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Researching Information in Engineering: Making and Reading as Two Sides of the Same Coin

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Abstract:

Engineers belong to a specific category of scientists and, as such, make use of a wide range of information, from very simple to very complex, through various means. Their research outputs include technological products, processes and services which have been developed using different methods, from texts to physical experiments and documented prototypes, based on observations and learning through reading and experiencing. Our historical analysis shows that this is not a new research method, since understanding the world around humans has consistently involved the study and reading of things that comprise it.

In this paper, we discuss parts of the process of 'making', which creates knowledge through experience when researching a particular subject matter whilst simultaneously being open to the occasional accidental happy discovery, otherwise called serendipity, as a way of conducting research. In 2018, within the library of the Technical Chamber of Greece (TEE/TCG), an initiative to create a space dedicated to research through reading things and 'making' was undertaken, equipped with basic traditional and desktop manufacturing technological tools, i.e. a computer aided design (CAD) workstation, a 3D printer and electronics kits, in order to foster the creation of verbal and non-verbal information. The new services offered by the TCG Technical Library coexist with its printed collections, encouraging their cross-pollination and providing an environment for multidisciplinary hands-on research.

Keywords: library collection; engineers; experiential learning; non-verbal information; laboratory

Introduction

Libraries are places where information is collected and curated in a way that is accessible to the public. Lately, libraries are increasingly being redefined as places to access information in various formats and from various sources. They provide material from a variety of digital resources, and are increasingly turning into community hubs, inviting new and old patrons to participate in educational programs and engaging in ‘lifelong learning’. They have also begun to offer services such as dedicated spaces to boost creativity, playrooms for the younger and even makerspaces. But is this a redefinition or is it a rediscovery of the library? By examining methods of study from ancient times, one can identify scientists seeking information beyond written documents. In this paper we investigate how a new service in the Library of the Technical Chamber of Greece, a library directed mostly to engineers, aims to cover the information needs of its users by offering new channels for research. A laboratory where engineers can actually *read things*[1] could be considered an innovation in 2019 but looking back in history, research could prove otherwise. We argue that scientists, especially engineers, use more than information stored in texts to carry out research. They need to observe things, experiment, test, and evaluate plausible solutions to their research questions, often aided by physical experiments and geometries, which help to better visualise, understand and develop their research endeavours. Things, contrary to the notion of libraries lending out objects such as tools, kitchen supplies, electronics etc, are more than utilitarian items. Rather, we consider them information carrying vessels, worthy of conveying meaning, ideas and thoughts, which, in turn, can be *read*.

A bit of history

The act of collecting artefacts, as Susan Pearce (1994) explicates, goes hand in hand with the human need to explain the world. Looking back in history one can read about Aristotle, who upon his return from tutoring Alexander the Great, around 335 B.C., established a collaborative community in Athens known as the Lyceum (Morison, n.d.). It was envisioned as a gathering place for scholars to use philosophy as a means to explore different scholarly paths. Aristotle would travel, collect and systematically categorise and document over 500 species of fish, reptiles, and mammals, accumulating this material into a collection. His aim was not to provide answers but rather to raise questions, as fuel to his curiosity. Thus, Aristotle pioneered the scientific method in ancient Greece alongside empirical biology and his work on logic, rejecting a purely deductive framework in favour of generalisations made from observations based on nature. Ancient Greek geographer, philosopher, and historian Strabo argues that the type of categorisation of materials in the Library of Alexandria was modelled after Aristotle's own private library and was linked to a larger institution called ‘Museum’ (*Μουσείον),* a shrine devoted to the Muses, the inspirational goddesses of literature, science and the arts. Both Institutions are often celebrated for their role in the history of scholarship. In the Museum, a community of academic scholars engaged in the study of astronomy, geometry, mathematics, medicine, anatomy and Greek literature (Erskine, 1995), underwriting the first programme of *cultural imperialism*. Unlike today’s museums, it did not collect sculptures or paintings as works of art, but contained a garden, a zoo and an observatory, and it was destined to be far more than a mere repository of scrolls. A bright example of an inventor spending time in the Museum is Archimedes, the genius of 'Eureka'. While there, he observed the rise and fall of the flood of the river Nile, laid the foundations for the science of hydrostatics and outlined methods for calculating areas and volumes (Mac Leod, 2004).

[1] For the purpose of this paper the term *things* is used for both *objects* (everyday material items around us) and *artefacts* (material objects made by art or skill)

This idea of a collection of gathered physical objects being made available originally for ostentation but later used for study can be found in recent centuries in the archetype of the Cabinet of Curiosities, or Wunderkammer, or Studiolo. During the sixteenth century in Europe, it became fashionable for wealthy wanderers and royalty to amass large collections of artefacts during their journeys, including botanical and geological specimens, fauna and scientific apparati (*naturalia, mirabilia, artefacta, scientifica*). Studying these objects to grasp how they operated, what their attributes and properties were, based on the principle of observing, examining, combining with prior knowledge and analysing in order to understand, meant that the area of study could lead to a range of knowledge in various scientific fields. In 1565, in Munich, Flemish physician, librarian and curator Samuel Quiccheberg published a book under the title *Inscriptiones*[2] providing the rationale for Cabinets of Curiosities. This book is considered the first treatise on museology, based on the premise that the purpose of collecting objects was to offer means of producing practical knowledge and promoting technological innovation (Quiccheberg, 2013), such as a collection, commissioned by Quiccheberg's employers, of machine designs to be built in full scale should the need arise. Quiccheberg comments on the importance of a library within a collection with the scope of providing relevant literature to study objects (Schulz, 1994, pp.175-177). These types of private collections, broken down and regrouped in a different taxonomy so as to tell a significant story, the 'ruins of cabinets', were the origins of the museum as we know it today (Mullaney, 1988, pp.61-62).

The connection between reading, observation and making can be identified in the documentation of the work of Leonardo Da Vinci, one of the great creators of the Renaissance. His time in Florence succeeded the years when scholars from the decaying Byzantine Empire relocated to the Italian north, bringing along important books and scrolls from libraries that are said to host knowledge from the time of the Library of Alexandria (Harris, 2002, Setton, 1956). This scholarly trend, combined with financial might, was the catalyst for the evolution of the Renaissance. One could claim that Da Vinci was lucky for living during these creative times and that all his grand creations were a mere coincidence. However, it takes a special kind of skill for one to appreciate the knowledge laid before her and act upon it. Viewing Da Vinci's notebook, one can see his wide range of observations with annotated graphical representations, sketches, renderings of human faces, machines, and their elements, as well as observations of nature, visuals of dams, buildings, fortifications, guidelines for machine models built by himself and evidence of his close contact with guild workers in order to turn things into reality (Moon, 2007).

[2] The full title translated into English is: *Titles of the most ample Theater That Houses Exemplary Objects and Exceptional Images of the Entire World, So that One Could Also Rightly Call It a: Repository of artificial and marvellous things, and of every rare treasure, precious object, construction, and picture. It is recommended that these things be brought together here in the theater so that by their frequent viewing and handling one might quickly, easily, and confidently be able to acquire a unique knowledge and admirable understanding of things.*

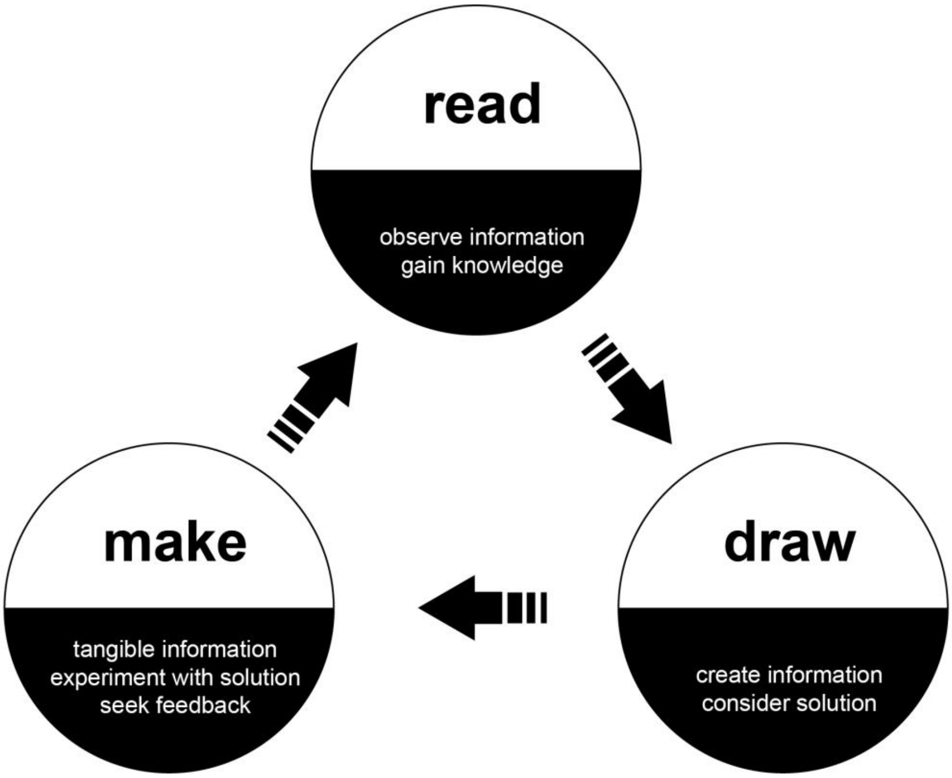

Figure 1: The circle of creation

Aided by his instinctive curiosity, observative nature and remarkable ability to illustrate, describe, and prototype ideas, Da Vinci became one of the greatest inventors and artists of his time, a genius that spent years studying the anatomy of the human face in order to create the famous smile of Mona Lisa (Worrall, 2017).

The idea of purposeful observation with an open-ended quest for discovery is part of the concept of *serendipity*, a term coined by Horace Walpole in 1754 (Merton and Barber, 2004, p.2) to describe the act of accidentally making meaningful discoveries. More than just luck or being at the right place at the right time, it is the ability to combine events or observations in meaningful ways and seeing connections where others do not, leading one into the accidental happy discovery (Rond et. al, 2011). Serendipity requires prior knowledge, observational skills, an experimental mentality, a habit of tinkering and embracing the unknown and, equally importantly, an open mind in order to realise the instance at which the researcher discovers a new more promising and interesting research theme worthy of refocusing her work. As discussed by Darbellay, et al. (2014), when a researcher operates in a spirit of discovery and innovation, she can deliberately divert the course of her research when unexpected observations are made, sensing new discoveries 'as a result of hybridization between theories, concepts and methods belonging to different disciplines in a logic of "creative marginality"'. Such have been the stories of discoveries such as 'Super Glue', a well-known material bonding chemical product or the discovery of the temperature of the universe by Penzias and Wilson (Wikipedia, 2019), to name a few. These accidental discoveries could not have occurred had it not been for the combination of their original research theme, openness to a shift of interest, study methods and available collections of knowledge in various formats, categorized according to the information-seeking needs of the researchers. This process could be a conscious research method, which may help to guide the information scientists of today.

The Information-Seeking Habits of Engineers

Understanding the information-seeking habits and practices of the users is a common theme in library literature. Engel, Robbins and Kulp (2011) review the literature of engineers' information needs, showing that engineers seek for easy-accessed information and up to date journals' literature. The engineering profession is unique in that it is an applied science, which creates or improves products, technologies or services with immediate practical application, and its nature determines the engineers' information seeking habits. Unlike scientists, engineers typically work on projects in teams, be it in industry or government, and focus their goals on company or organizational success (Seggern and Jourdain, 1996). In academia, engineers tend to use a greater variety of resources and rely more on formal channels for information; however, practising engineers, rather than search for a set of documents on a topic, seek immediate answers to specific questions even among colleagues and personal connections, making the library a least preferable choice (Tenopir, King, 2004). They prefer easily accessible channels over higher-quality sources (Toraki, 1999), since they tend to seek information and use knowledge to make decisions, contrary to scientists, who generally use knowledge to create new knowledge (Pinelli, 2001). This sought after information, as discussed earlier on the historical work of Leonardo Da Vinci, comes in the form of both texts (verbal means) and physical manifestations (non-verbal means).

Information on Physical Objects, read and assimilated through Experiential Learning

Admittedly, reading and writing have been integral to the development of humankind through the creation of texts, which carry meanings and ideas capable of being instilled in the minds of their recipients. In his seminal work on semiotics, Roland Barthes (1964) considers language as an intermediate object between sound and thought, thus being the medium for communication, distinguishing a word's physical manifestation, its *image* as a written text and *sound* when the text is made audible, otherwise called the signifier, and non-physical dimension, its *meaning*, or the intangible idea it conveys, called the signified. These elements comprise the means of using, storing and conveying verbal information. However, Western society being compulsively verbal in communication and thought, seems to distrust visual communication and evidence, linking it to the preliterate people and artists, relying on written text to guide reasoning (Collier, 1986, p.154), which results in the omission of the rich information that an image, object or experience may carry and convey. Considering the non-verbal elements, correlations can be established with the concept of affordances and constraints existing on physical objects in order to make them understandable and information conveying, with the *image* and *geometry* of things being the signifiers, and the *meaning* and *ideas* they carry being the signified (Norman, 1998, p.9). Norman argues that knowledge can be embedded 'in the world' that has been artificially built, being declarative, (e.g. stopping at a red light), or procedural, (e.g. the accumulated skill of performing music), underscoring the importance and responsibility of those creating 'the world', i.e. engineers, designers etc. as meaning givers to matter. Procedural knowledge is mostly learned through practice and taught by demonstration (Norman, 1998, pp.57-58), most probably requiring time and effort in iterative trials before it is conquered, even if one commences e.g. a solution to a problem without any given strategy (Anzai, 1979). This continuous process of trial and error until one, per trial, gets closer to the optimal solution, generates knowledge as it progresses, known in literature as 'experiential learning' -a method where the researcher must be holistically involved in the process of learning by thinking, feeling, perceiving and behaving towards her goal- the developing experience being the catalyst for the creation of knowledge (Kolb, 1984, p.31). Importantly, after each trial, the availability and analysis of feedback is highly beneficial for the researcher to move forwards (Huber, 1991), as this can be an indication of whether the original research hypothesis can be validated or not. Simultaneously, to the unaccustomed observer, 'experiential learning' creates the impression of solving a problem on-the-go, in a non-scientific manner. However, it is noted that refined knowledge (or the scientific approach) and common sense (seemingly a non-scientific approach) need to be in constant dialogue during the process of 'experiential learning' (Kolb, 1984, p.38) in order to create meaningful, reasonable and rich research outputs.

In the above sense, the act of creating iterative physical geometries, otherwise called prototypes, to lead and develop new ideas and research themes of interest is based on prior knowledge, observation and novel tests manifested in the forms of not only freehand drawings but mock-ups and scale models of artefacts. It is important to mention that some engineering design faculty have begun to recognise the benefits of the aforementioned learning processes in order to develop the creative skills of engineers (Moon, 2007, pp.208-209). In this light, 'making', as thought of by the Maker Movement[3], is a multisensory craft of thinking, problem solving, tinkering and developing tangible ideas where the 'maker' is involved holistically in the hands-on research towards solving her problem, researching by doing, using all kinds of verbal and non-verbal information at hand, generating knowledge along the way. Pinelli (2001, pp.136-137) argues that the difference between scientists and engineers lies in the outputs of their studies and results. Both need information, but scientists tend to use and create verbal information, made easily available through journals etc., whereas engineers need both verbal information -the output from sciences like physics, chemistry, which are relative and contribute to engineering- and non-verbal information. Their output, however, is mostly non-verbal, producing physical research outputs, often complemented by a verbal documentation of the process. This non-verbal output can be demanding for the information scientist to collect, even though it can be the highlight of the research output. An engineering library, therefore, might need to find new ways of collecting, categorizing, and providing the full extent of the information required by engineers.

The Reading-of-Things Laboratory in the Library of the Technical Chamber of Greece

As Gutenberg democratised the ability to distribute written text through typography and printing, 3D printing, a technology developed in the 1980's, is capable of creating physical objects out of digital geometries made with computer aided design (CAD) software. Only a creators' imagination can halt her from what can be created, be it mechanisms, objects or environments, items which are part of our modern digital cabinet of curiosities. Compared to the past, 3D printers can assist prototyping geometries in a fraction of the time and cost. Moreover, geographically dispersed communities of 'makers' of digital information with access to similar desktop manufacturing equipment can collaborate, coordinate and create as peers, testing and validating ideas and assumptions, as well as exchanging feedback and opinions on their developments.

Nowadays, numerous libraries worldwide, from academic, (e.g. engineering faculty, biology etc.) to public or school libraries, offer 3D-printing services. Patrons can request a 3D print and use the equipment under specific policies and limitations, a type of service within library walls called a makerspace, which may offer various tools other than 3D-printing services (e.g. gardening, sewing, etc.). Should a 3D-printing service in a library for engineers function as a

[3] The Maker Movement is a social movement celebrating technological and non-technological creations made by professionals and hobbyists alike, based on the DIY culture, hacking and tinkering with existing devices and experiences and creating new ones.

mere photocopying machine? Could the presence of a 3D printer justify the name makerspace? Does the context of being within a library, with the aim to provide the fullest information possible, make no difference for the service a 3D printer may offer? The information-seeking habits of engineers, their way of studying and the historical facts discussed above may already give us a hint at the answer.

The Technical Chamber of Greece (TEE / TCG), being both the professional organization of Greek engineers and the technical consultant to the Government, aims at developing Science and Technology sectors related to its members' disciplines, helping the economic, social and cultural development of Greece, in accordance to principles of sustainability and environmental protection. Among other services offered, TCG is the mother Institute of a special technical library in Athens, founded at the beginning of the 1930s with the mission to serve the interests of TCG administration bodies, engineers all over the country, and anyone interested in engineering. Its collections encompass more than 68,000 book titles, 600 journal titles, Greek and European technical legislation and a rich digitised collection of the scientific work carried out by TCG. In mid-2018, with the already widespread use of desktop manufacturing, makerspaces and aware of the benefits they bring to technical research, members of the TCG Board responded with an investment to create a space within the technical library, offering basic 'making' services; a 3D printer, basic electronics toolkits, a PC workstation with CAD software, a portable photo studio operating as a 3D scanner and basic crafting tools now equip a dedicated room, the Reading-of-Things Laboratory, and are made available to library users for research and non-commercial purposes.

Although still in its early stages, the Laboratory is able to host small groups of visitors willing to experiment on their research theme, aiming at the conjunction of verbal and non-verbal outputs. Specialised photogrammetry software allows users to combine a range of digital images of a physical object and recreate them within CAD software as the 3D digital geometry of the original object. CAD software can then be used to edit or alter this geometry before it is printed on the 3D printer, thus creating a new physical artefact, available for observation and feedback. Additionally, collecting and being interconnected with online archives containing digital files of 3D geometries, a visitor may commence her research based on an existing digital 3D geometry, available under an appropriate license, and develop a solution iteratively. Furthermore, the users are encouraged to submit information regarding their original research scope, their intention, and their final findings, providing verbal information. Considering serendipity, all users are prompted to keep an open eye on the book collection within the library, while staff has been made aware to be of extra help to locate information and assist with their research.

Conclusion

Engineers, as presented in this paper, have special information needs which exceed the commonly associated format of the library medium, that of texts and books. Creativity in technology and innovation requires observation, collections of things (objects and artefacts), and information in texts. This has been a well-known fact since ancient times, and today it may be necessary to remind ourselves again of the past. A room dedicated to reading things in the premises of a technical library is not a service detached from the main library services. It is a collection of information where patrons can read, observe and produce new information through a specific process. A technical library collecting information solely in the medium of text -or verbal information- cannot meet the users' wide information needs which may include physical manifestations and non-verbal artefacts, hands-on experiments and results of experiential learning. Furthermore, it ought to be accepting to open ended research and serendipitous discoveries, able to foster creativity and beneficial developments. And in the evolving technological world of today, where globally, the speed of new innovations is higher than ever, it is only natural to search for new ways to 'address, support, and host the complex discovery-related priorities and concerns of its patrons', as stated by Carr (2015).

The Reading-of-Things Laboratory, a room within the Technical Library of TCG dedicated to observation of artificial environments, experimenting and experiential activities, is a step towards helping engineers to develop their curiosity in the hope to challenge norms, aiding patrons in their search to produce new innovative solutions and opening new paths for interesting cross-pollination of 'traditional' research formats with the latest technologies.

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