their thought experiments on depicting geological structures of the earth. Such visual expressions, when “appropriate to the subject matter of the sciences, can complement verbal descriptions and theories by communicating observations and ideas that could not be expressed in words” (Rudwick, 1976). Bastide (1990) further examined scientific iconography and explained how semiotic visual elements in them communicate meaning. She proposed multiple principles for reading the iconography, such as the comparison, the habit of thought or interpretation, the use of spatial dimensions, and the continuity and diversity perspectives.

Myers (1990), with a detailed account of the use of scientific illustrations in E.O. Wilson’s *Sociobiology*, demonstrated how different types of visualizations can be leveraged to communicate science to popular audiences. Myers’ (1990) article analyzed the use of illustrations in the textbook, with a particular focus on the visual forms of photographs, pictures, and graphs. Myers (1990) proposed a spectrum of abstraction for visual representations: at one

end of this spectrum are photographs, which are full of “gratuitous details;” drawings and maps sit in the middle, as they reflect certain realistic elements but also contain symbolic representations and the manipulation of details into general patterns. At the other end of the spectrum, as Myers (1990) argued, are visual categories such as graphs, models, or diagrams, where “irrelevant details” are removed and each symbolic mark represents only the meaning of the claim. However, that is not to deny photographs as a form of visualization. Photographers played an important role in constructing and defining the “realities” represented in a photograph; and this interpretation process inherent in the production of a photograph is at least “as complex as the optical and chemical processes that turn images into patterns of dots.” As Myers (1990) argued, the lavish use of photographs and pictures in *Sociobiology* successfully communicated the scientific ideas and stories to the wider public.

Some of the properties and functions of visualizations analyzed in Myers’ (1990) work were also echoed by Lynch (1990), but Lynch (1990) went further to elaborate on the dynamics between the various visual forms. Focusing on scientific journal publications in life sciences, Lynch (1990) proposed two processes to characterize the ways where inscriptions produce meaning, which are selection and mathematization. Selection concerns the ways in which the scientific methods of visualization simplify and schematize the objects of study; while mathematization concerns how such methods attribute mathematical order to natural objects. To illustrate the simplification process, Lynch (1990) discussed the *split-screen juxtaposition* of photographs, diagrams, and models, within which each inscription represents the same thing but in different fashion and with different purposes. In a split-screen juxtaposition, a photograph serves as a realist proof of the actual existence of a natural phenomenon, while the accompanying diagram or model is a schematic, simplified, and selective representation of the phenomenon with the purpose of highlighting certain messages (while ignoring the others). The split-screen juxtaposition, in this sense, is both directional and sequential, moving from phenomenological to theoretical. The diagrammatic rendering of the photographic representation also demonstrates scientists’ need to transform all forms of data and discoveries into evidence during the visualization process. Mathematization, by contrast, is a process which is usually embodied in graphs that map scientific work and phenomena onto Cartesian coordinates, numbers, points, lines, and scales. Mathematization

largely aims to represent the analytical procedures of science and adds to the authority of the scientific claims. Focused on the issue of authority in scientific visualizations, Richards' (2003) work was a good example that demonstrated how different visual characteristics, forms, and functions strengthened scientific argumentation. Using a combination of empirical analyses and the in-depth interview technique, Richards (2003) surveyed visualizations that appeared in the *American Journal of Botany* over an 80-year period and examined a former editor's reactions to the rhetorical strategies solicited in those visualizations. By means of this process, Richards (2003) identified multiple visual rhetoric strategies that can be applied to increase scientific authority, including using the beautiful, aesthetically appealing images, leveraging cutting-edge visual techniques to show novelty, and creating thematic scientific visualizations to generate insights from data.

Research studies have also addressed the visual-verbal interactions in scientific communication, and examined how they support argumentation in sciences. As Myers (1990) analyzed, the visual-verbal interaction often takes place at two locations in a scientific text, which are (1) the captions explaining the content of a visualization, and (2) the verbal accounts in the body of the text that position the visuals into the narrative. Building upon the extensive body of literature on the rhetoric of sciences, Gross and Harmon (2014) proposed a general theory of verbal-visual interaction in scientific communication from perspectives such as the taxonomy of visualizations, disciplinary inquiries and subjects, as well as the genre and media of communication (e.g., journal articles, public slides, the Internet).

2.3.3 The Digital Trend and its Impacts on Scientific Visual Representations

With the rapid development of information and communication technologies, STS scholars with an interest in scientific visualization started to shift their focus to look at how visualization is practiced during the scientific research processes and how scientists leverage complex technologies and procedures in creating visualizations. Coopmans (2014) commented that the increasing use of computer screens and technologies (e.g., databases, lines of codes, simulations) as scientific visualization media makes it important to explore how the visual representations are produced, what enables the representations, and what this

material mediation or practice means. Illustrating a case study of human brain rendering with the fMRI (functional magnetic resonance imaging) technology, Alač (2014) treated the digital scientific visualization practice as a “field for interaction” and demonstrated how scientists work together to fulfill the process of brain imaging. Digital scientific visualizations, in this context, “gain meaning in the lab not in isolation but when organized in a series, manipulated via computer commands, and embodied by the practitioners” (Alač, 2014). Numerous other studies have also looked at the issue from specific disciplinary perspectives (de Rijcke & Beaulieu, 2014; Barany & MacKenzie, 2014; Carusi & Hoel, 2014). Situated within these practices, issues such as the trust, objectivity, and transparency of digital visualization also emerged (Kemp, 2014; Frow, 2014). During the past 10-15 years, digital visualizations have become ubiquitous in scientific journal publications. Scientific journals, especially the high-profile ones, have committed to creating guidelines to aim for a more ethical treatment and inclusion of digital visual representations (Rossner, 2002; Frow, 2014). While the objectivity of visual representations has always been an issue in scientific visualization research, the digital trend has raised more challenges and a new context to examine the relationships between technologies and visual representations (i.e., the RD-RO relationship). These studies demonstrate that (1) the boundaries and implications of a “scientific visualization” have been extended with the increasing involvement of digital technologies and media in the research processes; and (2) the relationships among visual representations, associated practices, embodied technologies, and engaged communities get ever more complex. Therefore, further research into such relationships will be able to better inform the scientific visualization field; potentially, research into this direction may inform visualizations applied to other fields as well (e.g., visualization in digital humanities).

2.4 Summary of Research Literature

To summarize, this chapter reviews three areas of scholarship in digital humanities, visualization, and science and technology studies, which collectively build the scholarly foundation for this dissertation project. From the perspective of DH scholarship, the current

research literature demonstrates the ongoing debates in the DH field and illustrates the problem of the lack of empirical methods and inquiries. Literature on East Asian DH and multilingual DH, in particular, further lays out the agenda to examine the potential differences between the uses of inscriptions in different languages, cultures, and societies in the future. Visualization scholarship further addresses different ideas and perspectives of visualization in various contexts. Particularly relevant to this dissertation work, existing literature highlights different sets of principles for the “humanistic visualization” and the promise and challenges it poses for digital humanities research. Visualization from the LIS perspective, and especially the topic of visual literacy, also informs the significance of conducting this dissertation project and illustrates its potential impact on the societal and public well-being. To further complement the DH and visualization scholarship, literature in STS also examines the use of inscriptions and visual representations, particularly focusing on how such representations mobilize scientific knowledge production and communication. This group of literature focuses on the philosophical and rhetorical discussion of visual representations and is particularly informative to guide the discussion of narrative functions and roles of inscriptions in this dissertation. Moreover, the notion of “immutable mobiles” as discussed in the literature is also an important concept that guides the analysis of inscriptions and the design of the dissertation.

The review of existing literature from the three research areas also suggests a gap, which this dissertation aims to bridge. On one hand, there has been a lack of *empirical* exploration of digital humanities as a field of practice; and more specifically, despite the increasing application of visualizations in the DH research, few works have empirically investigated digital humanists’ visualization practices as well as their use of visual representations in research communication. On the other hand, among the literature examining visualization in multiple contexts, little has been known about how visual representations and technologies are used in DH research and how digital humanities researchers and practitioners work with visualizations in their research. This dissertation aims to address this literature gap by offering one of the first empirical studies that investigate visualization use and practices in the DH research context. More specifically, as I will discuss in later chapters, Study 1 examines the use of inscriptions in DH *research articles*, while Study 2 explores how digital

humanists from various domains work with visualization in their *research practices*. In the following chapters, I illustrate the conceptual framework I used to design the project, along with the research design, questions, data, and methods.

3.0 Conceptual Framework, Research Design, and Questions

Extending from the existing literature, in the following chapter, I discuss how I designed this dissertation project, particularly based upon Latour's (1990, 1987) theory of "immutable mobiles" and approach to scientific knowledge production. More specifically, I start with discussion of the conceptual framework for the dissertation, including the inquiry worldviews, subjectivity statement, and substantive content theory, as suggested by DeCuir-Gunby and Schutz (2017). Based on the conceptual framework, Section 3.2 presents the overall design of the dissertation, which is followed by a discussion of research objectives in Section 3.3 and the presentation of multiple research questions in Section 3.4.

3.1 Conceptual Framework

This section illustrates the conceptual framework I use to guide the research design of this dissertation work. The conceptual framework consists of three aspects, which are the inquiry worldview, subjectivity statement, and substantive content theories (DeCuir-Gunby & Schutz, 2017).

3.1.1 Inquiry Worldviews

Inquiry worldviews, also called research paradigms, describe a researcher's overarching belief in how research works. DeCuir-Gunby and Schutz (2017) demonstrated the five most common worldviews and their judging criteria, which include the positivist-postpositivist, constructivist-interpretivist, critical, transformative-participatory, and pragmatist-pluralist. In this dissertation, I adopt a transformative-participatory inquiry worldview. A researcher with a transformative-participatory inquiry worldview (1) adheres to the belief of multiple truths and the impacts of contexts on the understanding of a phenomenon; (2) attempts to actively engage with the communities being researched; and (3) values change as the

most desirable research outcome and aims to transform the situation based on the needs of the subjects of the study (e.g., participants involved in the study). The transformative-participatory paradigm is closely associated with the mixed methods design (DeCuir-Gunby & Schutz, 2017; Creswell & Creswell, 2018). In this dissertation study, I focus on the inscriptions as they are applied to the *context* of digital humanities research. I investigate *communities* of digital humanists connected by the inscription practices, with methods such as semi-structured interviews. The purpose of the dissertation is to develop a better understanding of the current inscription use and practices in digital humanities and the underlying dynamics and interaction mechanisms among the communities, so as to *change* the established paradigms in DH research, particularly, to inform best practices and efforts to improve visual literacy and digital humanists' experiences working with visualizations and visual technologies in their research.

3.1.2 Subjectivity Statement

Exploration and analysis of a topic are potentially impacted by the position of the researcher, and therefore, to be aware of the position as well as the subjectivity of the work is very important for a researcher and writer. A subjective statement is an explanation of the relationships between the researcher and the research topic (DeCuir-Gunby & Schutz, 2017). A clear awareness of the researcher's position is particularly important for ethnographic research, as ethnographic researchers are usually not neutral observers and are "very much part of the research process" (Chiseri-Strater, 1996; Lønsmann, 2016). I approach this dissertation study as a library and information science (LIS) researcher and a broadly defined digital humanist who have interests and previous research experiences in DH. With this researcher's perspective, the questions to be investigated in the project come from a combination of empirical investigations and my personal intuition, curiosity, and judgement of DH visualization issues. On one hand, the "closeness" between my research background and the chosen topic makes me, the researcher, as a *partial insider* among the participants, facilitating a deeper understanding and interpretation of the issues to be discussed in the study and probably enabling more smooth and productive communication with participants.

In addition, the LIS perspective to DH visualization may offer new interpretative opportunities and contribute to the desired *change* and *transformation* of visualization practices in DH. However, on the other hand, potential limitations to the study may involve interpretative biases or subjective judgements brought up by the researcher’s *partial insider* position. Awareness of my position as a researcher in this study guides me towards the most suitable research design. As will be detailed in the next chapter, the qualitative content analysis and quantitative analysis in the first stage of the project provide a solid, empirical foundation for a more productive ethnographic inquiry with the participants during the second stage of the research. Such a combination may potentially mitigate the problems associated with the *partial-insider* researcher’s perspective.

3.1.3 Substantive Content Theory

Substantive content theories refer to specific domain theories that guide the research inquiries and design (DeCuir-Gunby & Schutz, 2017). This dissertation work is guided by Latour’s theories on the mechanisms of scientific knowledge production, particularly the methodological approach on *science in action* and the theory of “immutable mobiles” (Latour, 1987, 1990). Latour’s *Science in Action* addressed the whole process of scientific knowledge production and communication: the book starts from the “ready made” science (e.g., a published journal article) and follows an imagined, curious *dissenter* to unveil the “rich, confusing, ambiguous and fascinating” laboratory scene of science *in the making*, i.e., the production processes of science. By means of following this imagined “dissenter” through the lab, Latour theorized and discussed a number of issues associated with *how science works*, such as how scientists create science with “inscriptions” and “machines,” how scientists debate to build scientific facts, how they search for evidence and support during disputes, how scientists see their professional identities, and how they present the scientific findings and engage in the collective process where an organized series of laboratory traces are received as scientific facts across the society. Rooted in the science and technology studies (STS) – in Latour’s own term, the “technoscience,” *Science in Action* raised both an insightful theoretical discussion on the system of scientific knowledge production and a methodolog-

ical proposal to investigate science within the larger sociotechnical context. Theoretically, Latour treated the *actors* (e.g., scientists or the “dissenting audiences”) and *things* (e.g., inscriptions and machines from the lab or the published papers that embody such laboratory traces) as important factors in the dynamic system of scientific knowledge production and transmission. Methodologically, Latour identified seven *rules of method* and six *principles* for enthusiasts who desire to follow the process. A Latourian approach, in this sense, emphasizes the material, procedural, and systematic aspects of knowledge production. “Immutable mobiles,” an important material aspect theorized in Latour’s approach to science, refers to the inscriptions created in laboratories that embody scientific discovery processes and can be leveraged to communicate and transform them into scientific facts and knowledge (Latour, 1990).

Latour’s (1987) theoretical and methodological contributions proved to be influential in STS and even beyond. As indicated in the Literature Review, the Latourian approach inspired a large body of STS scholarship on issues such as representation, scientific visualization, and visual rhetoric and scientific communication (M. Lynch & Woolgar, 1990b; P. Lynch, Rivers, & Latour, 2015; Coopmans, 2014). In other research areas such as the current informetrics and scientometrics research, Latour’s theory and approach has also been widely referenced and applied among scholars. In the field of digital humanities, it is also adopted for transformative purposes. Typical examples include Warwick’s (2012) monograph on digital humanities practices and Antonijevic’s (2015) work on the digital knowledge production in DH field, where they adopted a Latourian lens of investigation.

In this dissertation, I use Latour’s theory and approach of scientific knowledge production as the conceptual framework to guide the research design. Particularly, I apply it from three aspects: (1) This dissertation study adopts a systematic view into the interactive dynamics among communities of digital humanists (*actor*) and inscriptions as both a practice and a product (*material*). (2) Second, design of the two major studies as well as the research questions follows the Latourian process of moving from the *products* to the *production*. I start with the exploration of inscriptions as a form of end products of DH research articles, and then move to the production process where I investigate how various communities of digital humanists work with inscriptions and inscription devices during

their research processes. This research design enables a more comprehensive and in-depth understanding of DH inscriptions, which includes not just the phenomena (*what*), but also the underlying mechanisms that account for the phenomena (*why*). (3) Finally, following a Latourian approach where empirical observations and analysis are more emphasized than theoretical assumptions, this dissertation adopts a grounded-theory-based, mixed-methods design, leveraging a combination of qualitative and quantitative data analysis to develop understandings of DH inscriptions and offer insight into DH as a field of practice.

3.2 Overall Research Design

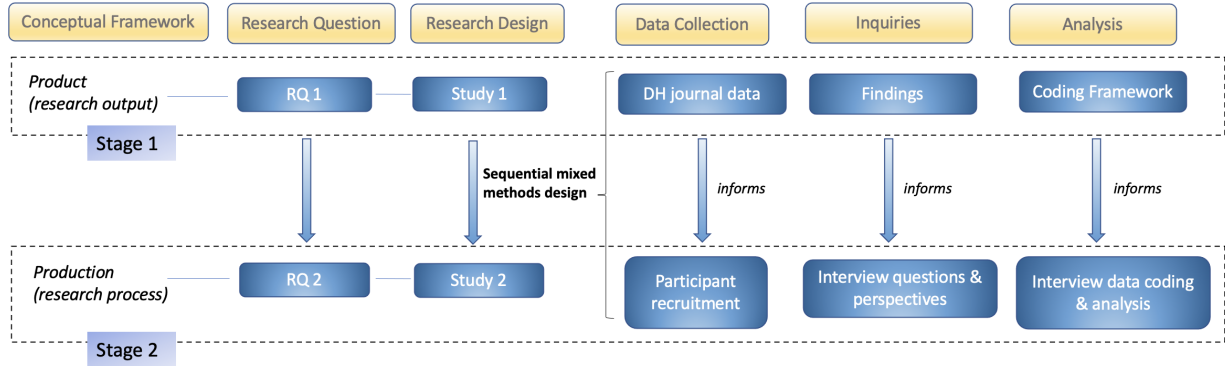


Figure 8: Overview of the Research Design

Based on the conceptual framework, this dissertation study consists of two stages of research. Figure 8 shows an overview of the research design and highlights the relationships between the two stages of research. Stage 1 focuses on a study (Study 1) that examines the use of inscriptions in DH journal publications; while Stage 2 addresses an exploratory study (Study 2) on inscription practices among digital humanists communities during their research processes. Between Study 1 and Study 2, I adopt a sequential mixed-methods design. The sequential design is demonstrated from three aspects, which are the data collection, inquiries, and analysis. From the aspect of data collection, the metadata of the collected DH journal articles (including the authorship) during Study 1 serves as the basis for the selection and

recruitment of participants for Study 2. Second, I use findings from Study 1 to guide the design of semi-structured interviews during the phase of Study 2. Finally, the taxonomy of DH inscriptions that emerged from Study 1 are also used to guide the coding and analysis of interview data in Study 2.

This dissertation also adopts a mixed-methods design. Mixed-methods design is a form of research design that involves a combination of qualitative and quantitative data analyses (Creswell & Creswell, 2018). The development of mixed methods resides in the idea that all methods have biases and weaknesses and a combination of diverse qualitative and quantitative methods will reduce and offset weaknesses of each method, so as to achieve the best analytical results (Creswell & Creswell, 2018). In addition, this dissertation also applies an exploratory mixed methods design, which starts with a quantitative examination of the general picture of data, and then moves on to investigate specific issues with qualitative analyses (Creswell & Creswell, 2018). The overall design of this dissertation follows the explanatory design, with Study 1 committed to a quantitative examination of the *status quo* of DH inscriptions and Study 2 aiming to explore reasons and mechanisms underlying the revealed phenomena with semi-structured interviews. Specific studies and the corresponding methods applied to each study are described in detail in the Data and Methods chapter.

In addition, both the analytical processes for Study 1 and Study 2 take a grounded theory approach. Grounded theory approach uses an inductive, bottom-up analytical process that is intrinsically data-driven and aims to build theory from empirical data (Glaser & Strauss, 1967; Corbin & Strauss, 2008; Charmaz, 2014). Typical analytic procedures in grounded theory approach include iterative data collection and qualitative data coding. This data collection and coding process facilitate the emergence of conceptual categories, new analysis, as well as new theories and understandings of the subject matter. In this dissertation, I apply the grounded theory approach in the sense that each study is designed as data-driven and aims to leverage insights from either the empirical publication data or the viewpoints collected from interviews to develop understandings of specific phenomena and practices of DH inscriptions.

3.3 Research Objectives

Corresponding to the sequential mixed-methods design, I identify the following research objectives:

The overarching goal of this dissertation is (1) to understand inscription use and practices among digital humanists based on empirical methods, so as to (2) offer an insight into the research identities as well as the dynamics of digital humanities as a field.

More specifically, I identify the following objectives:

Objective 1: To present a comprehensive overview of the current use of inscriptions in DH journal articles, including (1) the major types of inscriptions, (2) their narrative functions in supporting claims and arguments, and (3) the distinct use of inscriptions across time, communities, and journals;

Objective 2: To develop a better insight into the inscriptions practices in DH research processes and explore how digital humanists of various knowledge domains and research conventions work with inscription technologies, including (1) how they perceive a good inscription or visualization; (2) the purposes of using inscriptions in research, and (3) what challenges they encounter with inscription practices;

3.4 Research Questions

To achieve the research objectives, I investigate two sets of research questions: The first set of research question (RQ 1) and its sub-questions aim to address the Objective 1 from multiple perspectives, while the second set of research question (RQ 2) and its sub-questions are designed to achieve Objectives 2.

RQ 1: What is the current state of using inscriptions in *research outputs*, particularly, in DH journal articles (2011-2020)?

RQ 1.1: What are the major types of inscriptions commonly used in DH journal articles?

The purpose of this question is to establish a working taxonomy of inscriptions that can better identify and describe the most commonly used and important types of inscriptions in DH scholarship. Qualitative, manual coding of inscriptions is used to modify and expand an existing classification system of inscriptions (Arsenault et al., 2006). Findings of this research question serve as basis to further analyze inscription use in DH research corpus. This survey also represents the first piece of empirical evidence of how different types of inscriptions are used in DH scholarship.

RQ 1.2: How does the use of inscriptions evolve over time?

This question intends to trace the evolution of how inscriptions are used in digital humanities scholarship across the past ten years (i.e., from 2011 to 2020). Specifically, I investigate how the mean number of inscriptions and the variety of inscriptions have changed over time, two key indices of how inscriptions are used in scientific publications. The findings of this question present an overview of the temporal development of inscriptions commonly used in the DH field.

RQ 1.3: How are inscriptions used differently across research communities?

This question aims to look at the different inscription practices and the potential tensions between research traditions in the DH field, especially the humanities and STEM (Science, Technology, Engineering, and Mathematics), as the evolution of digital humanities has dramatically benefited from the constant learning, critique, and incorporation from STEM research conventions and practices, such as information technologies, data science, or statistical approaches (Alvarado, 2012; A. Bradley et al., 2018; J. Bradley, 2019; Fitzpatrick, 2012). To identify the research communities, I classified all the authors represented in the dataset based on their institutional affiliations. Building upon the domain classification, I evaluate how inscriptions are approached by humanities and STEM researchers under different collaboration situations, so as to understand the dynamics of inscription use in the DH field.

**RQ 1.4: Which journals do different DH communities prefer to publish in?
How does inscription use differ across journals?**

This question aims to examine the roles of journals as a venue to reflect the cross-

disciplinary inscription use. Building upon the analysis conducted for previous research questions, I analyzed how the distribution of different types of inscriptions across the selected journals reflects distinct inscription preferences across various DH communities, especially the humanities and STEM communities.

RQ 1.5: What narrative functions do DH inscriptions serve in research communication?

This question aims to understand specific rhetorical roles and functions of different types of inscriptions in DH research communication and attempts to analyze the major ways in which inscriptions mobilize the argumentation process in DH journal articles.

RQ 2: How do various communities of digital humanists work with inscriptions during their *research processes*?

RQ 2.1: What does it mean to be a *quality* inscription or visualization in DH research?

This question explores the perceptions of effective and quality inscriptions among various communities of digital humanists. Findings of this research question also present implications for comparing DH inscription and visualization principles with general, widely-acknowledged visualization guidelines in other disciplines and research contexts.

RQ 2.2: What are the underlying purposes that digital humanists seek to fulfill with visualizations (or inscriptions)?

This research question analyzes digital humanists' purposes of using inscriptions in their research processes. Findings of this question further contribute to understanding why inscriptions are important to digital humanities scholarship and how the motives of using inscriptions and visualizations in DH differ from other research contexts.

RQ 2.3: What are the major challenges and barriers encountered by different communities of digital humanists working with inscriptions or visualizations in their research?

This question aims to explore the major challenges and barriers that researchers encounter in digital humanities research. Findings of this question can further inform future

research on best practices for visualization, particularly focused on the context of digital humanities. More broadly, the research findings can also contribute to visual literacy studies and improvement.

4.0 Data and Methods

To examine the two sets of research questions, I used a mixture of qualitative and quantitative methods along with two major datasets. In this chapter, I elaborate on the specific data collection process and analytical methods used in each proposed study in this dissertation project. Section 4.1 illustrates the research methods used to analyze the use of inscriptions in digital humanities journal articles,¹ while Section 4.2 details the methods used to explore how digital humanists practice visualizations and inscriptions in their research processes.²

4.1 Study 1: Inscription Use in DH Journal Articles

4.1.1 Data Collection and Sampling Strategies.

To examine the *status quo* of using visualizations in DH research outputs, I focus on peer-reviewed DH journal articles published during the last ten years (2011-2020) as the major dataset. One major reason for this choice is that peer-reviewed journal articles are still embraced as the most authoritative and best received scholarly communication channel for high quality research within the humanities, especially in terms of the academic evaluation for scholars. Although journal articles suffer from a relatively longer publication cycle compared with conference papers, presentations, or blog posts, they usually go through a more rigorous peer review process and thus present more well-argued studies. In addition, the generic style of journal articles (e.g., typical length, writing style) also makes articles tend to include more elaborate information about visualizations and how they work with the narrative (Hopkins & Dudley-Evans, 1988; Taylor, 1994; Thompson, 1993). Conference papers and presentations

¹Sections of this study have been published in: Ma, R., & Li, K. (2022). Visuality in a cross-disciplinary battleground: Analysis of inscriptions in digital humanities journal publications. *Journal of the Association for Information Science and Technology* 73 (2).

²Part of Section 4.2.2 Interview Design is edited based on the conference paper: Ma, R., & Xiao, F. (2021). What is a good visualization for digital humanities researchers? An exploratory study. *Proceedings of the Annual Meeting of the Association for Information Science & Technology* 58 (1).

in DH, in comparison, tend to be shorter with less narrative and thus contain less information for analysis. Multimedia project websites, although gradually gaining popularity as a form of research outlet for digital humanities, tend to be highly project- and institution- dependent, which makes it a less desirable dataset to investigate the shared practices and standards among communities of digital humanists.

The first challenge faced with the construction of the journal publication dataset for this study was to determine which journals qualify as *DH journals*. Instead of implementing a top-down data collection approach with an arbitrary, subjective definition of *DH journals*, I adopt the “exclusively DH” journal list developed by Spinaci et al. (2020) in a recent study. Spinaci et al.’s (2020) research applied an unsupervised learning method to form clusters of journal publications based on their similarities and differences. According to the clustering results, they proposed three major categories of DH journals; namely, the exclusively DH, significantly DH, and marginally DH journals. More specifically, the “exclusively DH” journals include, for example, *Computers and the Humanities*, *Digital Medievalist*, *Digital Scholarship in the Humanities*, and *International Journal of Humanities and Arts Computing*, which validates the soundness of the method and the credibility of the study results (Spinaci et al., 2020). Their analysis also demonstrated that Crossref has the most comprehensive coverage of “exclusively DH” journal articles, compared with other databases including WoS, Scopus, and Dimensions (Spinaci et al., 2020).

Based upon the results in Spinaci et al.’s (2020) article, to construct the dataset for Study 1, a collaborator and I retrieved the metadata records of all the research articles published in the “exclusively DH journals” from 2011 to 2020, using the Crossref database (Lamme, 2014) that demonstrates the most comprehensive coverage of the exclusively DH journal publications. A total of 1,566 journal articles were acquired on July 30, 2020. From all the retrieved articles, 300 articles were randomly selected as the sample of the dissertation and their full-text PDF files were manually downloaded from the journal websites. In the case where the PDF file was not available on the journal’s website, the HTML version was acquired instead, which was then saved into the PDF format. It should be noted that while all retrieved articles were marked as English-language research articles by Crossref, some of them were written in a different language and were not research articles. Such articles were

further removed from the sample during manual coding. The selected 300 research articles contain a total number of 2,548 inscriptions. An overview of the sample dataset is shown in Table 1. The list of all sampled publications is available in the Zenodo repository (Ma & Li, 2021). Figure 9 shows the distribution of publication years of all these papers. This dataset is used for Studies 1.1-1.5, as demonstrated in the next section.

Table 1: Overview of Sample Dataset

Data Attribute	Value
Database	Crossref
Time Period	2011-2020
Paper Type	Research Article
Number of Papers	300
Number of Inscriptions	2,548
Journal Coverage	<i>Digital Scholarship in the Humanities,</i> <i>International Journal of Humanities and Arts Computing</i> <i>Journal of Computing and Cultural Heritage,</i> <i>Literary and Linguistic Computing, Digital Medievalist,</i> <i>Journal of Cultural Analytics,</i> <i>Frontiers in Digital Humanities</i> <i>Digital Studies /Le champ numérique, etc.</i>

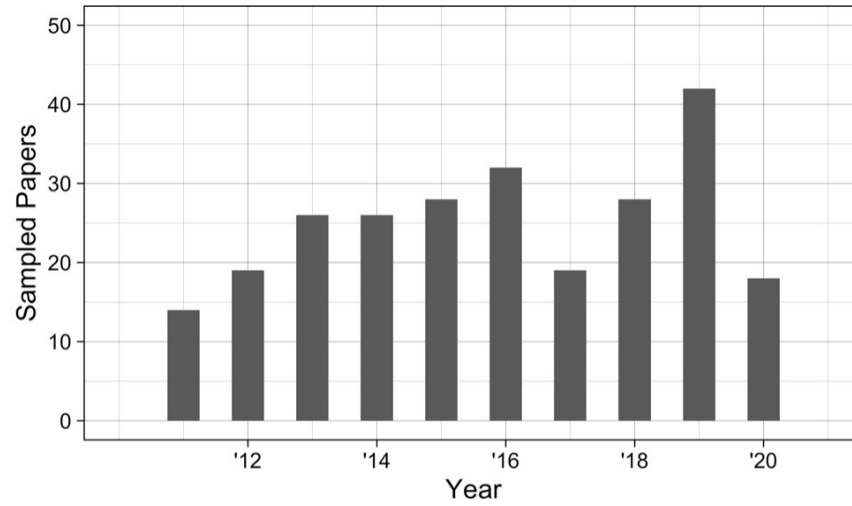


Figure 9: Count of Articles by Year

4.1.2 Data Coding and Analysis

To fulfill the objective of Study 1, I conduct five sub-studies that aim to address RQ 1.1-1.5, respectively. Table 2 demonstrates the specific coding and analytical methods for each study.

Table 2: Research Structure of Study 1

Study	RQ	Methods
Study 1.1 A Working Taxonomy of DH Inscriptions	RQ 1.1	(1) Qualitative Content Analysis
Study 1.2 DH Inscription Use across Time	RQ 1.2	(1) Quantitative Analysis
Study 1.3 DH Inscription Use across Research Community	RQ 1.3	(1) Qualitative Content Analysis (2) Quantitative Analysis
Study 1.4 DH Inscription Use across Journal	RQ 1.4	Quantitative Analysis
Study 1.5 Narrative Functions of DH Inscriptions	RQ 1.5	(1) Close Reading (2) Qualitative Content Analysis

4.1.2.1 Study 1.1 A Working Taxonomy of DH Inscriptions. To identify the major types of inscriptions used in digital humanities scholarship, I apply the qualitative content analysis (Elo & Kyngäs, 2008; Pickard, 2013) and strive to classify all the inscriptions represented in the dataset by extending an existing framework of scientific research inscriptions (Arsenault et al., 2006). The purpose of this inquiry is to raise an adapted, working taxonomy of inscriptions used in DH.

Arsenault et al.’s (2006) framework contains three categories of inscription, which are the graphs, non-graph illustrations (NGI), and non-visual inscriptions (NVI) (Table 3). In this classification scheme, a graph is defined as a figure that has scales and conveys quantitative information. Statistical graphics such as the line chart, scatterplot, histogram, all belong to this category. Non-graph illustrations (NGIs) refer to visual representations that are not necessarily created based on quantitative data, but are still frequently applied in literature

to demonstrate research objects or procedures. This category includes visual forms such as diagrams, illustrations, and photographs. Finally, the non-visual inscriptions (NVIs) are comprised mainly of equations and tables in scientific research.

Along with a collaborator, I reviewed the downloaded PDF files of selected articles and classify the inscriptions in the articles based on Arsenault et al.’s (2006) framework. We retained most of the categories in Arsenault et al.’s (2006) original scheme, especially the three high-level categories (i.e., graphs, NGIs, NVIs), as they fit the context of digital humanities research. In addition, during the coding process, we also add a few new categories to the classification scheme to better reflect inscription use in the digital humanities context. Particularly, we made changes along two directions: First, we identified inscription types that are emerging and recent , which have not necessarily been indicated in Arsenault et al.’s (2006) older framework; and second, we identified the inscription forms that are potential specific and unique to DH research. The inter-coder agreement between the two coders is 0.887, which reaches the “very good” level based on Landis and Koch’s (1977) classic recommendation. All differences between the coders were resolved before analysis. The developed working taxonomy of DH inscriptions is demonstrated in the Results chapter, along with the definitions of each category.

Table 3: Arsenault et al.’s (2006) Inscription Classification Framework

Category	Sub-category and Example
Graph	e.g., line chart, scatterplot
Non-graph Illustration (NGI)	Diagram (e.g., flowchart, schematic) Drawing and Illustration Photograph Map Montage
Non-visual Inscription (NVI)	Equation Table

4.1.2.2 Studies 1.2-1.4 Inscription Use across Time, Community, and Journal

Quantitative methods were applied to provide a thorough analysis of the inscription use across time, research community, and journal in DH.

Measurements of Inscription Use. Earlier works have adopted frequency per page (i.e., the count of inscriptions per page; Butler, 1993) and fractional graph area (i.e., the ratio of publication area devoted to visual inscriptions; Cleveland, 1984; Smith et al., 2000) as quantitative indicators of how graphs are used in scientific publications. In this work, we used a measurement that is similar to frequency per page, i.e., the total count of inscriptions, because some papers were published as web pages and their page numbers were essentially impossible and meaningless to be counted. Moreover, building upon the working taxonomy of DH inscriptions established for RQ 1.1, we also used the variety of inscriptions as a supplementary measurement. Both measurements are explained below:

- **Total count of inscriptions:** This parameter measures the total count of inscriptions used in a publication. We did not standardize the count using the number of pages or words in publications, because of the diversities of files acquired from the journal websites, in terms of the format and quality.
- **Variety of inscriptions:** This parameter measures how many types of inscriptions are used in one publication.

Identification of Author and Paper Domain. To further analyze inscription use across research communities, I also used qualitative content analysis to classify digital humanists. I assigned authors of all the selected articles into research domains based on their institutional affiliations at the time of the associated publication. I reviewed the information of all authors in our sample and applied the classification scheme. I relied on the following sequence of information sources to determine an author's affiliation: (1) information supplied in the article, (2) the author's personal websites or institutional pages, and (3) other information sources with such information, such as ResearchGate and Academia.edu. I prioritized author information indicated in the article as it is the most accurate and up to date at the time of the publication. But for articles that do not contain author affiliation information, I assumed that the authors' research domains do not change very easily and use other resources to locate their affiliations.

As a result, five *author domains* have been identified: Humanities, STEM (Science, Technology, Engineering, Mathematics), Social Sciences, Interdisciplinary Institutes, and Non-academic. I specifically distinguished authors working in an academic institution from those who are not. The latter category, named Non-academic, includes libraries, archives, schools, and companies that are related to DH research. For academic domains, I classified authors into STEM, Social sciences, and Humanities. Over the past few years, there has been a growing trend to establish DH-focused institutes in academic settings, such as the Department of Digital Humanities at King’s College London and the Institute for Advanced Technology in the Humanities at the University of Virginia (Fraistat, 2012). For researchers who work at these DH-focused departments or institutions, I use Interdisciplinary institutes instead of one of the aforementioned domains. Table 4 summarizes the five author domains as well as their total numbers in the dataset. From the table, humanities and STEM authors are the major contributors to DH journals.

Table 4: Classification Scheme for Author Domains

Author domain	Total number
Humanities	208
STEM	248
Social Science	10
Interdisciplinary Institute	14
Non-academic	5

Building upon the community classification, my collaborator and I also introduced a concept of *paper domain* to better conduct quantitative analysis on the level of individual papers. Paper domain was determined based on the domain of its first author. We acknowledged that different authorship practices may exist in DH communities (Siemens et al., 2012), despite the lack of empirical evidence. However, the decision was made based on the assumption that the first author has been commonly accepted as the most important contributor to publications in most cases since the end of the 20th century, in spite of the

competing authorship practices, such as alphabetical authorship (Waltman, 2012). Therefore, we believe it is reliable and feasible to classify the papers based on the first author, a best practice that is also supported by previous DH works (Earhart, Risam, & Bruno, 2020). Table 5 demonstrates the total number of papers for each identified domain, along with a summary of the number of single-authored and non single-authored papers. As demonstrated in the table, STEM and Non-academic papers tend to be more collaborative, including a larger portion of non single-authored papers. This observation is further supported by Table 6, which demonstrates that STEM papers have an overall largest number of involved authors.

Table 5: Summary of Paper Domains

Paper domain	Total number	Single-authored	non single-authored
Humanities	104	53	51
STEM	82	19	63
Interdisciplinary Institute	32	14	18
Social Science	20	10	10
Non-academic	14	5	9

Table 6: Level of Collaboration

Paper domain	Mean number of authors
Humanities	1.91
STEM	3.24
Social Science	2.1
Interdisciplinary Institute	2.22
Non-academic	2.36

Journals. The papers represented in the dataset are also distributed across journals.

Table 7 summarizes the number of articles published in different journals. Four journals contain more than 20 articles in the sample, and they are used as the primary sources for journal-based analysis. As demonstrated later in the Results chapter, a journal-level analysis of the inscription use contributes to the overall analysis of how different research communities in digital humanities use inscriptions in their preferred research outlets, which facilitates the understanding of the state of digital humanities as a field of research and practice.

Table 7: Count of Journals

Journal	Count
Digital Scholarship in the Humanities	82
International Journal of Humanities and Arts Computing	37
Journal on Computing and Cultural Heritage	33
Literary and Linguistic Computing	29
Digital Studies/Le champ numérique	19
Journal of the Text Encoding Initiative	18
Frontiers in Digital Humanities	17
Digital Medievalist	7
Journal of the Japanese Association for Digital Humanities	4
International Journal of Digital Humanities	2
Journal of Cultural Analytics	2
Revista de Humanidades Digitales	2

4.1.2.3 Study 1.5 Narrative functions of DH inscriptions. Due to the lack of existing framework to analyze the interplay between inscriptions and their surrounding narrative, I apply, for this particular study, a qualitative research method, and more specifically the technique of close reading, to explore how inscriptions are used in a DH article to support interpretation and argumentation in the article. Close reading is a method that emerged

from literary studies during the 20th century (Apramian, Cristancho, Watling, & Lingard, 2017; Brooks, 1979), which focuses on examining the dynamic interactions between texts and visuals with specific, case-by-case analyses. Close reading has the advantage of capturing the most nuanced interactions between words and visuals in the text.

Data. As the close reading method tends to be time-consuming and subjective, I chose to focus on a smaller corpus of research articles from a specific journal, the *Journal of Cultural Analytics*. *Journal of Cultural Analytics* is an open-access journal launched in 2016, which is dedicated to the computational study of culture and intends to “promote high-quality scholarship that applies computational and quantitative methods to the study of cultural objects, processes, and agents.” Themes represented in this journal include data and infrastructure (12 articles), genre (10 articles), gender (5 articles), race (3 articles), sound (2 articles), among others (i.e., food, space, geography, image, and change, each containing only one article). For the analysis of this study, I selected 37 articles published between 2017 and 2019 as they demonstrate the most comprehensive coverage of articles in the journal. I also classified all the represented inscriptions, based on the working taxonomy established previously in Study 1.1. As a result, I identified a total number of 319 inscriptions across the three higher-level DH inscriptions (i.e., graphs, NGI, NVI).

Using this journal for the study has multiple benefits: First, *Journal of Cultural Analytics* is one of the “exclusively DH journals” developed by Spinaci et al.(2020), which makes it appropriate for this study. Findings based on this case study can potentially serve as the basis for further analysis of inscription use in other *typical* DH journals. Second, this small-sized, thriving journal contains only 57 peer-reviewed articles since its inception but includes a large and heterogeneous collection of inscriptions, making it a well-suited candidate for the scope of this analysis. Finally, the use of this journal also rules out the potential impact of journal norms on inscription use, to exclusively focus on identifying and analyzing specific functions for different types of inscriptions in DH journal articles. Results can provide a baseline to inform further generalization to larger datasets.

Analysis. I apply the close reading method to analyze the interplay between the inscriptions and their surrounding narratives in the identified corpus. More specifically, I investigate the following aspects of the visual-text interaction: (1) how the inscriptions represent hu-

manities data; (2) how compositions of inscriptions facilitate meaning and arguments; and (3) how narrative contexts (e.g., the section of the article where an inscription is embedded) shape the effects of inscriptions in the argumentation process. Table 8 summarizes this coding structure. This coding structure is used to analyze the visual-text interplay in a more consistent manner. Further, to analyze these three aspects, I particularly looked at three data sources: the visual form of the inscription, its caption and legend illustrating information in the inscription, and the text narratives surrounding the inscription in the article.

Table 8: Narrative Functions Coding Structure

Narrative Elements	Example
Data Representation	e.g., qualitative vs. quantitative
Composition	e.g., juxtaposition, combination, single presentation
Context	e.g., methodology, results, discussion

4.2 Study 2: Inscription Practices in *Research Processes*

Following the examination of inscription use in DH publications, I proceed in the second stage of the research to explore how digital humanities researchers and practitioners work with inscriptions in their *research processes*. In this study, I conduct an exploratory study and particularly use the method of semi-structured interviews (Pickard, 2013) to seek first-hand experiences and insights from DH researchers and practitioners. The decision to solely use the semi-structured interview, rather than other ethnographic methods, was made due to practical concerns and limitations, which are to be further discussed in Section 4.2.4 “Reflection on the Change of Methods”.

4.2.1 Participants

To recruit participants for the semi-structured interviews, I use the inclusive definition of the “digital humanist” as discussed in the Introduction chapter, and apply a broad pre-screening criteria, in which any researcher and practitioner who engages in digital humanities work and utilizes inscriptions in the work can qualify as a participant for this study. I use the snowball sampling technique (Biernacki & Waldorf, 1981) to recruit participants. On one hand, I look to my personal research network to identify suitable participant candidates and recruit them to participate in the study. On the other hand, I also recruit potential interviewees from the authors represented in the data for Study 1, especially the corresponding authors and first authors of the papers because they represent the leading workforce of the papers. The participant pool is then expanded based on the recommendations of the recruited participants. I recruited potential participants by means of emails, sending along an invitation letter and a detailed interview protocol. The invited participant is also welcome to invite their co-authors to join the interview if they prefer. This approach is particularly beneficial to explore issues related to collaboration dynamics among researchers and practitioners in DH work. A participant recruitment email (A.2) and advertisement (A.3) are attached to the Appendix.

I recruited 16 participants for Study 2. Table 9 presents an overview of the participants recruited for the study, including information about their academic positions, fields of study, the major areas in which they receive DH training or conduct DH work (“DH Region”), and how long they have been engaging in DH work (“DH Age”). All the recruited participants and their interviews were anonymized and randomly assigned an ID number for further analysis.

Table 9 demonstrates an international and multidisciplinary participant pool, representing researchers from North America, Europe, and Asia, and with disciplinary backgrounds in the humanities, social sciences, information science, among others. A few researchers (e.g., P2, P4, P5, P16) also have interdisciplinary training in their careers, which may have contributed to their research in digital humanities. In addition, participants’ experiences with DH also vary. A few participants have over ten years of experience with DH projects

(e.g., P13, P16, P3, P4), while some participants only start to engage with DH work (e.g., P8, P1, P2). Most participants recruited for the study work at academic institutions, except for one curator working at a prestigious museum (P3).

Table 9: Overview of Participants

ID	Academic Position	Field of Study	DH Region	DH Age
P1	PhD candidate	History	North America	2 years
P2	PhD candidate	Religious studies, information science	North America	2 years
P3	Art Curator	Art history, museum studies, sociology	Europe	10+ years
P4	Assistant Professor	Chemistry, Japanese, information science	North America	10+ years
P5	Master's student	Math, East Asian studies	North America	2 years
P6	PhD candidate	Linguistics	North America	7 years
P7	Postdoc researcher	Religious studies	North America, Asia	11 years
P8	PhD candidate	History	North America	1 year
P9	PhD candidate	Cultural computing, digital humanities	Asia, North America	3 years
P10	Assistant Professor	Anthropology, museum studies	North America	5 years
P11	Assistant Professor	English, digital humanities	North America, Europe	9 years
P12	Master's student	Information science	Asia	3 years
P13	Associate Professor	Digital cultural heritage, information science	North America, Asia	16 years
P14	Assistant Professor	Bioinformatics	North America, Europe	10 years
P15	PhD candidate	Information science, library science	Asia	3 years
P16	Associate Professor	Biomedical information, digital humanities	North America	10+ years

4.2.2 Interview Design

I conducted semi-structured, in-depth interviews with each participant. Placed in the middle of the continuum between the structured and unstructured interviews, semi-structured interview is a qualitative research method that elicits information from participants with both the predetermined, standardized questions and open-ended, flexible questions led by the informants (Pickard, 2013; Kallio, Pietilä, Johnson, & Kangasniemi, 2016). A semi-structured interview is a suitable method for this inquiry because it provides both the structured guidance and flexibility for interviewees to discuss their personal experiences and practices with inscriptions during the everyday research processes. The organized and rich data points collected from the semi-structured interviews are more useful for future qualitative analyses. Each interview was conducted virtually through Zoom and designed to last for 45 minutes to one hour. All the interviews were audio-recorded and then transcribed in their entirety for future analyses.

Each interview consisted of three parts, guided by three sets of questions: The first set of questions collected additional, less-observable demographic information of the interviewees, such as their “academic position,” “field of study,” “DH age” (i.e., period of time in which they engage in DH work), and “DH region” (i.e., where they receive DH training or conduct DH work).

The second set of questions focused on participants’ experiences working with inscriptions in one specific project. I used the Critical Incident Technique (CIT) approach to guide the design of this section (Butterfield, Borgen, Amundson, & Maglio, 2005; Byrne, 2001). CIT focuses on the study of “critical incidents, or significant instances of a specific activity, as experienced or observed by the research participants” (Lipu, Williamson, & Lloyd, 2007). In this section of the interview, I asked the participant to focus on one particular DH project where they apply and work with inscriptions, and to illustrate (1) their overall research topic, (2) the purposes of using each inscription, and (3) how they made design decisions for the inscription practices.

Building upon the first two sections of the interview, the final set of questions aimed to explore the participants’ general thoughts and ramifications on inscription practices beyond

specific projects and papers. Specific aspects covered in this section of the interview included: (1) how researchers reflect on the criteria for inscription and visualization use; (2) how researchers reflect on the roles and functions of inscriptions in addressing their research questions and purposes; (3) what challenges and barriers they encounter, (4) how they assess their visualization skills and knowledge; and (5) how they collaborate on inscription practices and use. The interview protocol, including specific interview questions, is attached in the Appendix (Appendix A.1).

I utilized the grounded theory approach for data coding and analysis (Charmaz, 2014). First, I conducted an open coding of all the interview transcriptions, identifying answers for each interview question. Open coding is the first step of coding and analysis in the grounded theory approach, which aims to formulate theoretical insights from the empirical data (Charmaz, 2014). Building upon the initial stage, I coded and analyzed information on (1) participants' criteria for good visualizations, (2) research tasks and perceived purposes associated with visualizations, and (3) researchers' self-confidence in their visualization knowledge and skills. Two coders then compared and discussed the open coding results to ensure they were accurate and comprehensive.

4.2.3 Justification and Potential Risks

The semi-structured interview is a suitable method for this study. On one hand, this method offers a way to explore inscription *practice* generated in actual digital humanities research process. Such practices offer an empirical basis for the conceptual, theoretical understanding of the roles of inscriptions in DH research. On the other hand, the use of semi-structured interview has advantages over other ethnographic research methods such as the participant observation or case study. First, semi-structured interviews are more practical and realistic to implement, especially during the COVID-19 pandemic period. Second, semi-structured interviews can provide a way to collect more detailed, first-hand accounts about the use and practice of inscriptions in DH research.

However, there also exist potential risks and uncertainties associated with the proposed methods for Study 2. First, the participant recruitment process may encounter difficulties,

particularly when that there is no personal connection between the interviewee and me. To address this risk, as demonstrated in future chapters, I slightly changed the method used to recruit participants, to focus on recruiting DH researchers and practitioners based on my personal research network. Closely related to participant recruitment, another potential risk is associated with the possibility that the participant pool might not evenly reflect how diverse research communities in the DH field use inscriptions. To address this potential risk, I treat this study as exploratory and aim to illustrate the findings that may inform further research.

In addition to the benefits and risks brought by the semi-structured interview, other risks related to data collection, storage, and analysis have been addressed as well. For example, all the personal information collected along with the interview participants was de-identified to protect the confidentiality of individuals. The study was approved by the Institutional Review Board at the University of Pittsburgh under STUDY21010213.

4.2.4 Reflections on the Change of Methods

This dissertation was conducted and composed during the COVID-19 pandemic period. Closely related to this fact, the chosen methods for Study 2 have been changed according to practical concerns to better address the potential risks emerging from the study. When I proposed my dissertation in 2020, the original plan was to conduct ethnographic research that included participant observations and in-depth interviews of digital humanists at multiple DH labs and teams, following the recommendation in Latour's *Science in Action* (1987). By means of such ethnographic methods, I would be able to observe the interactions between researchers and teams, how they collaborate, and how they work with inscriptions and inscription devices in their research processes and activities. However, due to the ongoing pandemic and the associated travel and remote work restrictions, the original methods have to be changed to solely focus on semi-structured interviews. The use of semi-structured interviews has proved to be effective in addressing the research questions and identify interesting findings for further studies. The limitations associated with the semi-structured interview method, however, will be addressed in the future work extending the dissertation.

5.0 Results

Analysis of the research questions using the mixed-methods approach generated multiple interesting results. In this chapter, I discuss the results of each proposed research question for the two studies. Study 1 identifies the major types of inscriptions used in DH research publications and reveals the major use patterns of DH inscriptions across time, research community, and journal. Analysis also suggests the major narrative functions of DH inscriptions in scholarly communication. Study 2 explores digital humanists' visualization practices in research processes, identifying their different perceptions of good visualizations, the major purposes of using visualization in research, as well as the challenges and barriers they encounter in the process.

5.1 Study 1: Inscription Use in Digital Humanities Journal Publications

To address the first set of research questions, I explore the current state of inscription use in digital humanities scholarship from multiple perspectives, including the categories of DH inscriptions, the change of their use across time, research community, and journal, and the specific functions they serve in supporting research in digital humanities. In the following sections, I discuss the findings for each aspect, before illustrating the implications of these findings.¹

5.1.1 Study 1.1 Working Taxonomy of DH Inscriptions

To address RQ 1.1 which aims to establish a working taxonomy of inscriptions commonly used in digital humanities research, we expanded Arsenault et al.'s (2006) classifi-

¹Some results for Study 1.1, Study 1.2, Study 1.3, and Study 1.4 are edited based on the published article: Ma, R., & Li, K. (2022). Visuality in a cross-disciplinary battleground: Analysis of inscriptions in digital humanities journal publications. *Journal of the Association for Information Science and Technology* 73 (2). In addition, results presented for Study 1.5 are edited based on the conference article: Ma, R., Li, K., & He, D. (2021). Understanding the Narrative Functions of Visualization in Digital Humanities Publications: A Case Study of the *Journal of Cultural Analytics*. *iConference 2021 Proceedings*.

cation scheme. First, we retained all the existing, higher-level categories in the framework, which include the graphs, non-graph illustrations (NGIs), and non-visual inscriptions (NVIs). In addition, new sub-categories of inscriptions were identified along two major directions: First, we explored how an inscription reflects the emerging, new visual forms that are not necessarily included in Arsenault et al.'s (2006) framework. Second, we identified inscription types that are potentially unique and special to digital humanities research. As a result, three new inscriptions types were identified and amended to construct the taxonomy of DH inscriptions: the simulation (under NGIs), and code and text (under NVIs).

Simulation is added to NGI, which refers to inscriptions created based on virtual reality (VR) or augmented reality (AR) technologies (Figure 10). With the rise of new visual technologies and techniques such as virtual and augmented realities, simulations are frequently applied in papers on virtual cultural heritage and archaeology to showcase the design of a virtual program or the re-modeling of a physical site (Pujol-Tost, 2017). Partially, this could be attributed to the fact that dynamic, 3-D simulations offer more faithful and authentic representations of an artifact or an archaeological site.

Under NVIs, we identified two new inscription types, i.e., the code and text. Codes are defined as demonstrations of specific computational procedures of a task (e.g., algorithms or blocks of programming codes; Hsiang, Chen, Ho, & Tu, 2012). The frequent use of codes suggests an increasing emphasis on introducing new computational methods and techniques in DH (Figure 11). Codes also create a common ground to engage diverse groups of researchers who may have different disciplinary knowledge base and skills. Finally, the analysis also demonstrates the use of text as inscriptions. Text identified under this definition refers to the situation in which textual information are embedded in the articles as inscriptions (Figure 12 and Figure 13). The textual information includes, for example, XML or HTML texts, or screenshots of printed texts. Unlike other inscription types, text is visually indistinguishable from narrative texts. However, text as a form of inscription is functionally distinct from narrative texts. Similar to other types of inscriptions, text also functions as a form of “immutable mobiles,” meaning that inscription texts can also be taken out of the original narrative contexts and still be able to deliver the same and consistent messages and information across contexts. The development of texts is associated with the enduring need

in DH research to work with textual information in the digital environment.



Figure 10: Example of a “Simulation” (Pujol-Tost, 2017).

Given an Imperial Edict d with signature $s = \langle w_1, w_2, \dots, w_n \rangle$, let d' be a document.

Define $n-1$ bi-grams $b_1 = \langle w_1, w_2 \rangle, \dots, b_i = \langle w_i, w_{i+1} \rangle, \dots, b_{n-1} = \langle w_{n-1}, w_n \rangle$ and two functions

$presence(b_i, d') = 1$ if b_i occurs in d'

$presence(b_i, d') = 0$ if b_i does not occur in d'

and

$$score(s, d') = \frac{\sum_{1 \leq i \leq n-1} presence(b_i, d')}{n-1}$$

Then d' is a candidate if $score(s, d') \geq t$ where t is a predefined threshold.

In our experiment, we set $n = 20$ and $t = 0.6$.

Figure 11: Example of the “Code” Inscription (Hsiang et al., 2012).

love; *De vulgari eloquentia* (Alighieri, 2011a), a Latin essay written between 1302 and 1305 discussing the relationship between Latin and vernacular; *Monarchia* (Alighieri, 2014b), a Latin treatise on secular and

II 7. UT PHYLOSOPHUS DOCET: «come il Filosafo insegna» (Anonimo, pp. 155-6); «come dice Aristotile» (Ficino); cfr. *Ethica ad Nicomachum*, 1094 b 12; 1098 a 27. Cfr. sopra, II II 1. EX MANIFESTIS SIGNIS ATQUE SAPIENTUM AUTORITATIBUS: sull'*auctoritas* come forma di premessa in in un sillogismo che conduce a conclusioni probabili v. qui *Imbach* (p. 293), *Kay* (pp. 100-1, nota 21) e *Cassell* (pp. 304-5, nota 121), con rimando a Pietro Ispano, *Summulae logicales*, V, 36, ed. de Rijk, pp. 75-6, Cfr. più oltre, II V 6. ILLIUS POPULI GLORIOSI: cfr. sopra, II I 4 e più avanti, II V 5 e II IX 19.

Fig. 2 Example of commentary to Dante's *Monarchia*. The format of the commentary is different from that of *Convivio*


religious power; and *Rime* (Alighieri, 2011c), lyric poems that Dante wrote throughout his life, based on the poet's varied existential and stylistic experiences.

Figure 12: Example of a "Text" Inscription.

```

1 <app> (= critical apparatus)
2 <rdg n="r1" source="score"> (= reading)
3   <beam xml:id="beamA"> (= beam of notes as container-element)
4     <note xml:id="n1" pname="b" oct="4" dur="8"/> (= individual beamed note)
5     <note xml:id="n2" pname="e" oct="4" dur="8"/>
6     <note xml:id="n3" pname="f" accid="n" oct="4" dur="8"/>
7     <annot xml:id="ann1" plist="#n3">This note may be wrong.</annot>
8   </beam>
9   <annot xml:id="ann2" plist="#beamA">This beam is obsolete.</annot>
10 </rdg>
11 <rdg n="r2" source="part">
12   <note xml:id="n1" pname="b" oct="4" dur="8"/>
13   <note xml:id="n2" pname="e" oct="4" dur="8"/>
14   <note xml:id="n3" pname="e" oct="4" dur="8"/>
15   <annot xml:id="ann3" plist="#n1 #n2 #n3">These notes sound like an insect.</annot>
16 </rdg>
17 </app>
18 <annot xml:id="ann4" plist="#r1 #r2">Source r1 differs to source r2.</annot>

```

Violin



Violin


Figure 13: Example of a “Text” Inscription (Hadjakos et al., 2017).

Table 10 summarizes the working taxonomy of DH inscriptions along with the definition for each type. In addition, Table 11 further demonstrates the number of inscriptions for each category represented in the dataset. The taxonomy guides further quantitative analysis of the inscription use in DH journal articles.

Table 10: Taxonomy of DH Inscriptions

Category	Sub-category	Definition
Graph	Graph	Graphic representations of empirical and quantitative data (Azzam, Evergreen, Germuth, & Kistler, 2013).
Non-graph Illustration (NGI)	Diagram	Spatial arrangement of elements to convey information and show hierarchical organizations (Arsenault et al., 2006).
	Drawing & Illustration	Pictorial representation of natural objects and phenomena. Terms such as drawings and pictures are also used in scientific literature to refer to this type of visual representations (Myers, 1990; Arsenault et al., 2006).
	Map	Visual representation of geographical location information (Grant, 2019).
	Collage	Combination of multiple types of visual forms into one single display (Montgomery, 2002).
	Photographic Representation	Isomorphic, realist representations of natural objects and phenomena (e.g., photos, computer screenshots) (Myers, 1990).
	Simulation	Virtual reproduction of physical scenes (e.g., archaeological sites) or virtual blueprints created with AR or VR technologies.
Non-visual Inscription (NVI)	Equation	Mathematical expressions that were set off from the body of the text in the style of a block quotation (Arsenault et al., 2006).
	Table	Arrays of information consisting of rows and columns and set off from the body of the text (Arsenault et al., 2006).
	Text	Encoded representation of textual information (e.g., HTML, XML).
	Code	Textual display of digitalization or computational procedures (e.g., algorithms, programming codes).

Table 11 also shows the total counts of all inscription types identified in the sample. Tables, graphs, and photographic inscriptions are the three most frequently used types. On the other side of the spectrum, montages, illustrations, and maps are among the least frequently used categories based on the classification scheme.

Table 11: Count of Inscription Types

Type	Count
Table	678
Graph	483
Photographic images	350
Diagram	281
Equation	237
Text	237
Simulation	71
Collage	50
Code	44
Map	29
Drawing & Illustration	11

5.1.2 Study 1.2 Inscription Use across Time

To understand the distribution of inscriptions in our sample, my collaborator and I analyzed the change of the data by time. More specifically, we calculated the mean number of inscriptions per paper and inscription variety over time, as shown in Figure 14. The graph illustrates a slight increase in both variables during the past ten years, despite the yearly fluctuations. For the number of inscriptions per paper, the number has increased from 8.5 to 11 from 2014 to 2020, whereas the mean inscription has remained around 3 since 2015.

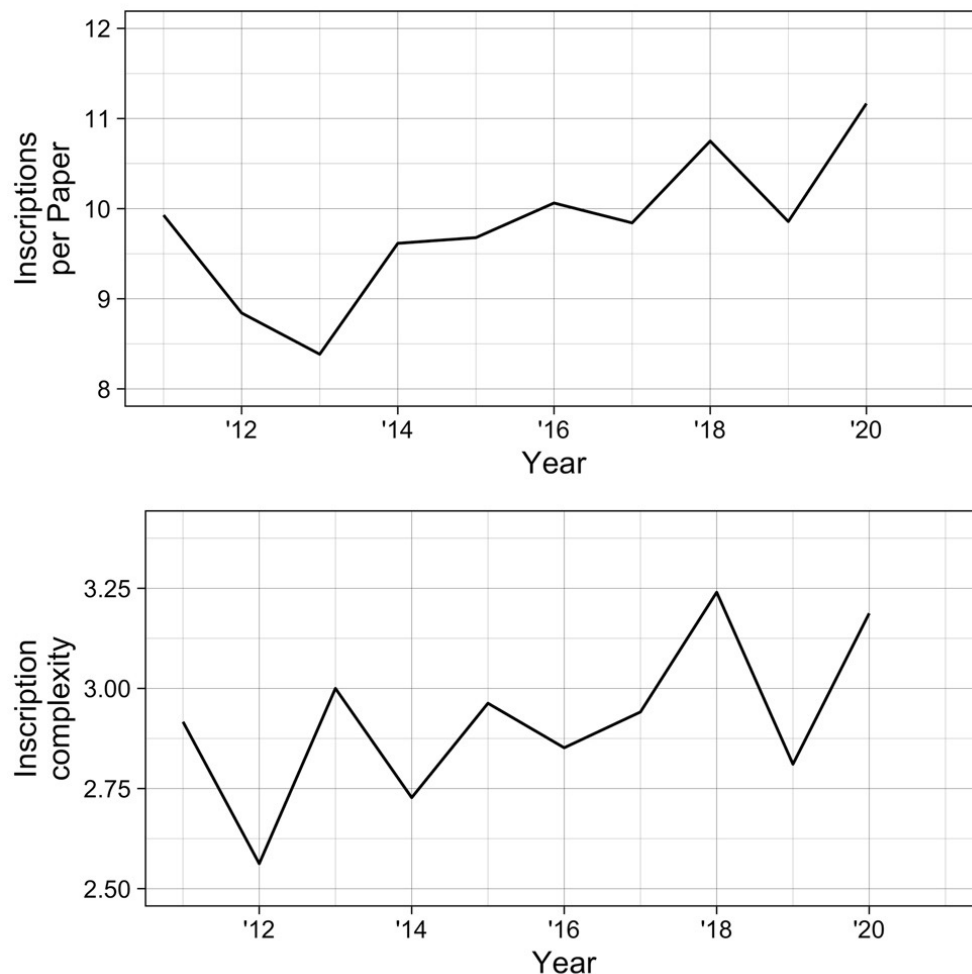


Figure 14: Inscriptions Per Paper (Top Panel) and Inscription Variety (Bottom Panel) over Time in the Sample

In Figure 15, the temporal trend of all inscriptions is broken down into each category, with collages, codes, maps, illustrations, and montages combined into a single others category, given their low frequencies. The y-axis of the graph shows the mean recurring frequency of each inscription type on the paper level. Some inscription types show rather radical year-to-year changes, which is attributed to the relatively small occurrences of these types in the sample. However, two patterns emerge from the results. First, equations are increasingly used in the sample during the publication window while the text shows a strong opposite trend. This supports the general idea that DH research is becoming more mathematized

and less textualized. Second, nearly every inscription type, other than the texts, has been increasingly used since 2012. We calculated coefficients of the publication year to the outcome variable based on Figure 15. The slope values for graphs and diagrams, the most increased categories following equations, are 0.064 and 0.033, respectively, comparing to 0.162 for equations. The coefficients values of all other categories are lower than 0.01, despite being positive. Against this general rising trend, text is the only category with a negative slope value, which is -0.152.

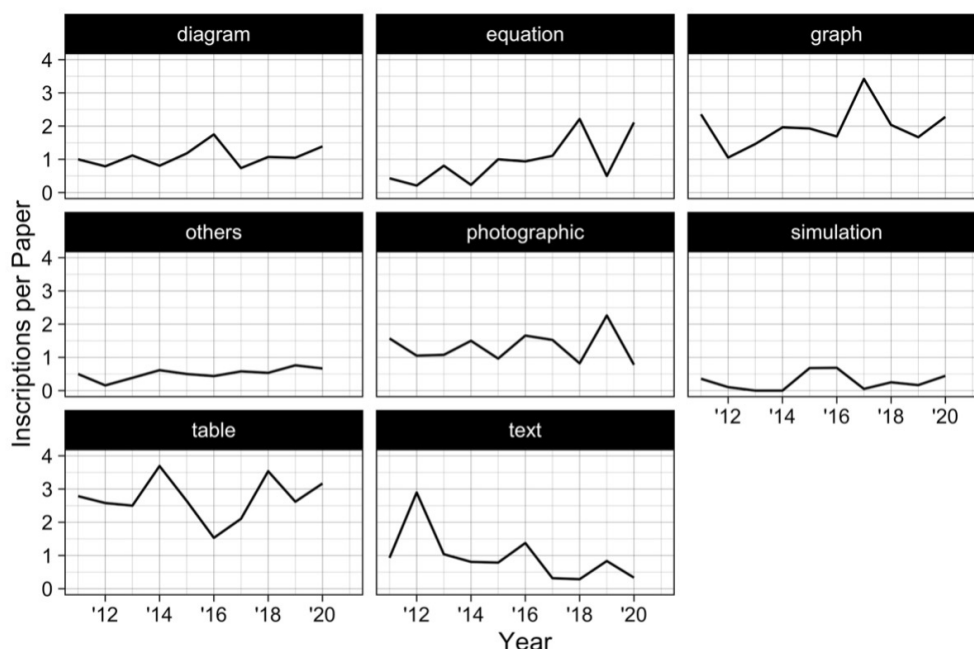


Figure 15: Mean Numbers of Inscription Types over Time

The temporal change of inscription use from 2011 to 2020 demonstrates that digital humanities has gradually developed into an increasingly formalized field, with an increasing use of graphs and equations and a decline in the use of texts in journal articles.

5.1.3 Study 1.3 Inscription Use across Research Community

A central interest of this work is to analyze how researchers from different domains, especially the STEM and humanities, use inscriptions in DH journal publications. Table 12

shows that papers with STEM researchers as the first author (STEM-first-author papers) are more inscription-intensive in terms of both count and variety, while all the other categories except the non-academic have similar statistics. One of the reasons for the very low number of inscriptions used in the non-academic category may be its low number of papers.

Table 12: Inscription Use among First-Author Domains

First-author domain	Inscriptions per paper	Inscription Variety
STEM	13.16	3.34
Interdisciplinary Institute	9.44	2.59
Social Sciences	8.65	2.6
Humanities	8.32	2.06
Non-academic	3.71	1.14

Figure 16 shows the number of each major category of inscriptions in these different domain-oriented paper groups. This figure demonstrates that nearly all inscription types are the most heavily used in STEM-first-author papers, except for the text. However, while graphs and tables are the most intensively used in STEM papers, there is normally not a big difference between STEM and other groups.

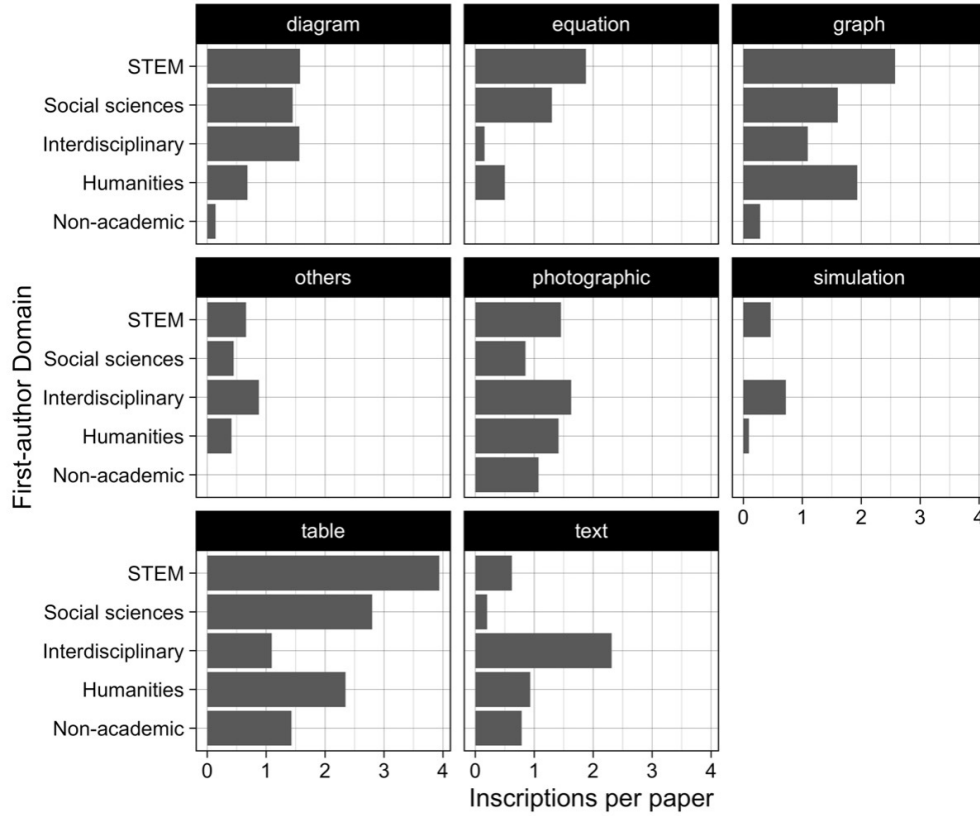


Figure 16: Inscription Types across First-Author Domains

To further analyze the distinct inscription use across current research communities in DH, we further narrowed down the focus on two specific research communities that contribute to the majority of the papers in the dataset: the STEM and the Humanities. From Table 12, we can see that STEM papers tend to include more inscriptions per paper and demonstrates an overall higher level of inscription variety than Humanities papers. In addition to this difference, the analysis based on inscription types also suggests that STEM and Humanities papers prefer different types of inscriptions. As Figure 17 demonstrates, although STEM papers tend to use *overall* more inscriptions for every type (except for the text), they still have different preferences. STEM papers use *proportionally* more equations, simulation, and tables; while Humanities papers include *proportionally* more photographic images and texts.

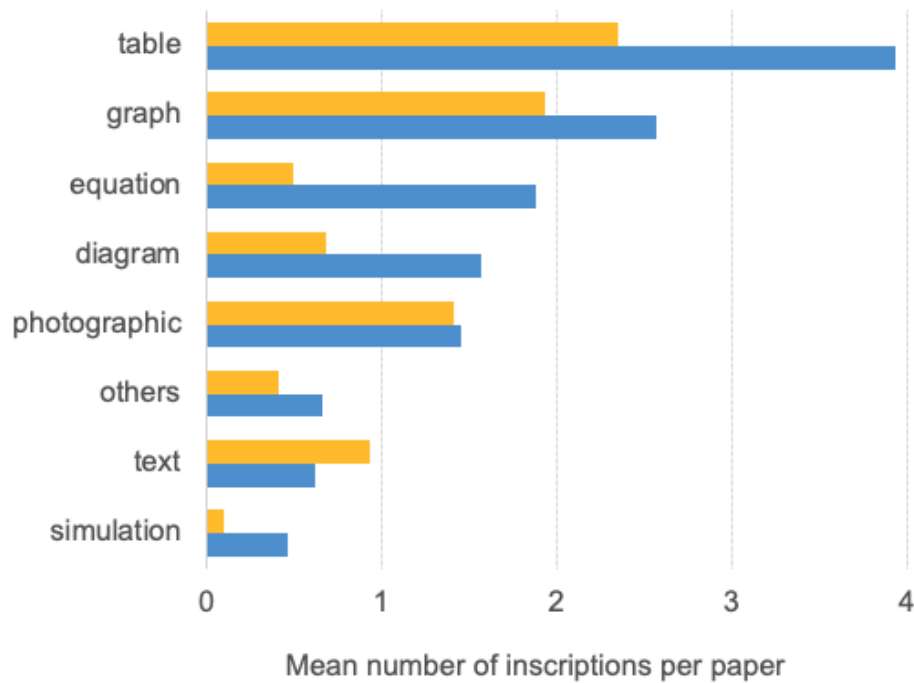


Figure 17: Inscription Types in STEM and Humanities Papers

This analysis demonstrates that STEM and Humanities research communities have distinct preferences over inscriptions use, in terms of the number, overall level of variety, and types. However, only 40% of the papers in the dataset are single-authored papers, suggesting that collaboration is a frequent phenomenon in DH research. What would happen if researchers of the two communities collaborate with each others?

To better understand the impact of collaboration on inscription use and preferences across STEM and Humanities communities, we conducted an additional analysis of the inter-community collaborations using the same dataset. Since “paper domain” was coded only based on the domain of a paper’s first author (as illustrated in detail in the Data and Methods chapter), there exists, for both communities, a large number of papers with additional authors from the other community. Based on this situation, we separated the collaborative papers between the two communities from the non-collaborative papers for each research community, and compared the inscription use between the collaborative and non-collaborative papers. Table 13 shows the statistics of the papers collaborated between

humanities and STEM researchers.

Table 13: Collaboration between STEM and Humanities Authors

First-author domain	Collaboration	Non-Collaboration
STEM	16	66
Humanities	12	92

The collaboration analysis presents interesting results which are particularly inspiring to rethink the distinct inscription uses between STEM and Humanities communities. Table 14 demonstrates that no matter which domain the first author comes from, when the paper is collaborated between STEM and Humanities authors, the inscription use tends to reach a middle ground between the two fields, both in terms of the inscription number and the inscription variety. In addition, the statistics also suggest that STEM and Humanities researchers in collaboration even slightly tend to follow the common practices used among the STEM field (Table 14).

Table 14: Does Cross-Field Collaboration Affect Inscription Use among Humanities and STEM Domains?

Domain	Collaboration with each other?	Inscriptions	Inscription Variety
STEM	Non-Collab	13.29	3.39
STEM	Collab	12.62	3.12
Humanities	Collab	10.75	3.17
Humanities	Non-Collab	8	1.91

The analysis of collaboration presents a dynamic picture of the DH field and also raises new questions about the future directions of the DH field. And particularly, would collaboration change the dynamics of the DH field? How? Figure 18 visualizes the current

dynamics of DH between the STEM and Humanities research communities. It suggests a slight increase in collaboration between the two communities, although the impact of such an increasing level of collaboration would deserve further research.

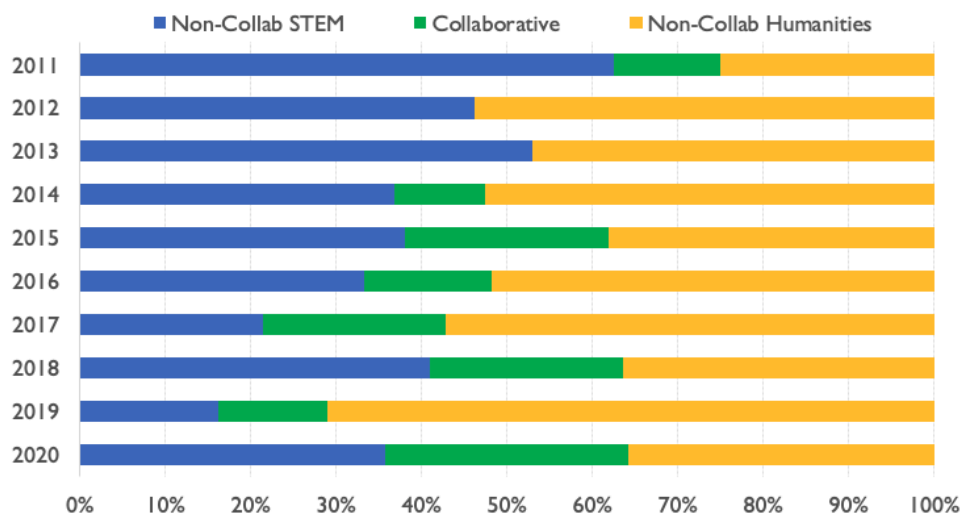


Figure 18: Collaboration between STEM and Humanities Researchers

5.1.4 Study 1.4 Inscription Use across Journals

In light of the relationship between researchers' domains and inscription use in DH publications presented above, we also aim to understand the roles of journals in DH research landscape. More specifically, for this analysis, we focused on four representative DH journals that contribute to the majority of the articles in the dataset (Table 7): *Journal on Computing and Cultural Heritage* (JCCH), *Digital Scholarship in the Humanities* (DSH), *Literary and Linguistic Computing* (LLC), and the *International Journal of Humanities and Arts Computing* (IJHAC).

Table 15 shows the summary of the mean number of inscriptions and the mean inscription variety on the paper level for the four selected journals. The results, again, show a quite strong correlation between these two measurements of inscription use in DH publications. But more importantly, the *Journal on Computing and Cultural Heritage* stands out as

the most inscription-intensive journal, both in terms of inscription number and inscription variety, among the four candidates.

Table 15: Use of Inscriptions across Journals

Journal	Inscriptions	Inscription Variety
JCCH	16.7	4.42
DSH	10.52	2.51
LLC	8.97	2.07
IJHAC	6.87	2.02
Others	7.65	2.14

Inscription use across the four journals was also evaluated in terms of inscription types. Figure 19 shows the composition of inscriptions in the four journals as well as all the other journals. JCCH stands out again for its distinct preference for inscription types: As seen from Figure 19, JCCH includes more photographic inscriptions, equations, diagrams, and simulations, many of which are indicative of an algorithmic and formalized style of research. By contrast, the use of tables and graphs are quite similar across journals.

Such differences in the use of inscriptions can also be explained by the composition of researchers from different domains in these journals. Table 16 summarizes the ratios of papers in each journal that have the first author from humanities, STEM, and other domains. The table shows that JCCH has a significantly higher ratio of STEM articles than other journals. We can observe a strong correlation between the composition of authors in each journal and its inscription use. The *Journal on Computing and Cultural Heritage* has the highest ratio of papers with STEM first authors and much heavier use of inscriptions than other journals. One exception in this general relationship is the *Digital Scholarship in the Humanities*: even though it has one of the lowest STEM paper ratios, its inscription use is more intensive than the other two journals, which can be further explained by the high portion of the cross-field collaborative papers in the journal.

Results from the journal-level analysis also suggests a clear sense of community in the digital humanities field. JCCH includes the largest portion of STEM papers (69.7%) across all the four journals, demonstrating that JCCH has become a preferred venue among STEM researchers to publish DH works. By contrast, humanities researchers, when leading a DH project, prefer other journals, especially the DSH and IJHAC. These findings suggest the variety of intellectual conventions within DH field as well as the potential, dynamic development of the field.

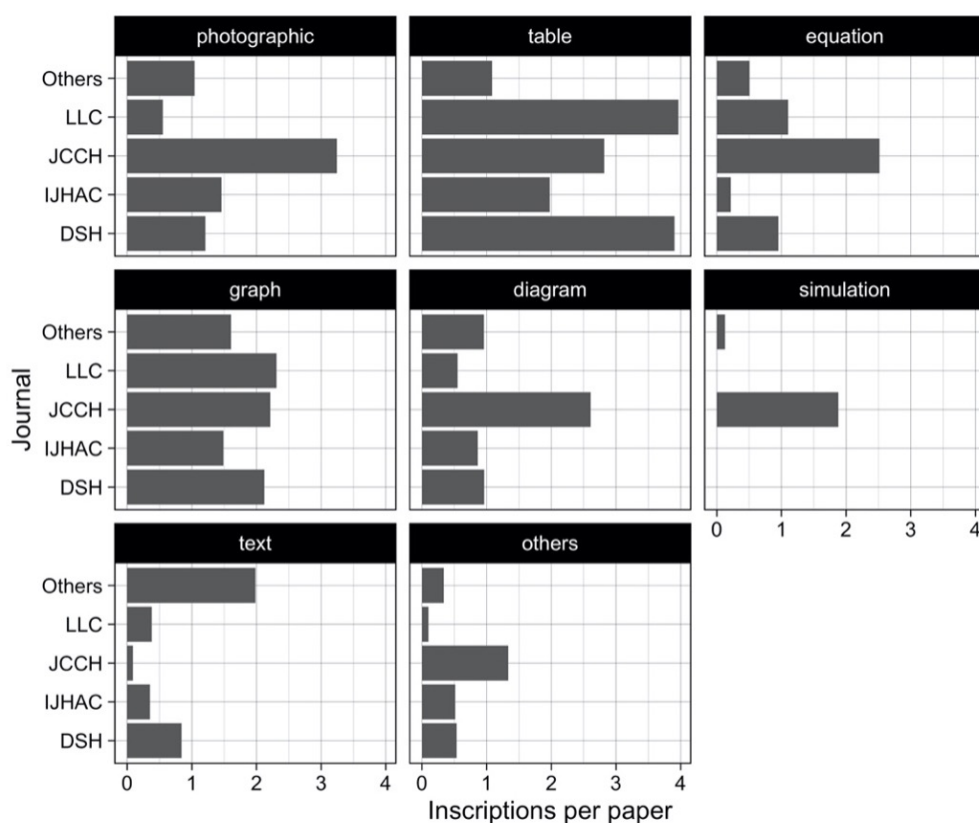


Figure 19: Inscription Types across Journals

Table 16: Paper and Author Distribution across Journals

Journal	Humanities Papers Ratio	STEM Papers Ratio	Other Papers Ratio
DSH	48.8%	30.5%	20.7%
IJHAC	40.5%	29.5%	29.7%
JCCH	15.2%	69.7%	15.2%
LLC	34.5%	44.8%	20.7%

5.1.5 Study 1.5 Narrative Functions of DH Inscriptions

This study aims to understand how various types of inscriptions facilitate narrative construction in DH articles. Through the methods of content analysis and close reading, I analyzed narrative functions of various types of inscriptions in the argumentation process with a selected sample of research articles published in the *Journal of Cultural Analytics* from 2017 to 2019. With the empirical analysis, this study presents a preliminary yet innovative examination of DH’s visual language and proposed suggestions on integrating existing functional frameworks of inscriptions from the digital humanities research context. Results presented in this study have been published in a conference paper (Ma et al., 2021).

Due to the lack of established framework and the time-consuming manual labor of qualitative manual coding and close reading, I narrowed down my focus to conduct an initial round, open analysis of the inscriptions in the dataset. More specifically, I selected 37 articles published between 2017 and 2019 as they demonstrate the most comprehensive coverage of articles in the journal, and then classified the inscriptions in them based on the working taxonomy of DH inscriptions. Table 17 shows the number of the three types of inscriptions across the dataset.

Table 17: Number of Inscriptions across *Journal of Cultural Analytics* (2017-2019)

Graph	NGI	NVI
169	54	69

The preliminary analysis of the inscriptions in selected articles suggests their essential roles in mobilizing humanities claims. A detailed analysis of the narrative functions of inscriptions in the selected corpus is presented with examples below. The observations cover aspects of data representation, rhetoric of different types of inscriptions, and the contextual verbal-visual interactions, as indicated in the Data and Methods chapter.

5.1.5.1 DH inscriptions represent both quantitative and qualitative data Creating “mathematically tractable visual and graphic displays” (Goodwin, 2000) and thus scientific meanings from raw data is one of the key functions played by scientific inscriptions. As a field that is deeply influenced by the data-driven research approach, the mathematization of quantitative data is inevitably reflected in the paper sample. For example, in Figure 20, the authors offered a series of network graphs to show how the technique of LargeVis dimensionality reduction captures different types of textual similarity and differences in the full HathiTrust collection. However, the representation of quantitative, large data is not the only form of inscription in our corpus. The *Journal of Cultural Analytics* authors also use visual representations of carefully curated, qualitative datasets to support argumentation. For example, Figure 21 is used to illustrate the claim on misrepresentation of indigenous communities in archival data held by non-Indigenous collecting institutions. The image in Figure 21 (left) shows the original untouched negative of a Piegan lodge on the *Library of Congress* website, which presents three Piikani individuals in their lodge with a clock centered between them. However, in Figure 21 (right) that audiences would have viewed in *The North American Indian*, a twenty-volume collection to record the Native and Indigenous life curated by Edward S. Curtis from 1907 to 1930, the clock was deliberately cut out from the image to “curate a desired representation of Native American peoples” that does not bear

signs of modernity or contemporary lifestyle. By introducing the original negative first and then contrasting it with the purposely curated however widely accessible image, the authors demonstrated the biased data representation in indigenous archives. As shown in previous studies, data-oriented visualizations are more frequently used in research fields that are more *scientific* (Arsenault et al., 2006; Coopmans, 2014; Smith et al., 2000). Similarly, it should be expected that DH as a research field is more strongly reliant on qualitative visualizations than most, if not all, research fields in sciences. This mixture of qualitative and quantitative visualizations is further supported by the diversity of research topics and methods adopted within the DH community (Porsdam, 2013).

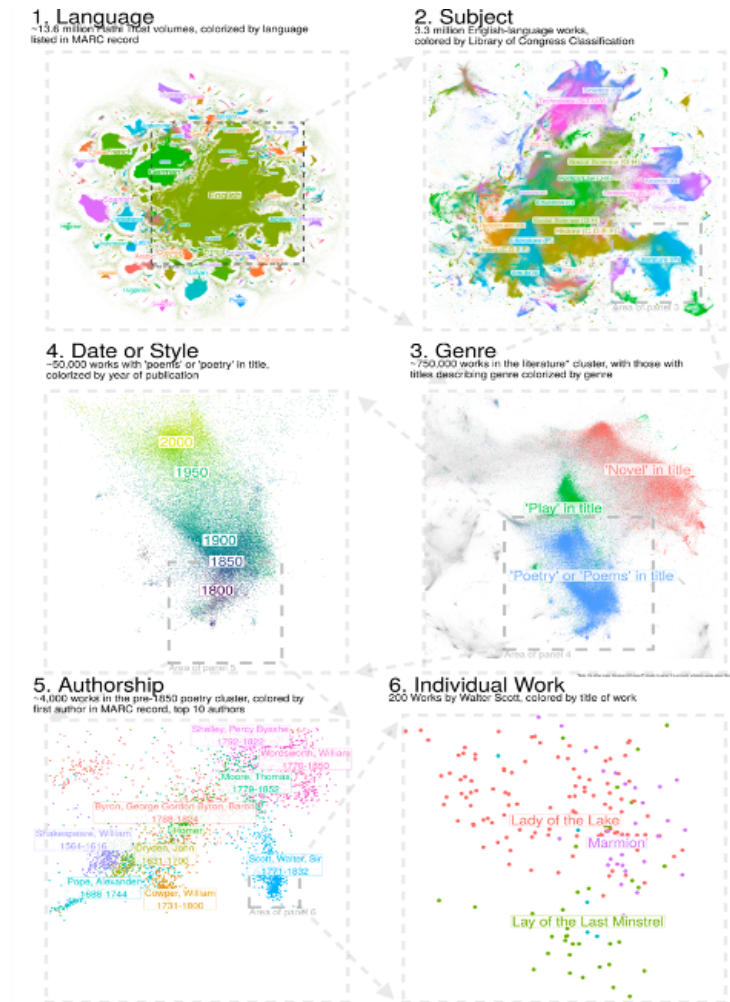


Figure 20: Six Successive Zoom Levels of a Single LargeVis Dimensionality Reduction (Schmidt, 2018).



Figure 21: (Left) Untouched Negative of an Image of Three Piikani Individuals in their Lodge with a Clock Centered between them. (Right) Retouched Image of Three Piikani Individuals in their Lodge without a Clock (Guiliano & Heitman, 2019).

5.1.5.2 Realism of photographic representations strengthens arguments A Latourian conceptualization defines photographs as the representation of the original forms of social phenomena in the simplification process (Arsenault et al., 2006; M. Lynch & Woolgar, 1990b). Lynch (1990) argued that the “split-screen juxtaposition of photographs, diagrams, and models, each of which represent the same thing” enables the discussion of the scientific simplification process. In the selected dataset, photographic representations are heavily used; the repetitive, accumulative use of photographic representations and the juxtaposition of them convince readers of the actual existence of a phenomenon. For example, in Figure 22, the book covers were selected and combined by the authors to demonstrate their claim that “the pleasure of reading is, for girls, the act of reading itself, absorption, time alone and in one’s own head, be it indoors, by the seashore, or even among the leafy boughs of a tree.” This form of visualization is similar to what Manovich (2011) defined as the “direct visualization”. By only piecing together a selected number of original images of the collection, two important lessons can be drawn from Figure 22. First, similar to scientific articles, DH scholarship also requires the juxtaposition of visual evidence, especially the comparison and contrasting between them, to create new meanings and knowledge. Second, due to the char-

acteristics of humanistic research, photographic realism can contribute to the construction of arguments in DH publications in a more direct way.



Figure 22: Selected 19th century Book Covers Supporting a Gendered Reading (Tatlock et al., 2018).

5.1.5.3 Graphs demonstrate analytical procedures and inspire alternative interpretations Graphs are defined as figures that have scales and convey abstracted quantitative information (Arsenault et al., 2006). The analysis of this study demonstrated the use of graphs in the corpus to facilitate analytical procedures and inspire possible alternative interpretations, instead of solidifying and reinforcing one final conclusion. In an article examining the early modern discourse of race in Shakespeare's *Othello*, the authors imple-

tional methods for the automatic extraction of semantic elements such as facial recognition and shot breaks in movies, the authors used a massive number of visualizations to demonstrate the superior performance of their methods compared with other techniques (see Figure 24a). In Figure 24a, the authors used scenes from two sitcoms, *Bewitched* (1964-1972) and *I Dream of Jeannie* (1965-1970), to demonstrate the advantages of convolutional neural networks (CNN) in accurately detecting faces from the shots to the popular, shaped-based histogram of oriented gradients (HOG) detector technique. After justifying the methodology with a visual example, the authors followed up with a line graph showing the face recognition testing results for the accurate detection of primary characters in the sitcoms (see Figure 24b). The visually assisted justification of the methodology laid a solid foundation for applying the method to the discovery of visual styles in the two sitcoms in the second part of the article.

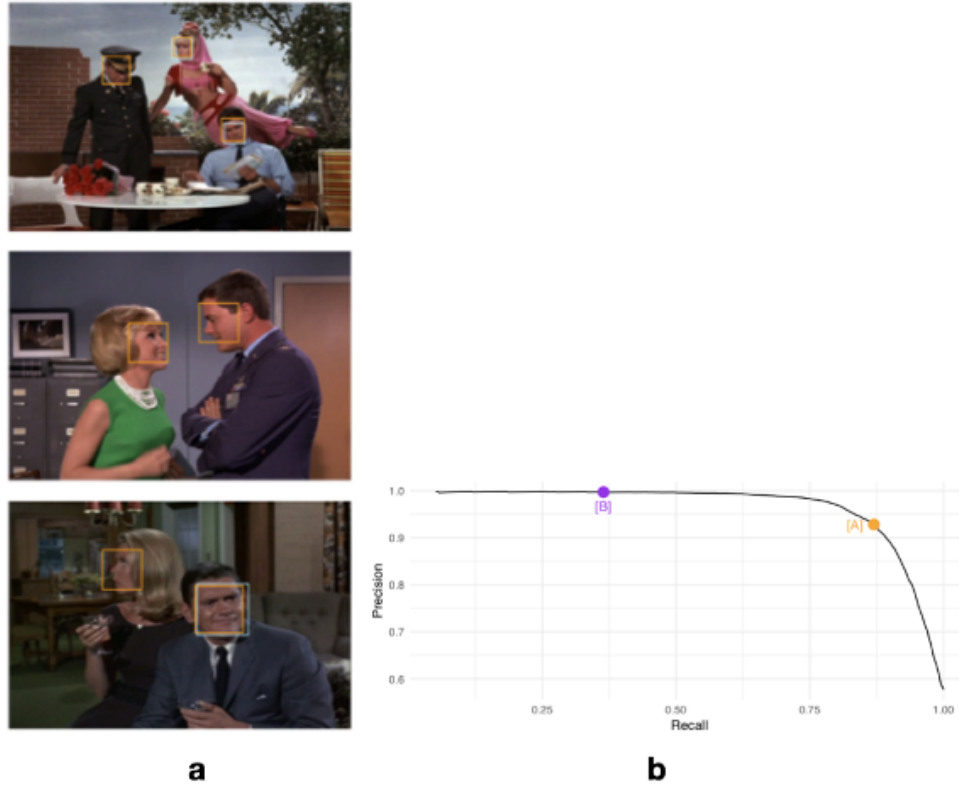


Figure 24: Inscriptions Used to Validate New Methods. (a) Faces Detected Using a HOG Detector (Blue) and a Neural Network (Orange) from Screenshots of *I Dream of Jeannie* and *Bewitched*. (b) Precision and Recall Curve for Varying Cut-off Scores in the Algorithm (Arnold et al., 2019).

5.1.6 Summary of the Results

In Study 1, I addressed five research questions that focused on both the macro- and micro- level perspectives and presented multiple findings. The working taxonomy of DH inscriptions, which addressed RQ 1.1, set a foundation for the analysis of overall inscription use in journal articles. Building on the classification and the 11 identified categories, Study 1.5 offered a micro-level analysis of the narrative functions of different types of inscriptions used in DH scholarship, identifying four major functions based on a smaller publication corpus within the dataset for Study 1. Among the four identified narrative functions, the use

of graphs to demonstrate the process of interpretation in DH work highlighted the potential uniqueness of the narrative functions of DH inscriptions compared with those applied to other contexts. Extending from the micro-level analysis, I also provided a quantitative, macro-level overview of inscription use across various aspects, including time, research community, and journal. The examination of these various perspectives demonstrated the DH field is adopting more data-driven and formalized approaches and methods, with the increasing applications of graphs and equations over the years. Certain research communities, especially STEM and Humanities researchers, are the major workforce that have been driving this change, with their distinct preferences for inscription use and their practices in publishing different DH journals. A preliminary examination of the co-authorship practices between the two communities also suggested that collaboration can be a factor that affects the future development of the DH field, which deserves further investigation and discussion. Examination of Study 2 further builds on the results from this study, exploring how DH researchers and practitioners evaluate inscriptions – and more broadly, visualizations – in their research processes, how they choose specific forms of visualizations and inscriptions, and the major challenges and barriers they have encountered during the process.

5.2 Study 2 - Inscription Practices in Digital Humanities Research

As illustrated previously, Study 2 focuses on the *practice* aspect of the Latourian framework, which aims to explore how inscriptions and inscription devices are applied in the everyday, real DH research practices and process. Inspired by the ethnographic methods discussed by Latour (1987) in *Science in Action*, this study used the semi-structured interview method and conducted in-depth, practice-oriented virtual interviews with 16 recruited digital humanists from various knowledge domains on a set of questions related to their inscription practices and perceptions. The following sections present the findings of this study and answer research questions of RQ 2.1, RQ 2.2, and RQ 2.3. Due to the practical limitations related to the COVID-19 pandemic, the findings of this study remain exploratory and demonstrates the potential for multiple directions of future research. Part of the results

presented below have been published in 2021 and edited based on the published work (Ma & Xiao, 2021).

5.2.1 What Is A Good Visualization for Digital Humanities Research?

This section reports the findings for RQ 2.1, which questions the criteria for visualization and inscription practices among digital humanists ². The results demonstrate that DH researchers have developed diverse standards and criteria to evaluate the quality of visualization. Among the answers obtained, **information clarity** and the capacity of a visualization to effectively communicate the embodied ideas are the most important criteria among participants (n=6). In addition, some participants (n=3) emphasized that **simple visual forms** are critical to them. A quality visualization, according to them, should bear simple visual forms to facilitate both the clear communication of the claims as an author and a straightforward interpretation of the visualization as a reader (P1, P2, P6, P9). P13 also emphasized the evaluation of a quality visualization from a reader's perspective, illustrating that "visualizations serve as a table of content or an index; [and therefore], the load and readability of information matters."

This idea of information clarity and efficiency is closely related to visualization types. For example, P2, who works with topic modeling of text, emphasized that clear labeling of information categories and a clear representation of clusters and topics in a topic modeling graph are very important elements to construct a quality visualization for his research. P9, who works on visualizing cultural heritage in the forms of photographic images and digital simulations, on the other hand, demonstrated that image quality and high-fidelity representation of original objects are key factors to define good visualizations in his work.

In addition to the ability to present clear and simple communication of data and arguments, another important value of inscriptions, as supported by a few participants (P2, P4, P15, P16), is the capacity of highlighting characteristics of reflexivity and uncertainty in humanities research. According to P16, a good DH visualization is one that "inspires."

²The results presented below are edited based on a published conference paper: Ma, R., & Xiao, F. (2021). What is a good visualization for digital humanities researchers? An exploratory study. *Proceedings of the Annual Meeting of the Association for Information Science & Technology* 58 (1).

It is important for a visualization to be able to represent the narrative, interpret the data, and raise new thoughts, ideas, and questions. Visual representations are also not something that is objective and affirmative, but rather, subjective, interpretative, and saturated with claims and arguments; and therefore, every decision made related to the visualization, ranging from what data to include, the scale, color, and even labelling and legends, is an action of interpretation.

When asked about their criteria for a good visualization in their research, a few participants ($n=3$) did not provide a clear answer but rather demonstrated that “it is something that depends.” P3, a curator currently working in a museum, emphasized that visualization “should fit the purposes of research questions and be created with the most suitable tools to satisfy research goals.” P8, a PhD candidate in history, indicated that the most valuable visualization attribute to her is its ability to “clearly present arguments.” Besides the effectiveness of addressing research questions, P7 also demonstrated that a good visualization needs to have “a high level of manipulation and flexibility” so that users can customize how complex they want the visualization to be based on their research needs.

However, most of the participants who valued information clarity the most in a visualization tend not to appreciate visual aesthetics. For example, as indicated by P1, “as long as the visualization shows clear information, visual elements such as the color do not matter that much to me.” Only three participants acknowledged the importance of visual aesthetics and design in a visualization. An information designer with academic training in both East Asian humanities and biophysics, P4 emphasized the importance of using effective “visual metaphors,” in which data are manipulated and represented in a way that best expresses the ideas they aim to embody. One vivid example that P4 gave was to visualize non-linear, complicated narrative structures of movies. Visualizations, in this context, should be designed as an effective and powerful **rhetorical device** to visually inspire and express the narratives of the research objects. From another aspect, P7 also claimed that he would make the visualization pretty towards the end of the research, naming the aesthetic values as “the point of having a visualization, rather than a table or a list.”

The results demonstrate the variety and variance of criteria for a quality visualization among digital humanists. These findings also raise new questions. For instance, from a

comparative perspective, how do the perceptions of quality visualization among digital humanists differ from other research communities? Are there differences even differ within digital humanists, depending on their research domains and skills? What factors account for the variety and variance of DH visualization perceptions and criteria? Due to the relatively small data size of this exploratory study, I have not reached conclusions about these questions. However, preliminary analysis demonstrates that criteria and perceptions of a quality DH visualization are correlated with scholars' research purposes as well as their visual knowledge and skills. This correlation and other implications of this study are discussed more thoroughly in Chapter 6.

5.2.2 Underlying Purposes of Inscription and Visualization Practices

To address RQ 2.2, I asked participants to elaborate their purposes of using inscriptions and visualizations with a specific DH project they worked on and demonstrate how inscriptions help them tackle their distinctive research questions. Participants reported various purposes of using visualization in their research. Two most commonly identified visualization purposes include: (1) describe data (P6, P9) and present research findings to make them easier for understanding (P1, P2, P7), and (2) support DH analysis.

5.2.2.1 Describe Data and Present Results P1 claimed that visualizations can better show results and conclusions about data, making it more clear and easier for readers to understand compared with texts and tables. P1 also indicated that visualization works the best for addressing questions related to change, while P5 demonstrated visualization is instrumental for him to answer pattern-oriented questions. P6, a Japanese linguistics doctoral student, and P7, a South Asian religion scholar, also support this claim that inscriptions and visualizations aim to describe data and demonstrate the information. The use of simple forms as well as the information clarity represented in the inscriptions are therefore important elements in a visual representation.

Another related interesting finding revealed the unique nature of humanities data presentation with inscriptions. P3, an art historian working at a museum, worked on a project

that aimed to identify pictorial representations of daggers in the Mughal empire and associated them together to locate their places and specific times, before formulating clusters of the visual representations based on families, times, and regions. This use of visual representations and inscriptions in this project corresponds to what Manovich (2011) defined as “direct visualization” that focuses on creating visualizations with original humanities data without any *reduction*. P13, an information scientist researching digital cultural heritage, also demonstrated their use of original artifacts and objects as base materials to create visual representations and results presentation.

5.2.2.2 Support Analysis and Interpretation Compared with simply describing data and presenting results, visualization and inscriptions are also applied in a more complex manner to support humanistic analyses and inquiries. P2 demonstrated in the interview that he treated visualization as an analytic tool, stating that “in the stage of analysis, visualization can show me some information that I did not realize at the beginning and can help me dive deeper into the data analysis.” With the Latent Dirichlet Allocation (LDA) topic modelling method, P2 discovered new issues and confirmed former assumptions with distant reading methods.

Participants also highlighted that visualization is particularly assistive to certain types of research questions in their fields. P4, an information scientist having an interdisciplinary academic background, demonstrated that visualization is particularly beneficial for “investigative research questions,” offering “another way of seeing data and documenting the investigation process of a question.” Using a case study where he collaborated with a film study researcher to create a visual narrative and guideline of a classic movie, P4 also illustrated that visualization can be extremely useful if it is “engaged with a philosophic way. ... visualizations also function as a way of documenting the investigation process of a question that does not have a precise end goal or end response.”

Extending from visualizing textual data, other studies have also emphasized the power of visualization in DH analysis. P12, an information science researcher working at a DH lab, explored how to apply interactive visual representations, particularly knowledge graphs, to facilitate both the “close” and “distant” reading of classical Chinese corpus. As demonstrated

in the following figures, various types of visualizations and inscriptions present different ways of exploration of the corpus in the interface. Application of visualizations and inscriptions to support interpretation and exploration of humanities questions and subjects has also been emphasized by P16 in the interview. Leading a highly interdisciplinary team with many researchers representing different knowledge backgrounds, skills, and various levels of academic experience, P16 claimed that visualizations are important to highlight the interpretive and reflexive nature of humanities research, and therefore, visual representations and inscriptions should also embody the characteristics of humanistic inquiries.

5.2.3 Barriers and Challenges for Working with DH Visualizations

As inscription practices and use are an emerging area in digital humanities scholarship, there exist various challenges and barriers for different research communities to practice and apply inscriptions and visualizations. In this section, I address RQ 2.3 and explore the major challenges identified based on 16 semi-structured interviews. The results suggest that digital humanists face challenges in three major aspects: the ability to handle and process data, challenges to build and develop infrastructures and tools, and barriers encountered related to teamwork and research collaboration. With the identified barriers and challenges, future research can benefit from the findings, particularly the works that inform the best practices of digital humanities and information studies.

5.2.3.1 Data Issues Due to the fact that many digital humanists work with archival data of various forms (e.g., text, historical images, maps), it is very “time-consuming” to collect, organize, and transform the collected data into machine-readable data formats (P1, P5). For example, P1, a doctoral student in history, discussed the challenges to input data properly into digital tools and applications, especially during the process to load historical maps into geo-spatial analysis software and “choose the most effective visualization methods for social network analysis.” As her research involves historical GIS, the first challenge she encountered was to collect and then input the historical maps into ArcGIS and use it as the basis for further analysis. In addition, as the relevant archival data may present a

wide range of data on various subject matters and in multiple forms, P2 found it difficult to transform selected information into the formats (e.g., numeric data, network data) that fit the best with chosen digital tools (e.g., tools for network analysis). For researchers working with multilingual DH, e.g., Chinese DH projects, one major challenge exists in data cleaning, which is to work with non-English texts using current programming applications (e.g., Python). Special packages are usually required to process Asian-language texts in the programming tools (P2).

P5, who worked as a master's student in theatre and an intern for a DH project at the time of the interview, discussed another data challenge. She demonstrated that due to the oftentimes "fragmented nature of humanities materials" she was working with, many data that can be used for analysis were not complete. And therefore, to construct a digital analysis and visualization (e.g., line graph to demonstrate trends, timeline-based visualization) based on the fragmented information has been challenging and involved enormous efforts in data manipulation and organization.

In terms of data presentation and visualization, scholars have also encountered certain challenges. P1 discussed how unwilling she is to utilize "old-fashioned graphs, such as simple pie charts" to visualize and present analyses in her work. She told the author that, in her view, the purpose of digital analysis and visualization is to enhance the original humanities analysis and should be used in a manner that texts and tables cannot easily fulfill. In addition, with another DH project that focused on digital cultural heritage, P9 discussed the copyright issues involved in digitalizing photographs, artifacts, and many other relevant objects in the project. In order to reuse the original materials in the digital environment, either in the form of visualization or reprint, copyright is an enduring issue that needs to be addressed.

5.2.3.2 Infrastructures and Tools Participants have also identified challenges and barriers related to infrastructure building and tool development. P3, who is an art historian working at a museum for over 10 years, demonstrated during the interview that because he works extensively with images in databases, the inefficient indexing of the visual materials has created problems for him to work on the projects. Scholars have also reported challenges

in working with digital applications and tools, including the limited functions and features of open-access, online applications to create data visualizations suitable for their research needs (P5), the costly nature of the extant data analysis and visualization software (P5, P6), and the difficulty in harnessing and modifying the available programming tools and codes (P6). Such challenges, especially those related to the usability of data analysis and visualization tools, are also emphasized by P12 from a developer's perspective. As an information scientist, P12 has been working on digital cultural heritage projects by designing and developing tools that facilitate users' interaction with digital artifacts (e.g., immovable heritage such as temples and architecture). However, as she demonstrated in the interview, the actual usability of such tools and applications among humanities scholars has remained unclear and it has become one of their major obstacles to improving such tools for better and wider use. To further push forward their work to design visual applications and technologies for digital cultural heritage, one of the primary tasks would be to identify the visual preferences and research needs among humanities researchers, who are the main users for their products.

In addition to the technical side of the infrastructural development, another major challenge faced by digital humanists focuses on the social dimension. More specifically, as reported by multiple participants, the lack of funding, staff, and institutional support is one limitation. For instance, P3 demonstrated that his DH project would benefit from access to certain databases and software as well as paid staff members assisting with the project. Similar to P3, most of the participants I interviewed work on independent DH projects, and therefore, to acquire sufficient infrastructural and institutional support is one big issue that matters for the success of their DH projects. Such issues of funding and institutional constraint are also acknowledged and discussed in research literature (Gold & Klein, 2019; Gold, 2012; Martin & Runyon, 2016).

5.2.3.3 Team, Collaboration, and Research Closely related to the social aspect of infrastructural challenges, collaboration, communication, and team work have also been an important barrier for digital humanists to engage in DH work. Three types of challenges exist: perceptions and willingness to collaborate, skill- or knowledge-related barriers, and communication.

Some participants proved to be solo researchers (e.g., P1, P2, P6). When asked if they would be willing to seek collaboration on DH project, P1 responded that she would “prefer to do independently.” Collaboration with researchers from the humanities and social sciences would be an option if she failed to work on it independently. But P1 also demonstrated that seeking collaboration and assistance from libraries would also be an option. Similar to P1, humanities researchers such as P2 and P6 also value the solo efforts of engaging with DH research. This finding points to potentially interesting association between the preference for collaboration and the researchers’ home discipline and its academic research conventions. Although the current data size cannot support the generalization of such a result, it seems that junior DH researchers who come from a humanities field have a stronger tendency to engage with DH projects in an independent manner, compared with digital humanists from other communities and knowledge domains.

By contrast, for some other DH researchers, collaboration has been a natural choice, especially among scholars working on topics and domains related to digital cultural heritage and information science. For example, P12, a master’s student in information science working at a DH research lab, demonstrated a collaborative project she has been working on that consists of teams of programmers, researchers in the humanities, interface designers and product managers. Working as the product manager and also responsible for creating information visualizations for the interactive DH interface, P12 demonstrated that collaboration made it possible to gather experts’ feedback on the visualizations, conduct usability testing among various groups of users, and create the best possible visual representations of the corpus (i.e., a classic Chinese philosophy text from Ming-Qing period) based on the discussion and feedback.

For digital humanists working in a collaborative environment, choosing the suitable collaborators that can bridge the gap in skills or knowledge is an important task. P5 demonstrated that the main motive for her to seek collaboration was to “have support from a technical side,” particularly to seek support on “customized visualization based on her research needs.” Other participants have also reported that the main purpose of soliciting collaboration is to learn from researchers with various expertise, skillsets, and knowledge (P4, P6, P8, P13).

In addition, another major obstacle to collaboration among digital humanists of various domains is communication. P8 demonstrated that “it is good to collaborate, because we can all apply to their own skills and learn from the others, but communication could be time-consuming. For example, knowing the terminologies and vocabularies in others’ fields can be challenging. I would benefit from collaborating with professionals in information science and data science, but it requires learning their languages and certain knowledge to have a smooth collaboration rapport.” P16, who is leading an interdisciplinary DH team including historians, information scientists, and students of various disciplines, also identified in-depth communication and a shared vocabulary for communication as the key factors to a successful collaboration, however a hard one to achieve. Therefore, creating a mutual understanding among digital humanists of various backgrounds would be a central task to address collaboration challenges in DH research processes. And this would be the major path to reach a “true and equal collaboration” as expected by many researchers (e.g., P4; Flanders, 2012a; Edmond, 2016).

5.2.4 Summary of the Results

Based on semi-structured interviews with 16 participants, findings of Study 2 illustrated *visualization practices* among digital humanists from three major perspectives: researchers’ and practitioners’ perceptions of quality visualizations, the underlying purposes of using inscriptions and visualizations in research processes, and the barriers and challenges digital humanists have encountered working with visualizations.

My analysis demonstrated that digital humanists have developed various criteria, principles, and perceptions for high-quality visualizations, and their criteria tend to vary according to researchers’ purposes of using visualizations, their research tasks and questions, as well as their self-assessment of visual knowledge and visualization skills. As suggested by multiple specific cases and examples collected during the semi-structured interviews, DH researchers who perceive to have more advanced visualization knowledge and skills tend to use more complex visualizations in their research while taking into account more complex visual components in the design of the visualizations (e.g., visual metaphor). Additionally,

DH researchers and practitioners who treat visualization as a method of interpretation and the investigation of research tend to be more concerned with issues related to uncertainty, reflexivity, and complexity, when designing and applying visualizations in their research. Finally, Study 2 also identified multiple barriers and challenges that digital humanists have come across working with visualizations. More specifically, I identified challenges from the perspectives of data, infrastructure, and research environment. From the perspective of data, researchers are faced with the difficulty of processing data, various challenges to transform data into corresponding and effective visualizations, and concerns related to copyright and data reuse. In addition, how to choose the best visualization tools and software and how to acquire infrastructural support, funding, and staffing have been concerning a few researchers. Finally, the social aspect of research, especially the collaborative aspect of DH research, also posed challenges for digital humanists. Among them, the willingness to collaboration, finding the best collaborators according to knowledge and skill sets, as well as communication, are major factors and barriers that impact the effectiveness of collaboration in DH research.

Findings of Study 2 further complement results from Study 1, discovering behind-the-scene practices and decision-making processes related to visualization in DH research. In the following chapters, I discuss the implications for these results, particularly for research areas and scholarships in DH, visualization, science and technology studies, and library and information science.

6.0 Discussion

The findings of this dissertation have implications for current research in DH, visualization, science and technology studies, and library and information science. In addition, the findings also have implications for setting up the agenda for future work. In this chapter, I discuss the variety of implications for each finding and research question, before proceeding to identify multiple directions for future work.

6.1 Implications of Study 1

The proposal of the working taxonomy of DH inscriptions and the quantitative examination of the inscription use in DH journal articles have implications to understand the overall status of DH and the unique functions of inscriptions in scholarly communication. As discussed in more detail in the following sections, inscriptions provide a lens to demonstrate how digital humanists of various communities work with inscriptions, sometimes with various preferences. In addition, by illustrating the unique narrative functions of inscriptions, this study also suggests different perspectives to examine various purposes and values of using inscriptions in humanities knowledge creation and communication.¹

6.1.1 Inscriptions Use in DH Publications

In Study 1, we expanded and modified an established classification scheme of scientific inscriptions by Arsenault et al. (2006) to include inscription categories meaningful to DH research. Focusing on inscription categories that are emerging (e.g., simulations) or specific to DH (e.g., codes and texts), we were able to construct a DH-focused working taxonomy

¹Sections of 6.1.1, 6.1.2, and 6.1.3 are edited based on my published article with a collaborator: Ma, R., & Li, K. (2022). Visuality in a cross-disciplinary battleground: Analysis of inscriptions in digital humanities journal publications. *Journal of the Association for Information Science and Technology* 73 (2). Additionally, sections of 6.1.4 are edited based on a published conference paper: Ma, R., Li, K., & He, D. (2021). Understanding the Narrative Functions of Visualization in Digital Humanities Publications: A Case Study of the *Journal of Cultural Analytics*. *iConference 2021 Proceedings*.

of inscriptions that can effectively represent inscription use in the latest DH scholarship. This working taxonomy contributes to scholarship of knowledge organization for an under-researched digital humanities context and has the potential to inform future studies on this topic.

Based on the extended classification scheme, we investigated how all the inscriptions in the dataset have been used over time. A slightly increasing trend was found in terms of both the total number of inscriptions and inscription variety in DH publications, showing strong evidence of the growing importance of inscriptions in DH scholarship over the past decade. Particularly, on the level of individual inscription categories, we found an increase in use among all inscription categories in the data sample, except for texts. Equation is the most increasingly used inscription type over the past decade, followed by diagrams and graphs. As the three increasingly used inscription types are highly associated with computational and mathematical research methods, especially the graphs – which is the focus of the *graphism* thesis illustrated and tested by Latour (1990) and scholars in science and technology studies, the findings of this study suggest the DH field has gradually adopted a scientific research paradigm rather than heavily relied on the traditional textual representation of knowledge, showing a divergence from the argument that “digital humanities is text-heavy, visualization light, and simulation poor” (Champion, 2016).

6.1.2 How Are Inscriptions Used Differently by Humanities and STEM Researchers?

Despite the increasing collaborations between the humanities and STEM researchers (Benito-Santos, 2020; Jänicke, 2016), no research has explored the impacts of such collaborations on shaping DH as a field of research and practice, especially in terms of using inscriptions as a collaboration index in examination.

Results of this study show that STEM researchers use the greatest number of inscriptions per paper and demonstrate the highest degree of inscription variety when they are the first author of the papers, as compared with researchers from other domains. In comparison, papers with the first author from humanities, social sciences, and DH-focused institutions all

have very similar statistics regarding inscription use. This supports the thesis that inscription usage is positively connected to how scientific a field is, as validated in previous empirical studies (Cleveland, 1984; Smith et al., 2000). In terms of the inscription types, a general correlation was found between the first author domain and the inscription types that are more strongly connected to sciences from the previous research question. For example, STEM researchers have the highest uses of equations, diagrams, and graphs among researchers from all domains, whereas the text is more frequently used by researchers from humanities and non-academic institutions.

Despite the different inscription preferences between humanities and STEM researchers, the findings demonstrate that inscriptions serve as an anchor for collaboration through which researchers of various domains become more familiar with each other’s mindsets. Table 14 illustrates that when humanities researchers seek collaborations from STEM authors, the use of inscriptions in their papers increases both in terms of the number of uses and the variety of inscriptions. By contrast, when STEM authors seek collaboration from humanities researchers, they tend to use fewer inscriptions and less complex inscriptions. This means that although both the humanities and the STEM researchers tend to use inscriptions distinctly when working alone, a collaboration between them reconciles the differences. Scholars tend to accommodate each other’s research conventions and find the middle point to achieve the best collaboration results. From this process, humanities researchers become more generally familiar with inscription types popular in sciences, such as equations, graphs, and diagrams, the three types of inscriptions found to be more increasingly used in our data sample. This is an interesting finding that sheds light on the cross-disciplinary collaboration dynamics in DH, which has not been investigated by theory-driven research.

6.1.3 DH Journals as Distinct Epistemic Research Communities

One question that has emerged from the previous analysis is: Despite the distinct preferences for inscription use among STEM and Humanities research communities, is the difference big enough to push researchers into different “intellectual camps” and inspire them to choose different research outlets? Results from the journal analysis demonstrate a clear

sense of community in DH in terms of inscription use. Different research communities, especially the STEM and humanities researchers, prefer different forms of visual communications and publication venues; and such preferences have shaped distinct epistemic cultures around journals. *Journal on Computing and Cultural Heritage* (JCCH) is a journal in which STEM researchers prefer to publish and embraces highly collaborative DH works. In terms of the inscriptions, JCCH demonstrates the most significant number of inscriptions on average and the highest level of inscription variety among all the journals being examined. The use of photographic images, diagrams, simulations, and equations exceeds all the other journals; but text, by contrast, is not a preferred inscription type in JCCH. Such a distinct use of inscriptions and domain composition in JCCH can be explained by the epistemic positioning of this journal. Launched in 2008, JCCH publishes work on the “use of information and communication technologies (ICTs) in support of Cultural Heritage.” Compared with the other three journals, JCCH has a particular focus on digital cultural heritage and a stronger technological emphasis.

Humanities researchers, in comparison, prefer to publish in more comprehensive DH journals such as *Digital Scholarship in the Humanities* (DSH) and the *International Journal of Humanities and Arts Computing* (IJHAC), which originated from a humanities discipline, embrace humanities research traditions, and cover all aspects of computing and information technology applied to arts and humanities research (Edinburgh University Press, n.d.). They also tend to use fewer and less variety of inscriptions – mostly the tables and graphs – and appear to prefer working with smaller teams (in this case, the average author number for each published paper in these two journals remains around two). The journal analysis empirically reflects two major communities of practice between STEM and humanities researchers with regard to their use preferences for inscriptions.

6.1.4 How Unique are the Narrative Functions of DH Inscriptions?

The exploratory study on DH inscriptions’ narrative functions identified four major observations based on empirical, qualitative analysis of inscription use in a representative DH journal. The findings demonstrate an overlap between the narrative functions of DH inscrip-

tions and those of inscriptions in other general contexts, such as a natural science research context or a business context. For instance, it is widely observable that a number of contexts use inscriptions to represent both qualitative and quantitative data, despite the fact that researchers may have distinct preferences across the contexts. In addition, inscriptions in multiple quantitative science research, especially graphs, tend to be used to present data trends, demonstrate quantitative analysis results, or justify effectiveness and superiority of the chosen research methods and techniques. Finally, inscription and knowledge representation research in science and technology studies has demonstrated that photographic images possess the ability to justify reality, and therefore, strengthen the credibility of the claims and arguments made in research outputs (Dimopoulos et al., 2003; Rudwick, 1976).

Faced with the shared narrative functions, what are potentially the unique narrative functions for inscriptions in DH? The case study on applying graphs to demonstrate the interpretation process of research, as illustrated in detail in the results of Study 1.5, showcases one of the *unique* narrative functions of DH inscriptions, which is to support exploration, rather than conclusion, in DH research. As illustrated in Figure 23, the purpose of using various topic model graphs in this case was not to reach one particular conclusion about the art of *Othello*, but rather, to demonstrate a process in which Shakespeare’s play can be *explored and interpreted from multiple perspectives* throughout the narrative of the article.

This narrative function is potentially unique to digital humanities scholarship as it corresponds to the nature of a *humanistic inquiry*. Among the numerous definitions of humanistic inquiry, one interesting metaphor stands out as aptly capturing the unique characteristics of a humanistic inquiry, which is the *sandcastling metaphor*. Hinrichs et al. (2019) applied the interdisciplinary knowledge of “critical theory, DH, design, human-computer interaction, and visualization” and raised the notion of sandcastling to rethink the roles of visualization in the humanities scholarship “as a mindset, methodology, and praxis.” Sandcastling is a suitable metaphor to describe the process of visualizing humanities knowledge, because it “incites play and creativity. ... encourages deconstruction, as well as reconstruction... It also allows different scales, multiple perspectives, collaboration, and participation” (Hinrichs et al., 2019). Corresponding to this demonstration, visualization, or alternatively, the process of inscribing for the humanities, is a constant, fluctuating process filled with flexibility,

change, and uncertainty, as captured by the sandcastling metaphor. The narrative function, supported by the case examining Shakespeare's *Othello*, fleshes out and vividly illustrates the connotations of sandcastling.

In addition to the uniqueness of DH inscriptions, the findings of this study also contribute to the broader scholarship of data visual literacy. Börner et al.'s (2019) recent framework on data visualization literacy used the term "insight needs" to refer to the basic task types behind the visualizations, and identified "categorize or cluster; order, rank, sort; distributions; comparisons; trends; geospatial; compositions; correlations or relationships" as the major purposes of visualization. The identified narrative functions of visualization in our corpus are found to be partially aligned with the "insight needs" in Börner et al.'s (2019) framework. Graphs are of prevalent use to visualize large-scale cultural datasets to demonstrate data trends and relationships between variables, facilitating a "distant reading" (Moretti, 2013) of culture (Figure 20). I also frequently found visualizations utilizing clusters to present literary topics, word associations, or corpora's themes (Figure 23). Comparison is also a task frequently fulfilled with visualizations in the corpus of my study (Figure 21).

Despite the shared characteristics in visualization tasks, the analysis of this study suggests how it can be useful and informative to also connect the specific tasks and purposes behind a visualization to the knowledge claims it tries to facilitate. A DH-centric visualization framework should look beyond the individual visual form and examine the use of a visualization in its context, from a visual rhetoric perspective; for instance, how the visualizations are embedded in the narrative, and how they are positioned to support argumentation. This is essentially what an examination of the narrative functions of DH inscriptions aims to achieve. From this perspective, two additional purposes were identified from this perspective: 1) accumulating evidence (repetition). As shown in Figure 22, individual book covers were positioned into a single visualization to persuade readers of the actual existence of the gendered reading phenomenon. 2) Justifying the method. Figure 24 is a typical example where the inscriptions demonstrate the unique privileges of the proposed methods of a study. These two visualization tasks can be related to the intrinsic characteristics of *capta* or domain inquiries represented in the humanities research.

Despite the informative findings, I also recognize the limitations of this study. Due to the

lack of an established analytical framework, the labor-intensive manual coding process, and the subjectivity of narrative functions, it is hard to expand and generalize the preliminary findings of the explanatory study to larger datasets. Therefore, this study on the narrative functions of DH inscriptions remains exploratory and the findings can be used as a starting point for future work; however, they are not exhaustive enough to demonstrate a complete examination of all the inscriptions used in the digital humanities scholarship. In my future work, I will aim to extend the findings and explore the identified narrative functions on larger datasets, so as to establish a framework to analyze narrative functions of DH inscriptions.

6.2 Implications of Study 2

Study 2 examines *visualization practices* in DH research processes with semi-structured interviews with 16 digital humanists. Findings from the interviews provide answers to the three raised questions, creating implications for new directions to explore these questions or future research. In the following section, I contextualize and discuss the findings within the research literature and explore further research opportunities.

6.2.1 Criteria and Perceptions for Good Visualizations

What factors explain the variety and variance of DH visualization criteria? The results reported earlier demonstrate interesting relationships between DH researchers' criteria for what they perceive as good visualizations and *their purposes of using visualization* as well as their *levels of confidence in visual literacy*. On one hand, researchers who only intend to use visualizations for data description and results presentation seem to solely emphasize information clarity and simple visual forms. By contrast, researchers who use visualization as an argument-based analytic and interpretation tool tend to value more about the design aspects of visualization. The findings imply that functions of visualization in DH are perceived differently across DH researchers, and the evaluation criteria for DH visualization

might vary based on distinct expectations and perceptions. Some uses of DH visualization demonstrate to follow the same principles of data abstraction and simplification discussed in research literature (M. Lynch, 1990; E. Tufte, 2001), while some other findings suggest the uniqueness of DH inscription use, especially in its special ability to capture and embrace the intrinsic uncertainty, complexity, and fluidity of humanities arguments with more reflexive and critical visual design.

On the other hand, visual literacy also plays a role in evaluating DH visualizations. To explore the impact of this aspect on the perceptions of DH visualization, I asked participants in the interview to rate their visualization knowledge and skills on a scale of 1(lowest) to 5 (highest) and elaborate on the reasons (Section 2 of A.1.3 in the Interview Guide). The majority (n=12) rated their knowledge and skills as between 2 and 3, while two participants (P3, P10) rated 1 and two participants (P4 and P16) rated 5. Almost all the participants explained their self-rating based on their technical skills. Participants who rated towards the lower end of the scale demonstrated that they either could not program or were not familiar with the massive visualization software and tools out there. Only two participants (P4, P10) evaluated their visualization knowledge and skills from the perspective of visual critique, e.g., the ability to critically choose visual forms for data display and argumentation.

The results indicated that researchers with higher levels of self-confidence in visualization knowledge and skills might be able to think more thoroughly about visualization criteria, especially in terms of going beyond the functional considerations of visual displays (e.g., information clarity) and extending towards rhetorical and philosophical considerations (e.g., visual metaphor). Researchers who are confident about their technical skills seem to have the tendency to treat visualization as an integrated component of their research, expecting a good visualization to embody the humanities argumentation and analytical procedures (e.g., P4). Less confident researchers, in comparison, are more likely to focus on channeling the simplification power of visualization to assist with data description and results sharing. Findings from this exploratory study offer preliminary insights and hypotheses for understanding how DH visualizations are evaluated, which can be further tested with larger datasets and mixed methods in future studies. One major approach to further testing the relationship between the visualization criteria and visual literacy may be to break down the

self-assessment metrics and investigate which specific aspects of visual literacy (e.g., understand graphic grammars, choice of visualization technique, data processing or programming) matter the most for DH researchers from various domains to cultivate and exercise confidence in visualization practices.

The current research literature have raised multiple other inscription criteria and factors that affect the criteria, as further demonstrated in the Literature Review chapter. In addition, many conferences and workshops focusing on DH inscriptions and visualizations, such as VIS4DH, demonstrate that perspectives including scale, process & interpretation, and data & question types, are also important factors to consider when appreciating and evaluating DH visualizations. Faced with this situation, a future survey may be applied to portray a more complete picture of the inscription criteria in the digital humanities scholarship.

This exploratory study demonstrates DH researchers' various evaluation criteria for a good visualization and how the criteria relate to researchers' purposes of using visualization and their self-perceptions of visualization knowledge and skills. However, I also acknowledge that this study bears certain limitations. First, the limited data size of this study made it difficult to draw more specific conclusions on, e.g., the relationships between visualization criteria and the data types visualized. Larger data points in future studies are needed to further generalize insights into this aspect. Second, the examination of the criteria for DH inscriptions also raised a new question about if DH inscription practices vary based on different research communities of digital humanists. Since most of the recruited participants come from humanities and social science research backgrounds, findings may represent more of the realities in these communities. Studies involving more diverse research communities, e.g., the STEM (science, technology, engineering, and mathematics) researchers, are needed to extend the current claims to other knowledge domains. Despite these limitations, this study demonstrates preliminary steps to understand how DH research communities perceive a good visualization, which create implications for information professionals to push forward visualization practices in DH scholarship.

6.2.2 Why Do We Need Visuals?

It may not be necessary to emphasize the importance and great value of visualization in research and even in our daily lives. Visualizations help us see patterns or phenomena that may otherwise stay invisible (Cheshire & Uberti, 2021). At this critical time of the COVID-19 pandemic, visuals and graphics have also been widely used in media to demonstrate coronavirus cases and lent an even more tremendous help for the general public to interpret and stay tuned about the pandemic situation. The *New York Time's* graph shown in Figure 25 is probably one typical example that a large population in the U.S. are quite familiar with and have used to assist with their everyday decisions. Historically, the production of maps and cartography helped the humankind understand the world and explore it. The innovation of statistical graphs in the 18th and 19th centuries, as illustrated by the opening case of Nightingale's rose diagram in this dissertation, played a significant role in addressing pressing issues in society, such as public health and warfare. In addition, visualization is particularly beneficial to scientific knowledge production and communication, as illustrated by the literature in science and technology studies. With the emergence of digital humanities as a research field, why do DH researchers engage in visualizations and inscription devices in their work, is a question to explore whose results may further inform the value and significance of visualizations in general and inspire future studies.

The findings of Study 2.2 demonstrate that digital humanists use visualizations and inscriptions based on a wide range of research purposes and motives. Some of the motives focus on leveraging the rhetorical power of visual representations to communicate insight from the humanities (e.g., describe or present results), while some findings demonstrate the use of visualizations as part of the research process. One particular interesting finding is the purpose of using visualizations to support humanities research analysis and interpretation. Although it is not uncommon to use visualization for research analysis, the ability for inscriptions to support *interpretation* may be special for digital humanities research.

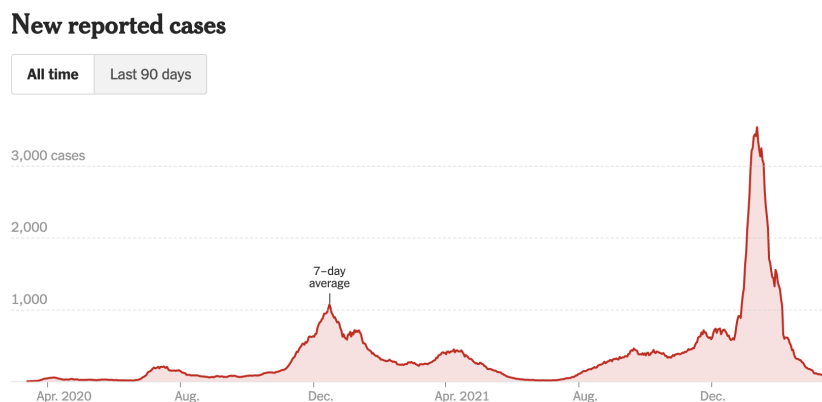


Figure 25: Coronavirus Cases Tracking in Allegheny County, PA, in *New York Times* (updated March 22, 2022)

As suggested by the findings, visualization is an effective method to support both the *close* and *distant* reading of the humanities data (e.g., text, images). Implemented in interactive platforms and DH applications, visualizations can augment and enhance the presentations of narratives and facilitate users' interaction with the digital materials, making a supported digital close reading and analysis of humanities data. Many interfaces and platforms demonstrated by recruited participants and presented in the literature all suggest this purpose and function of DH visualization (e.g., P12; Jänicke et al., 2015). From another perspective, visualization provides a better capacity of processing large scale data and representing them to emphasize humanities research insight. It is particularly useful and beneficial with the development of mass digitization and an increasing volume of cultural data starting to become accessible online. Under such circumstances, visualization functions as a valuable method to perform digital analysis of humanities data and address humanities research questions to reach the best insight. As visualization becomes an important part of humanities interpretation, how to design visual representations to let them embody the interpretive nature of humanities inquiries, has then become a question. This concern has been reflected in the research literature (Drucker, 2018; Hinrichs et al., 2019) and also leads to different principles and perceptions of quality visualizations as examined for Study 2.1.

Different purposes of using visualizations also relate to various tasks and research ques-

tions in the humanities research. This aspect of research also corresponds to the “insight needs” demonstrated in the data visual literacy framework raised by Börner et al. (2019). As demonstrated by the participants, research projects focusing on “representing change” and addressing “investigative questions” tend to use visualizations for in-depth analysis, while projects that aim to create DH end products are more likely to apply visualizations for results presentation and demonstration. Besides, researchers who are more confident in their visual knowledge and technical skills also seen to involve more inscriptions and visualizations in their research procedures and the stage of analysis. However, due to limitations of the participant pool and the semi-structured interview method, a stronger association between visualization purposes and research questions, visual literacy levels, as well as forms of analysis, cannot be concluded at this stage and deserves to be further examined.

6.2.3 Towards Better DH Inscription Practices

Semi-structured interviews with 16 participants identified a few barriers and challenges among digital humanists to work with inscriptions in their research. How to address the major identified challenges, including the difficulty of processing data, building and using infrastructures and tools, and facilitating better team work and research collaboration? Efforts to increase visual literacy may help address these issues. More specifically, librarians and information professionals may play an instrumental role in facilitating such efforts. As illustrated in the Literature Review chapter, libraries and cultural heritage institutions are in well-suited positions to build partnerships with digital humanists and engage in DH work, especially in the area of information visualization, so as to contribute to visual and data literacy (Cassella, 2017).

The traditional domains of expertise and strength of library and information science (LIS) such as metadata, information classification and organization, archives and digital curation, as well as the emerging practices of data science, can be effectively leveraged to offer training or professional workshops to assist DH researchers in building knowledge and skills working with digital data and resources. In addition, libraries, archives, and cultural heritage institutions can offer infrastructural support to DH scholars, such as software and

programming support, consultation, or funding support. Given that many institutions' DH centers or digital scholarship centers are located in their libraries, librarians' and information professionals' engagement will be instrumental for the long-term development of DH endeavors. Information professionals' engagement may also extend from data and infrastructural support and engage in improving research collaborations. Partnership between libraries and scholars in DH work is not a new phenomenon and many DH projects have been initiated and driven by cultural heritage institutions. However, to develop more in-depth and effective collaborative relations, more has to be learnt about the specific needs for collaboration of researchers of various backgrounds and fields. Findings of the exploratory study presented earlier demonstrate various needs of digital humanists, which can potentially inform information professionals' efforts to facilitate research collaboration. Additionally, given the collaborative nature of DH work, libraries can also help build and extend networks to identify and accelerate collaboration among multiple parties and communities of digital humanists. The extended networks, training, as well as infrastructural support offered by information professionals and cultural heritage institutions will in the long term address the identified challenges in DH work and create opportunities to improve best practices for DH inscriptions. Despite the deliberation of such solutions, however, further empirical research would be needed to examine whether these solutions will prove to be effective in reality. As I further elaborate in the "Future Work" section of Chapter 7, future research on DH collaboration using empirical methods would be highly beneficial to address the existing challenges, as well as developing a better understanding of the DH field.

7.0 Conclusions

My dissertation used a sequential, mixed-methods design to examine the use of inscriptions in DH research publications and visualization practices among digital humanists of various communities and domains. The findings of the dissertation, as well as the implications for the results, add to the current research literature at the intersection of digital humanities, visualization, science and technology studies, and LIS, while setting up multiple agendas for future work. In this concluding chapter, I discuss (1) the scholarly contribution of this dissertation as well as its broader impacts, (2) the limitations of this dissertation work from the perspectives of data, scope, and research design and methods, and (3) multiple directions of future work proposed based on the limitations and their potential value.

7.1 Significance and Contribution

7.1.1 Scholarly Contribution

This dissertation project is an interdisciplinary research study that can potentially inform various scholarly communities, especially the digital humanities, visualization, and science and technology studies (STS) (Figure 26).

Significance to DH research: Among DH communities, data visualization is an emerging practice and research agenda, where most of the existing discussions are focused on theoretical or case-by-case explorations (Flanders & Jannidis, 2019; Drucker, 2011, 2018; Jänicke, 2016). Studies from this perspective proposed the hypotheses and ideals for the concept of “humanistic visualization,” but failed to provide empirical evidence about how inscriptions are applied in DH research context. This dissertation fills this research gap, facilitating a thorough understanding of how visualizations are practiced and utilized in DH research with an empirical approach. In addition, this treatment of DH visualization also engages with essential debates about what “digital humanities” entails and contributes to a

better understanding of the overall landscape and community structure of the field. Findings of this dissertation provides an empirical investigation of the dynamics of DH and demonstrates its evolution into a data-driven, formalized, and computational field. DH researchers and practitioners who are currently or hoping to engage with visualization in their work can benefit from this dissertation study.

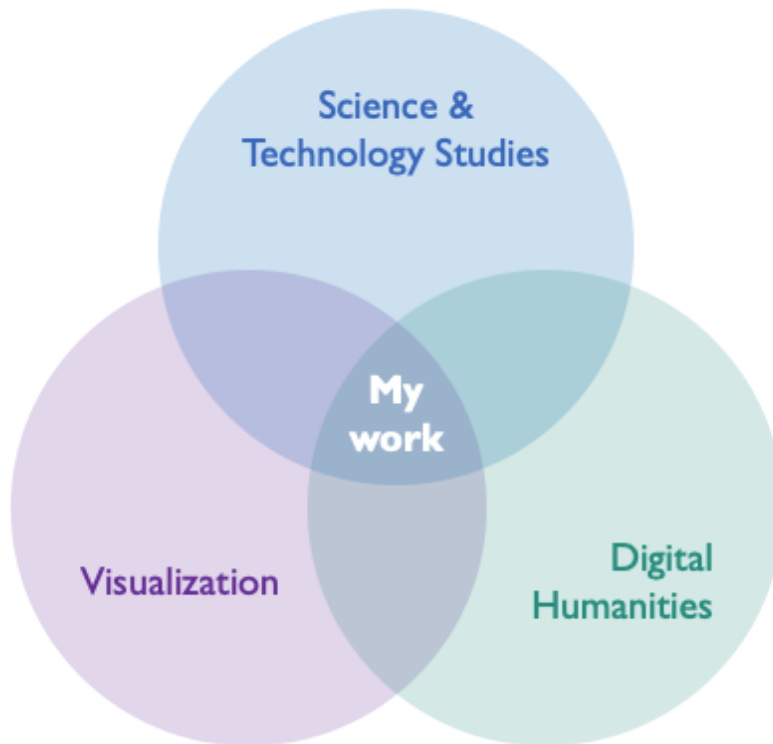


Figure 26: Scholarly Contribution

Significance to science and technology studies: Inscription and visualization have been a major topic of examination in science and technology studies (STS). A large volume of scholarship discusses inscriptions from sociological, philosophical, and rhetorical perspectives (M. Lynch & Woolgar, 1990b; M. Lynch, Coopmans, Vertesi, & Woolgar, 2014), but few studies applied empirical or quantitative approaches, let alone focus on the inscriptions in the context of DH. My dissertation offers the first empirical investigation of inscription use and practices in the research context of digital humanities, using a combination of qualita-

tive and quantitative analysis of empirical datasets. Findings of the dissertation empirically demonstrated that inscriptions can be a way to examine scholarly communication and collaboration within an interdisciplinary research field. This dissertation also provides a basis for further cross-domain, comparative analysis of inscriptions in scholarly collaboration and communication in the broader STS context.

Significance to visualization scholarship: Visual images and visualizations, as an important component of human knowledge as well as a method for knowledge representation, generate important issues to consider about how information and knowledge are classified as well as organized in the society. Among the multifarious research literature studying visualization from its history, functions, design, and communication, few studies have focused on visualization in the context of digital humanities, especially seen from an empirical lens (Friendly, 2008; E. Tufte, 2001; Borkin et al., 2013, 2016; Börner et al., 2019; M. Lynch & Woolgar, 1990b). This dissertation proposed a working taxonomy of inscriptions in the context of digital humanities research. Findings demonstrate the most commonly used inscription types and their functions and roles in digital humanities research communication, contributing to visualization scholarship from an under-evaluated research context. Compared with the previously established classification framework of inscriptions in scientific research contexts (e.g., Arsenault et al., 2006), the new taxonomy of inscriptions proposed in my dissertation added multiple categories that are potentially unique and specific to digital humanities research. The DH-specific taxonomy retained the high-level structure of the scientific inscription framework and included three major categories of graphs, non-graph illustrations (NGI), and non-visual inscriptions (NVI). Under NGI, the new taxonomy added sub-categories such as simulations; while under NVI, new types including code and text were appended to the previous framework. This taxonomy contained 11 inscription types. Despite its focus on static forms of inscriptions in print and the exclusion of interactive visualizations and representations, this taxonomy provided an important foundation for both the qualitative and quantitative analyses of inscriptions in my dissertation and particularly added to the scholarship on visual knowledge organization and classification.

7.1.2 Broader Impacts

Despite the maxim that “a picture is worth a thousand words,” reading a picture has never been an easy task. According to the Association of College and Research Libraries (2011), visual literacy has become one of the most pressing issues in the 21st century. Faced with the information overload online, visual literacy plays an instrumental role in defeating widespread misinformation and fake news, increasing transparency and accessibility of information resources, and improving the general public’s social well-being. As demonstrated by research in human-information interaction, infographics have become the most memorable and frequently used form of information communication on social media and the Internet. Therefore, learning to critically interpret, evaluate, and create visuals wisely is an important skill for the general population to fully and effectively engage in their digital social lives.

In the cultural realm, it is even more so as increasing numbers of cultural products apply visual storytelling technologies (e.g., virtual reality) to enhance users’ cultural experiences and accelerate the diffusion of cultural information. Image-driven learning and scholarship, as a result, becomes a timely topic with the significance in accelerating digital culture. This dissertation embraces the challenge to increase visual literacy by providing an examination of visual communication in the emerging field of digital humanities, particularly illustrating how digital humanities scholars leverage visual and non-visual representations to support argumentation and interpretation in research. Findings of this dissertation (e.g., challenges and barriers for digital humanists to engage with inscriptions) may inform the best practices of visualization as well as potential ways and methods to raise visual literacy among researchers and the general public.

7.2 Limitations

Despite the significance and contributions of this dissertation, I recognize the limitations, particularly those related to the scope, data, and research design and methods of this dissertation. In the following section, I illustrate the major limitations in the above aspects of

the dissertation, before proceeding to discuss multiple directions of future work where I will extend this dissertation.

Scope. This dissertation focuses on inscription use and practice in a specific research context, the digital humanities context. Due to the specific and sometimes unique characteristics of the the DH field, the findings on inscription use and practices from this dissertation may better reflect the reality and situation in the context of DH, rather than other contexts. The findings of this dissertation, especially those related to narrative functions of DH inscriptions, also remain exploratory and need further research to expand. In addition, the analysis of inscription use in this dissertation focuses on journal articles, excluding other popular scholarly outlets such as conference papers, presentations, or even social media platforms such as Twitter and ResearchGate, which have also been the major channels for DH scholarly communication. In order to keep this dissertation manageable, DH inscription use among those media outlets has not been addressed in this work, which deserves further research.

Data. One existing limitation of this dissertation is the data size. As discussed in earlier chapters, the taxonomy of DH inscriptions offered an important first step to analyze the use and practice of inscriptions in the context of DH. However, due to the intensive manual labor involved in the process to assess each inscription in a selected journal article and identify its type based on an evolving framework, this dissertation used a relatively small publication dataset, including about 300 randomly sampled articles and 2500 inscriptions. Therefore, the quantitative analysis of the publication dataset, as illustrated in detail in the Data and Methods chapter, may have been confined to the data size. In addition, due to the difficulty of conducting ethnographic observations and recruiting participants for virtual, semi-structured interviews, Study 2 of this dissertation included only interview data of 16 participants. The limited data size largely determined the scale of the analysis, making this study exploratory by its nature and the results hard to generalize to a broader scope as well. Under such circumstances, to further strengthen and extend the analysis and results, the major bottleneck to solve is how to automate the process to detect and identify inscription types. Recent computational methods and techniques such as natural language processing (NLP) and image recognition make it possible to address the problem in future work.

Research Design and Methods. The design of this study was inspired by Latour’s *Science in Action* (1987), which includes the initial investigation of *inscription use* in DH journal articles and a follow-up further examination of *inscription practices* in DH research process. The first stage was implemented with both a qualitative and a quantitative study of a corpus of DH publication data, while the second phase was implemented with semi-structured interviews. The chosen methods bear certain limitations. First, due to the practical concerns of the COVID-19 pandemic and inconvenience for travel, I could only choose to conduct virtual interviews with participants, rather than to conduct ethnographic research (e.g., on-site ethnographic observations of DH practices) as Latour (1987) suggested in *Science in Action*. As a result, the findings based on the semi-structured interviews, limited to the participants’ accounts and demonstrations through Zoom, may not be as rich as it could have been for an ethnography of inscription practices in DH. In addition, as semi-structured interviews do not usually manage to include every single team member for a DH project, it has become difficult during this dissertation to gather information on the *collaborative use of inscriptions* in team work, which is an interesting topic and perspective that deserves future studies.

7.3 Future Work

7.3.1 Ethnography of DH Inscription Practices

Shifting focus from the “ready-made knowledge” as revealed in DH publications, for future work, I aim to investigate the humanities knowledge “in the making” with ethnographic methods, to address the limitations discussed earlier in the chapter. This future work will have great potential to unpack the black boxes in knowledge production and illustrate a complete picture of the process (Latour, 1987). The gradual “laborization” of the interdisciplinary, collaborative DH scholarship, in addition, provides an unprecedented opportunity to follow a Latourian approach as advocated in *Science in Action* (1987) and closely examines the real procedures as well as practices in humanities knowledge production.

The central question to tackle is: “How do visualization technologies and inscription devices impact the ways in which humanities knowledge is produced?” To investigate this, I am planning to conduct an ethnographic study on the cross-field visualization collaborations and their impact on humanities knowledge production, particularly examining how interdisciplinary teams of researchers work on DH projects through visualization practices. This ethnographic perspective and design is deeply grounded in the conceptual theories of tacit knowledge. Tacit knowledge, as opposed to formal, codified knowledge, is a form of complex, implicit knowledge that can only be acquired through experiences and human interactions (Polanyi, 2009). Nevertheless, tacit knowledge determines the nature of any field of expertise, including sciences, and in the context of this study, the humanities (Collins, 2010). The mentality and approach of utilizing visualization technologies is a form of tacit knowledge that has been traditionally coded in scientific research paradigms (M. Lynch & Woolgar, 1990b; Latour, 1990) but has remained relatively foreign to humanities research until recently (Münster & Terras, 2020). It is a skill that cannot be obtained simply by reading visualization guidelines or examples but needs to be passed on by experienced practitioners through interaction and collaboration. However, it is this tacit skill and its transfer process, as I argue in the study, that tremendously shapes the new paradigms of humanities knowledge production.

For future research, I plan to take a grounded theory approach (Charmaz, 2014) and use the technique of “thick descriptions” (Geertz, 1973) to provide an ethnographic account of such interactions at 3-5 selected DH-focused institutions spanning DH centers, laboratories, and departments that are comprised of interdisciplinary digital humanities teams and personnel (Fraistat, 2012; Oiva & Pawlicka-Deger, 2020). The selection will be based on (1) the institution’s type (e.g., scholar-led DH labs at a research university, DH initiatives hosted at libraries, or digital humanities departments), (2) its engagement with humanities data and knowledge visualization or inscription practices, (3) the team compositions at the institution, and (4) the access to the institution’s resources. By means of participatory observations at selected sites, I plan to collect massive ethnographic data in fieldnotes and analyze them with both qualitative and quantitative methods, to gain insight into the team dynamics in the DH research landscape and the mechanisms of knowledge and skills trans-

fer among research communities across various disciplines and knowledge domains. With thorough documentation and analysis of DH inscription practices, this study will illustrate the gradual, underlying transfer of the tacit knowledge and skill set in scientific research into the DH research space, and provide the empirical basis for theoretical discussions about the identities of DH as a field under the impacts of scientific research paradigms, an issue that has intrigued scholars for many years without arriving at a consensus (Smithies, 2017; Fitzpatrick, 2012).

7.3.2 Collaboration and Team Dynamics in Digital Humanities

Investigation of DH inscription use and practices in this dissertation also demonstrates the value of using inscriptions as an *anchor of collaboration* in DH work. As DH becomes increasingly interdisciplinary and benefits from teamwork with researchers of various domains and fields, it is very important to explore how various communities of digital humanists work together through inscription practices and the roles of collaboration in DH work. Despite the importance of this perspective, there have been few empirical studies on DH collaboration. Existing literature that discussed the benefits of collaboration in DH focuses on either case studies or the theoretical discussion of an in-depth DH collaboration (Edmond, 2016; Fenlon, 2020; Su, 2020; Griffin & Hayler, 2018). One possible explanation for the lack of research in this area can be the lack of large-scale datasets for quantitative analysis. Alternatively, this lack of systematic investigation of DH collaboration may also be explained by the phenomenon that a large volume of DH scholarship is often project-based and focuses on addressing practical concerns and issues related to individual projects. Collaboration and team science, however, has been a long-standing topic in science and technology studies (K. Hall et al., 2018; Sonnenwald, 2007; Mâsse et al., 2008). Computational methods such as complex network and other quantitative bibliometric methods are widely applied to empirically examine scientific research collaborations. For future work, I plan to empirically investigate the collaboration across DH research communities, through the lens and perspectives of inscription use. The ethnographic approach to inscription practices in DH offers a way to collect rich empirical data about DH collaboration and scholar interaction

among researchers and practitioners, making the study possible from the perspective of data availability. Building upon the analysis of the ethnographic data, the survey method further provides the opportunity to generalize the findings across DH cases and among larger research communities.

7.3.3 DH Workforce, Research Communities, and Labor

Closely related to the aspect of collaboration in DH research, another interesting research area focuses on DH workforce, labor, and research communities of digital humanists. The Literature Review chapter of this dissertation discussed two major definitions of “digital humanists.” Building upon the existing literature, this dissertation proposed five research communities based on their institutional affiliations and knowledge domains, including *STEM*, *Humanities*, *Social Science*, *Interdisciplinary Institute*, and *Non-academic*. However, such efforts are far from enough to illustrate a complete picture of DH workforce and their contributions and roles in DH scholarship. The research communities can be further specified to illustrate the variety of DH workforce and the different roles research communities play. For example, further and detailed exploration of the roles and contributions of data scientists, librarians, or archivists would help understand development of the DH field. Besides defining DH communities based on digital humanists’ institutional affiliations and academic domains, are there other ways to understand the community structure in DH? It would be a leading question for my future work from the labor perspective. For future work, I aim to further explore aspects and factors (e.g., relations to technologies, positions in DH scholarly networks, preferred work modes) that affect our understanding of major DH workforce and its research community structure. In addition to constructing DH research communities, I also aim to develop a better understanding of how various research communities contribute to the work and shape the future of the DH field.

7.3.4 DH Inscriptions Outside of Peer-Reviewed Journal Articles

One of the limitations of this dissertation, as I discussed in earlier sections, is the sole focus on inscription use in DH journal articles. In the context of digital humanities research,

journal publications are neither the only channel for scholarly communication, nor the only place where inscriptions are commonly used. Conference papers, extended abstracts, presentation slides, or even social media platforms such as Twitter have been widely used in the academic environment to communicate ideas, research findings, and network with other scholars. Inscriptions, as in journal papers, also play important roles in those channels for DH scholarly communication. Numerous examples suggest the potential differences of using inscriptions in those channels, compared with journal articles. Two major observable differences may be (1) the lack of accompanying text to explain the meaning of the inscriptions and (2) the use of fewer, however more essential, inscriptions in media presentations. This may be explained by the fact that conference papers or social media publications (e.g., a tweet) are often much shorter and compressed than a journal article; so the authors who choose such scholarly communication channels need to be more selective of the visual representations and inscription materials.

PowerPoint slides widely applied to professional and public presentations, for example, is also a typical media form where inscriptions and visualizations are used to facilitate knowledge communication (Gross & Harmon, 2014; E. R. Tufte, 2003). Tufte (2003) showed his disdain and criticism of PowerPoint in his book *The Cognitive Style of PowerPoint*, claiming that PowerPoint is a widely used software program whose bullet-point formats, when blindly accepted, leads to miscommunication and disruption of the content. In contrast to Tufte's negative attitude towards PowerPoint, other scholars have favored an alternative style: "a slide format in which a headline captures the main point in a complete sentence, underneath which is a supporting image accompanied by minimal text" (Gross & Harmon, 2014; Alley, Schreiber, Ramsdell, & Muffo, 2006; Neeley, Alley, Nicometo, & Srajek, 2009; Alley & Neeley, 2005; Markel, 2009). This favored style concerns one major characteristic of PowerPoint, which is the centering position and role of the visuals. Echoing such a design recommendation, Gross and Harmon (2014) further analyzed the interactions between visual images and the narrative with four classic examples of PowerPoint-assisted communication, demonstrating that "by means of verbal-visual interaction, the image has become an integral part of the grammar of the story [in PowerPoint]."

Extending from the case of inscription use in PowerPoint, for future research, I am plan-

ning to analyze the roles of inscriptions in other media channels, such as conference papers, extended abstracts, and academic tweets. Particularly, a comparative perspective to analyze the similarities as well as differences in inscription use across these media outlets would be a promising approach in revealing the various functionalities and roles of inscriptions in DH research communication. To achieve this research goal, one first step, which is also one major foreseeable challenge, is to collect data about DH conference papers, abstracts, and tweets. The computational methods as well as infrastructure building efforts such as Index of DH Conferences (Weingart, Eichmann-Kalwara, & Lincoln, 2020) make it possible more than ever to conduct such large-scale, comparative studies, in spite of the challenges. Findings of such future work will further complement this dissertation in presenting a more thorough and in-depth analysis of inscription use and practices in DH scholarly communication.

7.3.5 Final Remarks

It may be safe to say that this dissertation has raised more questions than it solved. New data, analyses, methods, and findings lead to new questions and assumptions that can be further examined and explored in future work. For a field like DH that has been constantly changing and includes highly interdisciplinary research agendas, this might be a good signal. In addition, as an interdisciplinary researcher, I have gained inspiration from multiple intellectual domains that have been well reflected in this dissertation, such as digital humanities, informetrics and scientometrics, visualization, knowledge organization, and sociology of science. Such an interdisciplinary vision and approach will continue to be applied in my future research in digital humanities from the perspective of information studies.

Appendix A Interview Guide

Date and time:

Location:

Recording ID:

Interviewer:

1. Demographic Information:

Current Institution:

Current Job Title:

Academic/Training Background:

Highest Degree:

Field of Study/Research/Work:

DH Career Age:

DH Academic Geography:

2. Visualization Practices for the Target Paper

Paper ID:

Table 18: Visualization Experience Record

Visualization ID	Description and Experience

Question Prompts:

- (1) What does the visualization demonstrate, and what stories does it mean to tell?
- (2) What do the various visual elements mean in the visualization? How and why did you make the specific design decision?
- (3) What kinds of analyses did you perform to create the visualization?
- (4) What techniques or tools did you use to create this visualization? Why did you choose them? How would you evaluate the tool (e.g., performance, problems, or if the tool reached the expectations)?
- (5) Who contributed to the visualization? In which ways?
- (6) What was the workflow of your study? During which stage or procedure of the research did you create and use the visualization? How do you think this visualization functioned in your research process or the progress of the study?
- (7) Did you encounter any challenges, barriers, or difficulties working on the visualizations? If so, what were those challenges and barriers? How did you overcome them?
- (8) How do you think the visualizations in your paper relate to each other and make the argument for the paper?
- (9) Were there failed visualization attempts that did not make it into the final published paper? What do you think made them “fail” or be regarded as a failure?
- (10) Do you think of any limitations in the presented visualizations? If so, any ways to improve them?

3. General Thoughts on Visualization in Your Research Practices

- (1) Reflections on visualization practices in DH research
 - How often do you use visualization in your research practices?
 - What kinds of research questions or tasks do you often expect to solve with the help of visualization?
 - What visualization tools and methods do you use the most frequently in your DH research?

- Why would you choose those methods or tools over others?
- How well do you feel visualizations are integrated in your research practice?
- Do you think visualizations change your research practices and processes? If so, in which ways?

(2) Assessment of visualization skills

- Do you think you have adequate visualization skills for your research?
- If not, how do you prefer to solve the problem and bridge the skill gap?
- If collaboration counts as a potential solution to you, who would you seek to collaborate with and what desirable knowledge or skills would you look for among the collaborators?
- If libraries and information professionals are to enter the scene on visualization, what would you expect them to offer?

Appendix B Interview Participant Recruitment Email

Dear xxx:

Hope this message finds you well. My name is Rongqian Ma and I am a doctoral student in Library and Information Science at the University of Pittsburgh. I came across your paper “xxx” in the xxx journal and found it very interesting. I would love to invite you to join an interview on digital humanities data visualization. This interview will be part of my dissertation research.

My dissertation examines inscription practices among various communities of digital humanists. More specifically, I explore (1) the preferences of different domains of digital humanists in using certain types of visualization forms or visualization techniques; (2) their decision-making processes in choosing certain visualizations; (3) the challenges and barriers they may have encountered during the process; and (4) the collaboration dynamics within and outside the communities when practicing visualizations in their research.

The interview will last for about 1 hour and conducted over Zoom. I have attached my interview protocol here for your reference.

This study has passed the IRB review at our institution, i.e., the University of Pittsburgh.

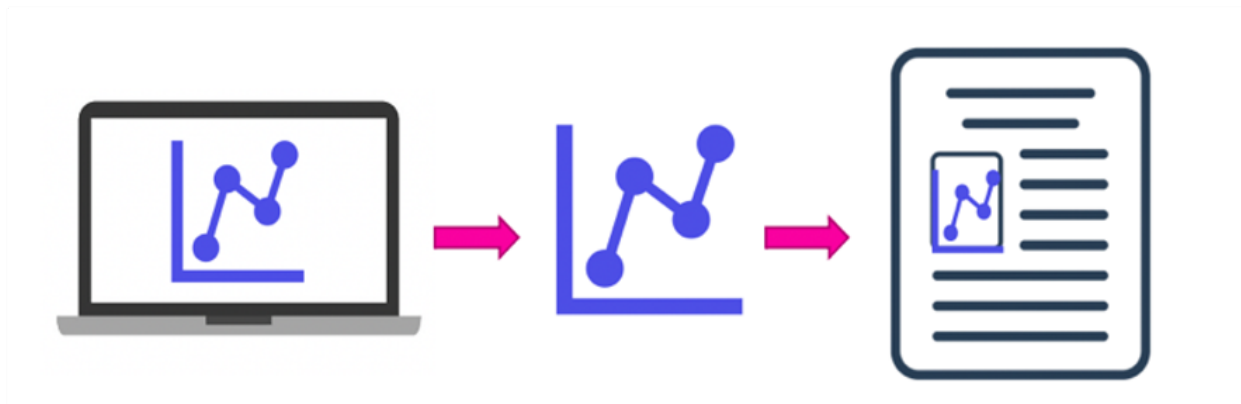
Thanks very much in advance for your contribution! I very much look forward to the opportunity to discuss further. Please feel free to let me know if you have any questions.

All the best,

Rongqian Ma

Appendix C Interview Participant Recruitment Advertisement

University of Pittsburgh Recruiting Volunteers for a Research Study



Research Title: Bridging Sight and Insight: Searching for the Soul of Digital Humanities from the Lens of Inscriptions

Research Objectives: This study aims to examine the roles and impact of information visualization in digital humanities research communication and knowledge production. This study also explores the challenges, barriers, and distinct needs of data visualization among digital humanists from various knowledge domains.

Participation: I am looking for participants who (1) conduct digital humanities research and (2) use information visualization tools and visual materials in their research, to participate in a semi-structured interview of about 30-45 minutes with me. During the interview, you will be asked to discuss a specific digital humanities research project of yours in which visualization is used and answer multiple open-ended questions. Thank you so much in advance for your time and participation!

If you are interested, please contact Rongqian Ma (rom77@pitt.edu) for further information. This research study is conducted by researchers who are members of University of Pittsburgh. IRB: STUDY21010213

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