From Tempests and Hydraulic Machines to the Arno Diversion: the Historical Significance of da Vinci's Study of Water

Yu-Jin Lee
Stanford University

In his elaborate narration of the project to divert the Arno River, historian Roger D. Masters (1998) speculates about the collaboration between Leonardo da Vinci and Niccolo Machiavelli. However, Masters's emphasis on the relationship between these two intellectuals is insignificant compared to what the Arno Project reveals about both the historical significance of water and da Vinci's development through his study of water. The reemergence of classical thought and the importance of water in society led da Vinci to pursue multiple water-related projects. Da Vinci's intellectual development from his study of water, manifested in sketches of tempests and hydraulic machines as well as the Arno Project, reveals his pivotal role in Renaissance society as well as in the development of the scientific method.

Historical Significance of Water

The historical significance of water was based on the revival of the classics, its essential domestic uses, and militaristic stratagems during da Vinci's lifetime.

The classical revival permeated the early Renaissance and initiated artistic manifestations of Greek and Roman river gods. During this period of ancient recovery, even the great architectural giants, Donatello and Brunelleschi emphatically explored and sought out the antique from the ancient Greek and Roman civilizations (Plumb, 2001). In addition to this search for the classics, those living in the Apennine Peninsula continued to commemorate their great ancient past, establishing a strong, concrete source of knowledge for da Vinci. The recovery of many works from classical authors, such as Seneca, Horace, Aristotle, and Ovid shaped the dawn of the Renaissance (Plumb, 2001). The discoveries of Roman statues of river gods manifested in the *Tiber*, *Arno*, and *Nile* sustained interest in the ancients (Lazzaro, 2011). Historian Claudia Lazzaro (2011) provides a detailed account of these river gods, including evidence that wealthy families exhibited their own series of ancient sculptures in their private gardens. The appearance of these ancient sculptures engendered increased

importance of the role of the river gods, especially among the wealthy rulers, and became evident in ceremonies and festivals starting in 1513 (Lazzaro, 2011). These river gods majestically presented in the courtyards of palaces demonstrated the ultimate historical prominence of water. This prominence of water among da Vinci's patrons may have prompted da Vinci to explore different manifestations of water. The influence of the classical revival will be discussed further throughout da Vinci's different portrayals of water.

In the domestic arena, water also served as an essential source of life. Historian Katherine Rinne (2001-2002) describes the importance of water through the everyday chore of laundry and focuses on the water infrastructure in Rome. She highlights the Tiber River as the primary source for all domestic needs and describes the unpredictable nature of the river: It was known for the perpetual and calamitous floods that ruined wash sites along the riverbanks. Because of this devastation, the Romans involved the church to control and manage the water infrastructure. Pope Pius V even established committees of cardinals to be in charge of the distribution of water. Like the Tiber, the Arno in Florence was also known for its unpredictable floods, and destruction left from the Arno likewise emphasized the major role of water in Florence.

Water played a remarkable role in the militaristic stratagems of cities to win wars. Rinne (2001-2002) describes water infrastructure as establishing the foundation of a civilization, but identifies how disregard and lack of information limited understanding of political, cultural, and social relationships. Therefore, Rinne emphasizes the significance of water and the need to analyze the strong physical relationships between water and topography (2001-2002). J. H. Plumb (2001) notes that Italian triumphs transpired in an era of constant violence. This historical context parallels the manipulation of water to destroy cities and win wars during the fall of the Roman Empire. In the battle of Rome in 537 A.D., the opposing Goths sabotaged the aqueducts—which were the classical infrastructure essential in bringing water to the city—to cut off the water supply, and forced Romans to migrate near the Tiber River (Rinne, 2001-2002). Like the Goths, the Florentines desired to divert the Arno River around Pisa to deprive the Pisans of their precious source of water (Kemp, 2006). The perceived control of water became an important military strategy to conquer cities and was a critical focus in much of the early Renaissance, especially among the Florentines. Da Vinci's intimate relationship with the Florentine rulers at this time may have influenced him to pursue his study of water.

Da Vinci's Manifestations of Water

Driven by the significance of water based on classical revival and domestic and militaristic uses, da Vinci's interest in water may have intensified. Historian Martin Kemp (2006) describes how da Vinci was

profoundly fascinated by the nature of water, as portrayed in his studies of water, sketches of hydraulic machines, and in the Arno Project.

In da Vinci's studies and sketches of water, he was first inspired by the revival in classical thought during the early Renaissance based on the earlier works of Archimedes, Euclid, Vitruvius, Pliny, and Albert of Saxony (Alexander, 1982). However, da Vinci experienced a shift to the modern observational approach of studying water, which was perhaps initiated by da Vinci himself (Alexander, 1982). Da Vinci's studies of water illustrated his precise methodology and creation of new terminologies—such as *torrente*, describing ephemeral streams, and *paludi*, referring to marshes and stagnant waters—that aided in clarifying vague theories (Alexander, 1982; Kemp, 2006). Another example of his precision is demonstrated by his meticulous studies of the formation and disbandment of bubbles (Kemp, 2006). With a detailed understanding of various aspects of water, da Vinci experimented with drawing sketches of tempests, the most difficult manifestation of water. Da Vinci's interest in fluvial geomorphology may have stemmed from his passion to find both the cause of and a panacea for human suffering (Alexander, 1982). This humane interest in the historical context of his life may have provoked his independent research. In his sketches of tempests, the *Deluge*, da Vinci uses water as a means to bring together nature in the form of trees and plants, other elements like the wind, and finally the realm of humans and their inventions, such as ships—resulting in the tempests (da Vinci, 2005). Through various sketches of tempests, da Vinci was able to experiment and further his understanding of the causes of suffering not only from water-based natural disasters but also from other causes based on extrapolation.

Da Vinci's experimentation in the form of sketching tempests and precise observations also prompted him to further knowledge. As his interest became more captivated by the architecture of his study subjects, he aspired to attain a complete mastery of the objects (Plumb, 2001). However, not only did da Vinci want to understand, he also wanted to apply his understanding in practical ways. Da Vinci's observations and early experimentation equipped him with a clear avenue to explore hydraulic machines, but manifested in sketches rather than models (Alexander, 1982). The classical revival during the Renaissance also influenced da Vinci's interest in machines. Da Vinci was aware of Ctesibius, the inventor of a water pump for birds, based on the account of Vitruvius, and he was also well-versed in the inventions of Heron of Alexandria, who created many machines that were driven by water and other forces (Kemp, 2006). In addition to inspiration from ancient inventors, da Vinci's environment in Milan allowed him to explore engineering, especially because of the extensive system of hydraulic infrastructure that was sponsored by the Visconti and Sforza rulers (Kemp, 2006). During this time, da Vinci experimented with various sketches of hydraulic machinery that could have proven to be useful, especially in

dredging up dirt in the Arno Project based on a straightforward lifting machine (da Vinci, 2005). In addition to this lifting device, he also sketched a series of machines, referred to as the Archimedean screw, that were capable of draining water when properly placed in an angle (Kemp, 2006).

While most of da Vinci's sketches of hydraulic machines were not realized, the Arno Project was one that was started. The Arno River was vital to the Florentines. During the early Renaissance, Florence had no aqueducts and the Arno, which bisected the city, served as the primary source of water in addition to various wells throughout the region (Else, 2009). However, the unpredictable and destructive nature of the Arno limited its capacity to fully serve the Florentines. Working with the Florentines to conquer the Pisans by diverting the Arno, da Vinci began an explicit study of the Arno's intricacies (Masters, 1998). Perhaps based on his experiences of precise observation and repeated experimentation from the sketches of tempests, da Vinci gained expertise in open-channel flow, which was helpful in understanding the flow of the Arno and elucidated the principle of continuity, which aided in recognition of the continuous flow of the Arno (Alexander, 1982). Da Vinci also provided accurate descriptions of the relationship of water and the land as well as the erosion of the riverbank (Alexander, 1982). Da Vinci comprehended that understanding the flow of water and its effects on land were crucial before designing a successful diversion of the Arno.

While researching the Arno, da Vinci validated the conclusions made by Giovanni Villani during the fourteenth century that, based on evidence from nature, the Arno had once been dammed by an immense rocky barrier that created two lakes, giving rise to Florence and Pistoia (Kemp, 2006). Using his acute observational techniques, da Vinci was able to satisfy his own knowledge by personally validating his source (Alexander, 1982). With his vast knowledge of the Arno and water, da Vinci attempted to explain how a simple understanding of the river current could be instrumental in its diversion (Kemp, 2006). With all his detailed studies of the Arno in place, da Vinci provided essential precepts to designing the Arno Project and useful topographic maps of the area (Alexander, 1982).

However, da Vinci's elaborate studies did not come to fruition. In addition to Machiavelli and da Vinci, many other engineers were consulted in the Arno Project. The confidence and reassurances of the extraneous engineers led to a premature start in the execution of the Arno Project. When digging began in 1504, da Vinci could not participate because he was fully immersed in preparing the *Battle of Anghiari*, commissioned by Piero Soderini for the Hall of Five Hundred (Kemp, 2006). The engineers of the project surrendered within three months, due to the perverse Arno River (Kemp, 2006). One can only speculate about whether the failure of the Arno diversion was due in part to da Vinci's preoccupation with another project or to his incomplete understanding of the Arno. Although failure must have been hard to accept for da Vinci, he

may have acknowledged his underestimation of the forces of the Arno River and gained a renewed respect for nature.

Historical Significance of da Vinci's Interest in Water

The failure of the Arno Project did not prevent da Vinci from pursuing other water-related projects, and these projects influenced the concept of an ideal city. The basis of the ideal city stemmed from the classical revival to mimic ancient cities by complying with logic and nature (Garin, 1969). Learning from the failed execution of the Arno diversion, da Vinci became involved in implementing another water project in Romorantin towards the end of his life under the patronage of King Francis I of France. According to Kemp (2006), the system of canals within Romorantin was the most striking blueprint among da Vinci's urban planning designs. In addition to an aquatic arena for tournaments, the Romorantin sketches included gardens complete with natural fountains that reflected the motifs of ancient cities as well as the strength and tenacity of men, which was the prevalent theme for designing ideal cities during the Renaissance (Garin, 1969; Kemp, 2006). Although da Vinci's experimentation did not come to fruition because of his death in 1519, his designs influenced the continued evolution of the ideal city concept. For Cosimo I de Medici, who became the Duke of Tuscany in 1537, water was a major priority in his design of Florence as an ideal city. The failure of the Arno Project in 1504 did not prevent Cosimo's desire to convert the dry Sardigna region into fertile land by manipulating the north bank of the Arno River. In addition, since water was a precious commodity because of the Arno's unpredictability, Cosimo envisioned not only power over the Arno, but also its system of tributaries, channels, wells, and public fountains (Else, 2009).

While da Vinci did have a major influence in the building of an ideal city, his studies of water may have had the greatest impact on furthering precise experimental and observational techniques. Da Vinci's obsession with precise measurements led him to question the actuality of his subjects, manifesting in logic and experimentation. These two concepts prevail today to serve as the foundation of the scientific method in any research setting (Plumb, 2001). For example, his precise observations in distinguishing between sediments from the river and from the sea allowed him to form the theory of open-channel flow of rivers as mentioned above (Alexander, 1982). In addition, he portrayed the epitome of a good researcher throughout his life, because he did not accept any presented evidence without his own experimentation and collection of data to further support a conclusion (Alexander, 1982). The process of verification continues to be a crucial element in quality research in any field of study. Whether da Vinci himself promoted the development of the scientific method and the extent of his influence are difficult to hypothesize. However, his mode of thinking reflects the current dogma of scientific inquiry.

Finally, it is important to note the impact of da Vinci's study of water even when many of his sketches and designs did not manifest themselves in three-dimensional form and the practical Arno Project was considered a failure. While the two-dimensional sketches remain on paper, these sketches and designs can be regarded as individual experiments contributing to da Vinci's intellectual development. And while the Arno Project succeeded after da Vinci's death, his vigorous study of the Arno may have provided the foundation essential for the victory of the Florentines against the treachery of the Arno.

References

Alexander, D. (1982). Leonardo da Vinci and fluvial geomorphology. *American Journal of Science*, *282*, 735-755.

Da Vinci, L. (2005). *Leonardo's notebooks* H. Anna Suh (Ed.). New York: Black Dog & Leventhal.

Else, F. M. (2009). Controlling the waters of granducal Florence: A new look at Stefano Bonsignori's View of the City (1584). *Imago Mundi*, *61*, 168-185.

Garin, E. (1969). *Science and civic life in the Italian Renaissance* (Peter Munz, Trans.). New York: Doubleday.

Kemp, M. (2006). *Leonardo da Vinci: the marvellous works of nature and man*. Oxford: Oxford University Press.

Lazzaro, C. (2011). River gods: Personifying nature in sixteenth-century Italy. *Renaissance Studies*, *25*, 70-94.

Masters, R. (1998). *Fortune is a river: Leonardo da Vinci and Niccolo Machiavelli's magnificent dream to change the course of Florentine history.* New York: Penguin.

Plumb, J. H. (2001). *The Italian Renaissance.* New York: Mariner.

Rinne, K. W. (2001-2002). The landscape of laundry in late cinquecento Rome. *Studies in the Decorative Arts*, *9*, 34-60.