2016

Design

Klaus Krippendorff
University of Pennsylvania, klaus.krippendorff@asc.upenn.edu

3rd Draft of an entry for the International Encyclopedia of Communication Theory and Philosophy. Klaus Brun-Jensen and Robert T. Craig (Eds.) Wiley-Blackwell, 2016.

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Klaus Krippendorff
The Annenberg School for Communication
University of Pennsylvania
kkrippendorff@asc.upenn.edu

Overview

The etymology of "design" goes back to the Latin *designare,* which means to mark out, set apart, or give significance to something by assigning it to makers, users, owners, or particular uses. It has the same origin as "sign" and "designate," calling attention to something other than material qualities. It entered the English language in the 16th century, referring first to drawing in the arts, crafts, and architecture, and later to other purposive activity. In contemporary English, "a design" (noun) refers to a proposal, plan, or specification for realizing something: an artifact, a deliberate assembly, or a pattern. "Design" designates the field of design practices. The propositional phrase, "by design" implies intentionality, made for a purpose. The verb, "to design" or "designing" is synonymous with devising actions that lead to something, as in planning a career, designing an experiment, organizing a campaign, or proposing a law.

Designing is fundamental to being human. It creates innovations that enhance ways of living. Ancient human artifacts suggest that all human civilizations constructed material worlds they desired to inhabit, including their own cultural identities. In contemporary society, design is the engine that maintains its viability in the face of external and internal perturbations.

While practiced in all areas of human endeavors, this entry focuses on the professional design of artifacts for the benefit of diverse stakeholder communities. It sketches the emergence of the design profession from its original preoccupation with crafts and industrial products, through its embrace of larger, more complex and abstract challenges, to efforts of designing and re-designing its own design discourses. In the course of this development, designers became increasingly cognizant of their larger objective of encouraging technological developments by rendering them individually and culturally meaningful. Successful designs not only energize supportive stakeholder networks, which are essential for their realization, they also intervene in the dynamics of existing cultural ecologies of interacting artifacts. While designing is always intentional to begin with, the consequences of introducing differences in how ecologies of artifacts respond are not easily, if at all, predictable. The latter point is exemplified here by the design of artifacts that grew out of human conversations and gave birth to other forms of human communication: monologues, discourses, social structures, and computational systems. The ethical imperative not to impair communities that cannot participate in a design calls for an ecological understanding of what designers' actions set in motion.

A brief history of professional design

Arguably, the design profession was born in 19th-century England. In 1837, the Normal School of Design opened in London—60 years later it became the Royal College of Art. This initiative was the first formal use of "design" by a government that recognized the need for educating "manufacturing artisans." Its courses included drawing, painting, and modeling ornamentation. Its objective paralleled the rise of the Arts and Crafts movement, which reacted against the increasing availability of low quality and excessively decorated mass products. William Morris (1834–1896), an outstanding spokesman of this movement, advocated traditional craftsmanship, symmetry of forms, colors and decor, and utensils whose forms are consistent with what they are made of. His criticism of meaningless ornamentation, largely of furniture, wallpaper, and textiles, was motivated by social ideals. He envisioned a society of free crafts-people and encouraged artists to be craftsmen-designers working by hand. The separation of the intellectual act of designing and the manual act of making, which dominates current conceptions of design, was considered both socially irresponsible and aesthetically offensive by this movement.

The British Arts and Crafts movement's revitalization of folk art inspired several national design movements in Continental Europe: Art Nouveau started in Belgium; De Stijl emerged in the Netherlands; the "Werkstätte" came to life in Vienna, and the "Werkbund" in Germany; Karin Larsson inspired Swedish design. However, Louis Henry Sullivan's (1896) dictum "*Form Follows Function*" began to undermine the idea of national styles. The German Bauhaus (1919–1933), under the leadership of Walter Gropius, moved out of an Arts and Crafts environment in Weimar to Dessau, later Berlin, where it fully embraced mass-producible geometric forms with the vision of improving the lives of many (Pevsner, 1965). Closed by the Nazis for pursuing socialist ideals and "degenerate art," the Bauhaus is currently associated more with abstract art than with the manufactured products it left behind.

While the Arts and Crafts movement and the Bauhaus were fueled by cultural visions, at the beginning of the 20th century, industry recognized the benefits of hiring architects and artists to give its products aesthetically appealing appearances and created numerous employment categories. Industrial, graphic, fabric, interior, and fashion designers, to name but a few, were called "applied artists" for their aesthetic abilities. In Europe, designers were called form-givers, in Germany "*Gestalter*," attesting to their professional ability to find appropriate and coherent forms or gestalts, rarely acknowledging that these narrow assignments served to expand the markets of industrial products.

In memory of the Scholl siblings, who were executed in 1943 for antifascist acts, and with the intent to contribute to the reconstruction of post-World War II material culture, not only in Germany, the Hochschule für Gestaltung (HfG) Ulm (1953–1968) was founded by former Bauhaus students and teachers. This university of design fully embraced "*Form Follows Function*" as a design principle but extended its functionalism to scientific, socio-cultural, perceptual, and system-theoretical conceptions. Its four departments concerned product forms, visual communications, industrialized architecture, and information. True to its avant-garde nature, the HfG was closed after only 15 years. However, its design curriculum inspired numerous educational institutions all over the world and its philosophy has guided the development of many celebrated designs. The appearance of Apple products would fall in this category, now called the "international" style for its seeming culture-neutrality. However, Apple's attention to user-interfaces and actionable meanings (Krippendorff, 2006) were not part the vocabulary at the HfG and contemporary institutions.

A trajectory of human-centered artificiality

The Arts and Crafts movement, the Bauhaus, and the HfG Ulm professed sociocultural visions but sought to accomplish them by designing products of everyday life: tableware, furniture, radio receivers, office equipment, and even public transportation. When working with manufacturers, designers were expected to collaborate with engineers in the development of specifications that could be turned into functional, useful, and widely affordable products. Figure 1 depicts *industrial products' forms and functions* as the original preoccupation of professed designers. International ambitions and beliefs in the universality of aesthetics had the unintended consequence of celebrating the lifestyle of the industrialized West at the expense of cultural differences. These convictions encouraged the distinction between developed and underdeveloped countries.

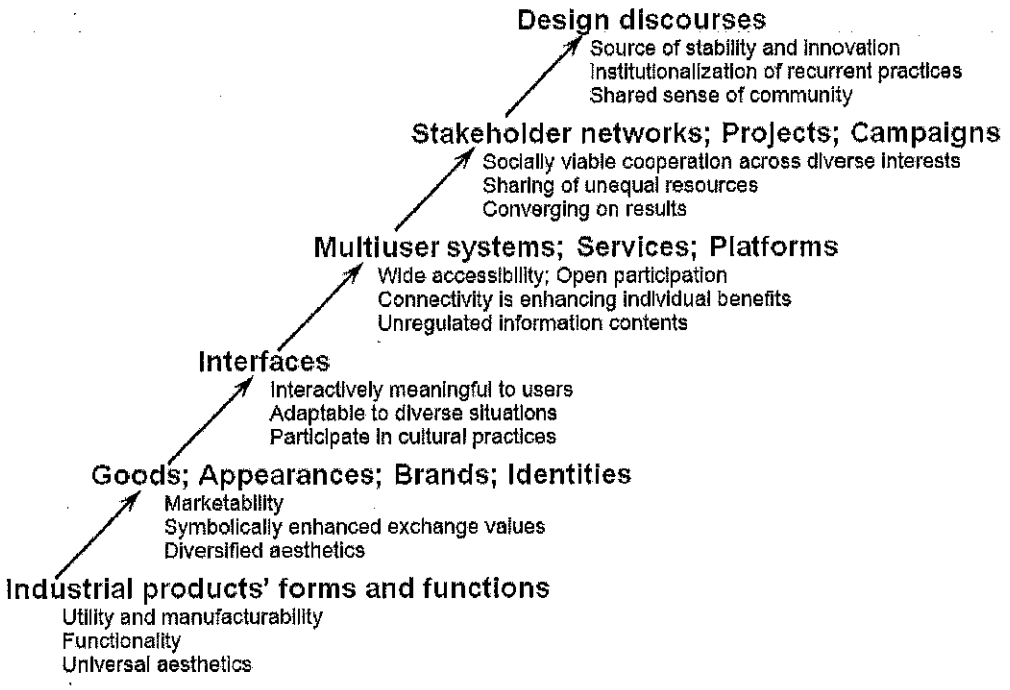

Figure 1: A trajectory of artificiality and its guiding design criteria

Starting in the late 1920s, US design shifted its attention from functional, aesthetically justified, and utilitarian mass products to that of marketable *goods*. For Raymond Lowey (1893–1986), design aimed at sales-enhancing *appearances*, *brands*, and public *identities* of manufacturers. Products for use became goods for sale. Lowey started as a window dresser for big department stores, designed the famous Lucky Strike cigarettes package, and "streamlined" numerous consumer goods, cars, and even locomotives. He stood for a design principle called "MAYA," an acronym for "*Most Advanced Yet Acceptable*," suggesting that designers should not go beyond what public taste accepts. The idea of a universal aesthetics lost traction to the recognition of diverse preferences in a growing consumer culture. The commercialization of design was not appreciated by many European design communities that, especially in the aftermath of World War II, faced socioeconomic issues unlike the United States.

The digital revolution presented new challenges for designers. Until the 1970s, everyday artifacts were usable with a few easily understandable options. By contrast, mainframe computers, used by large corporations and the government, were operable only by experts. The

idea of making computation available to everyone drove visionaries like Steve Jobs and Steve Wozniak, the Apple founders, to develop the personal computer. The realization of their vision called for designers to acquire a new expertise: the ability to connect complex computer hardware with everyday practices. Combining familiar artifacts—television screens plus typewriter keyboards—made computers obviously recognizable. But the design of human-computer *interfaces* began to rely on easily understandable *metaphors*, for instance, files to organize bit strings, trash bins to make unwanted texts disappear, and menus to choose alternative paths. Ordinary gestures of pointing, selecting, dragging, cutting, and pasting images and texts on a computer screen could be performed by a computer "mouse." The design of user-friendly interfaces made it possible for sophisticated hardware to participate in diverse cultural practices.

The success of enabling ordinary users to handle devices whose makeup they could not possibly understand encouraged an epistemological shift in what designers were asked to address. Krippendorff (2006, p. 47) put forth the axiom that "humans do not respond to the material composition of things but interact with their world according to what its artifacts mean to them." Turning away from essentialism, this shift called on designers to become cognizant of how individuals speak of, perceive, and interface with their world. Designs could no longer be seen as specifications for manufacturing products or goods to be sold, but as creating culturally meaningful spaces within which communities of users could interactively realize their own worlds.

Interface design largely summoned culturally available resources to enable individual users to handle individual artifacts. However, the digital revolution moved far beyond the problem of handling single machines. Personal computers became variously connected and challenged designers to cope with *multi-user systems, platforms*, and *services,* which provided interactive benefits to many, largely unknown users. The Internet, for example, is a vast system for transmitting, storing, and retrieving bit strings controlled from individual computers. The design of the Internet protocol is quite simple. It provides reliable connections among huge volumes of bit strings, manageable from countless locations. The value of the Internet for its users increases exponentially with their numbers. But its design—how it works—is quite separate from what diverse communities of users *do* with it. For example, information does not reside in the Internet but results from how readers make use of it. Designers were asked to afford multiple user conceptions. The design features of the Internet—open access, enhanced connectivity, and the freedom to enter, leave, and interpret what it does—became a model for the design of smaller multi-user systems: online discussion groups, electronic businesses, governmental services, and social media. Even libraries, fast-food restaurants, sports events, political campaigns, and start-up businesses came to be designed as multi-user systems whose materiality is secondary to how human participants see themselves participating in them.

The interactive realities that multi-user systems started to encourage questioned the traditional target of designers: the end user. This all-too-convenient fiction could have been recognized long ago. Consumer goods are not necessarily purchased by their users and after their retirement: actors with other interests almost always come to the fore to repair, recycle, and dispose of what is left of them—not to forget environmental activists and cultural critics. Whenever designs exhibited uncommon complexities, business executives, suppliers, engineers, financial backers, government regulators, sales persons, buyers, potential users, and advocates for the environment had to be brought on board. Each grouping had institutionalized stakes in

such designs and jointly controlled whether they led to anything. The recognition that "the fate of a design is decided within the network of its stakeholders" redefined designs as communications whose qualities either energized existing or actively assembled *stakeholder networks* or came to nothing.

Early responses to recognizing the decisive role of stakeholders' expertise encouraged designers to invite members of potentially affected communities into the design process, creating user-laboratories and practicing what became known as participatory design. This still left designers in charge. However, success within more complex stakeholder networks called for designers to possess not only rhetorical skills but also a willingness to delegate at least parts of a design to those able to contribute their creative competencies, resources, and interests to designers' *projects*. Conceptualizing designs not as specifications for innovations to be followed, but as invitations to stakeholders to network their contributions toward results, enabled designers to become respected participants in larger and more complex interdisciplinary developments.

Arguably, the most important challenge for contemporary designers and the one currently addressed by several research centers is the design of viable *design discourses*. With the exception of the socially motivated origin of design, the progressive extensions of designers' competencies, depicted in Figure 1, responded largely to industries' need to preserve the cultural relevance of their products in the face of emerging technological developments. The claim that "design is to make sense of things to those affected" fits that response.

However, since the HfG Ulm, efforts to develop design methodologies (Cross, 1984) have encouraged designers to become proactive in shedding the public image of "applied artists," and to define their own profession by engaging in original research, formalizing design methods, developing theories of the design processes, and teaching proven design principles. In the 1960s, Horst Rittel (Protzen & Harris, 2010) and Herbert Simon (2001) laid the groundwork for an epistemology of design. They had opposing takes on how design was to proceed, but agreed on how scientific and design discourses differed. Scientists aim at theorizing how the world works; designers, at what could be changed for the better. In his *The Sciences of the Artificial,* Simon argued that the logic of design is not propositional but *deontic*, concerned with solving problems systematically. Rittel described Simon's conception of problems as "tame," and instead focused attention on nontrivial or "wicked" design objectives. He recognized that designers' inquiries cannot be separated from the researching designer's possible actions. According to Donald Schön (1983), designers have to see themselves as reflective practitioners. Currently, design research embraces ethnographies of unrecognized possibilities, searches for combinable technologies, paths to innovation, experiments with the feasibilities of alternative designs, assessments of the interests and capabilities of potential stakeholders, and postdesign research to learn from what happened after a design was launched. These efforts aim not only at sound justifications of individual designs, but also at communicable design discourses that can serve design education and defining the design profession in the public sphere.

Design research, theories, principles, and methods are intimately tied to the constructive use of language among design theoreticians and practitioners, in interdisciplinary collaborations, and with stakeholders. Current design discourses are far from united. Different design thinkers promote their own discourses but they all inform design education on several levels, including doctoral programs.

The cultural ecology of artifacts

Figure 1 sketches the increasing number of objectives that professional designers have learned to pursue. It does not depict a history of design but a history of designers' diversifications and their slow embrace of cultural and discursive contingencies. This section goes beyond designers' attention and sketches a cultural ecology of the human use of artifacts (Krippendorff, 2006: 193–205), to which designers ultimately contribute.

Ecology explains how large numbers of species of organisms interact with one another, feed on each other, find niches to reproduce, proliferate, evolve, or become extinct. Commonly, it concerns species of animals and plants living in environments of nutrients and hazards. Although the human species is of necessity part of this ecology, it is largely ignored except when environmentalists point out how human activities cause rare species to disappear or disrupt ecological balances. Gregory Bateson (1972; Bateson, 1991), by contrast, became seriously concerned about the consequences of conscious purpose (i.e., of design) on the ecology. Unfortunately, designers who acknowledge the ecological effects of their designs tend to limit their concerns to using biodegradable materials or supporting recycling. A larger perspective was needed.

Kenneth Boulding (1978) observed that we know far more species of artifacts than species of living organisms: shoes, bottles, clothes, books, automobiles, tools, fasteners, furniture, paintings, airplanes, buildings, coal mines, streets, and telephones. Encyclopedias, department stores, and the Internet listings provide only small windows to this diversity. Species of artifacts also cover far greater ranges than biological species do. Skyscrapers are larger than whales. Jet planes are faster than birds. Computers have larger memories than living organisms, although of a very different kind. Satellites move where no biological organism could survive. The Internet connects more people and places than any living organism could ever visit.

Superficially, species of artifacts resemble species of living organisms: They are produced in great numbers, interact with their environment, and become prominent or extinct in ways difficult to predict. However, species of artifacts do not reproduce themselves, nor do they act in their own interest. Their mass production results from human activity and their interactions proceed in human terms, at least initially. Ecologies of artifacts are part of human culture and society. While ecology is a human discursive construction, what it hopes to explain escapes the possibility of designing it. It emerges from millions of stakeholders actively connecting trillions of available artifacts with each other and to their own actions, all in the expectation of improving the lives in their communities.

So, individual artifacts are produced by diverse stakeholder communities, craftspeople, manufacturers, and corporations, largely for their own benefits, not for that of their products. Once produced, artifacts compete. Not, however, for their own survival but for fitting in diverse discourse communities' conceptions. Markets offer competing goods and services, described largely in economic terms. But their exchange values are mere correlates of how well artifacts could conceivably cooperate in larger complexes that enable their buyers to maintain or improve their conceptions of social reality.

Ecologies of artifacts differ from ecologies of living organisms in another way, by cooperating largely across diverse species, and less within their own. Living organisms cooperate largely within their own species and with a few species that support them, but compete with other species for their survival. By contrast, the human use of artifacts is fundamentally one of

causally connecting artifacts from diverse species into larger cooperatives. Wiring a printer, fax machine, and a computer to the Internet coordinates their interactions in ways not explainable from either device. Designing cars to cooperate with roads and drivers enables the latter's locomotion. But when millions of people transport themselves, complex collaborations of cars, highways, road signs, traffic regulations, car manufacturers and dealers, gasoline stations, oil producers, and local governments, not to forget traffic courts, emerge without a master plan. The net effect of many stakeholders in diverse artifacts, each enacting their own conceptions, establishes extremely complex ecological systems of artifacts. Individual artifacts may break down and call for their replacement—justifying their mass production. Newer models of familiar artifacts may compete with those in place but tend to shift the dynamics of such systems only slightly. Figure 2 sketches the abovementioned relationships.

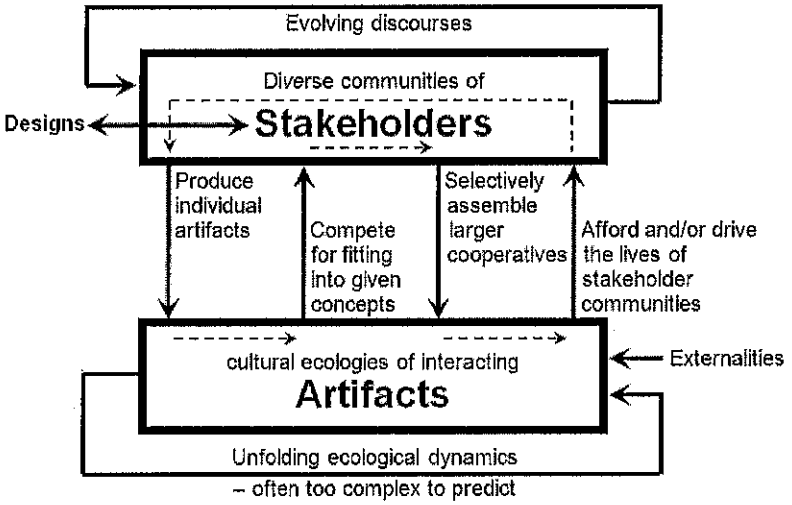

Figure 2. Determinants of a cultural ecology of artifacts

Unlike ecologies of living organisms, systems of cooperating artifacts tend to grow around artifacts that can attract other artifacts to cooperate with, an ability that accounts for how species can become dominant. The increased use of automobiles encouraged the design of highways, cities, oil explorations, and insurance companies. Similarly, personal computers grew in importance with software developed to expand their usability, and mobile phones with increasingly available apps. Supportive species of artifacts tend to overcome the initial limitations of a potentially dominant species, cannot exist without it, enhance the frequency of both, but then may well become primary movers of ecological complexes.

For any one artifact, competition in the marketplace is short-lived and relatively easily explained. But competition may also occur among larger ecological complexes. The well-documented competition between automobiles, public transportation (buses, subways, and railroads), and online work (through the Internet) has a long history. It emerges in the complex causal interactions among artifacts that surround the dominant technologies just mentioned. This dynamic is fueled less by exchange values than by the large-scale enactment of continuously evolving individual conceptions in the politics of institutional narratives.

However, causal connections are not the only constituents of such ecologies. When sitting in a garage, a car is not causally engaged but has the potential to become so. This exemplifies a

second way for artifacts to become ecologically connected: by association, by subordination to normative categories, or by playing parts in widely shared narratives. Table settings, the furniture in offices, the house of a parliament, and appropriate clothing worn by a judge in court are not causally active but normatively organized. Distinct styles, norms, and family resemblances distinguish among artifacts that belong and those that should not co-occur. Artifacts that do belong support each other conceptually. Their correlation may serve as a condition for something else to go forward. For example, legal proceedings may not start until all preparatory conditions are met.

A third ecological connection among artifacts is metaphorical. Metaphors are rooted in language as well. They structure the perceptions and interactions of users by importing experiences with more familiar species into the use of less-structured or novel artifacts. Interfaces with personal computers, mobile phones—in fact most information technologies—rely on such metaphorical connections. Talking of "platforms" in social media makes sense only with experiences of interacting with people that share a common ground. "Navigating" or "traveling" in cyberspace relies on the experiences of moving on one's own accord. Human-computer interactions draw heavily on experiences from the paper world of documents, files, and desk tops. Without such metaphorical connections, computers would have remained in the hands of a few experts and the digital revolution we are witnessing might never have emerged the way it did.

Understanding how such widely distributed and variously interpreted culture-specific narratives are enacted is the key to understanding how ecologies of artifacts are assembled and interact, and how discourses concerning them evolve. The extinction of typewriters was certainly motivated by recognizing their limitations after personal computers arrived on the scene, but the ecological consequences of replacing them could hardly be anticipated. By contrast, as a means of transporting people and goods, horses did not become extinct even as more convenient cars assumed that role. They survived in ecological niches of sports and hobbies while automobiles unpredictably emerged as a dominant species.

Creating differences

Designs are innovative by definition. All proposals project something that does not yet exist but claim the potential of being realized. Introducing designs into cultural ecologies of interacting artifacts intervenes in their dynamic. Designs that succeed in making differences tend to do so by expanding or improving some dimensions of human concerns at the expense of lessvalued other dimensions. However, such tradeoffs, typically justified by their designers and accepted by their beneficiaries, often result in unintended ecological consequences. They could lead to ecological disequilibria, give rise to surprising ecological revolutions, or cause unexpected extinctions. The example of designs that improve conversations illustrates the dynamic consequences of introducing differences into established practices.

Conversations are arguably the most mundane forms of human communication, starting as early as child's play. Among adults, they are the fastest evolutionary process imaginable. In conversations, ideas are freely generated, elaborated, agreed upon, and enacted or superseded by better ones. Most technological innovations are known to emerge in conversations, which is why designers often work in teams.

Genuine conversations easily devolve into other forms of communication (Krippendorff, 2009). Lectures, debates, and interviews follow conventional rules that restrict what can be said, to whom, and how. All discourses—scientific, legal, medical, public, and private—not only converge on specialized vocabularies, they also specialize in constructing discourse-specific realities, artifacts, whether they be predictive theories, legal judgments, medically treatable illnesses or disabilities, elected representatives, and family secrets. Discourse communities organize themselves by institutionalizing recurrent discursive practices, legitimizing methods and encouraging the emergence of social hierarchies of offices, experts, and privileges. All of these well-known features of discourses limit the freedom experienced in conversations while expanding the scope of their practitioners' accomplishments. Generally, designs to improve human communication can be seen as devolving conversation.

The earliest artifact that expanded conversations is writing. Its designers are unknown. Evidence suggests that it started as numerical accounts for transactions. Writing made human memory more enduring, and enabled more people and dispersed communities to share what had been articulated, far beyond the reach of human voices. However, writing required literacy, introduced social inequalities, and concealed the faces of its authors. One set of unintended consequences was the rise of empires, durable authority, and power (Innis, 1950). Another came with the spread of literacy. The Enlightenment sciences undermined religious authorities by issuing their own texts, and newspaper publishing subsequently supported public discourses that led to democratic forms of government.

The telephone was invented to transmit music by wires, something that escaped writing. However, its use soon morphed into allowing people to talk at distances without having to be literate, eliminating the time needed for responding to and in writing, and assuring the privacy of users. These benefits were knowingly offset by bandwidth limitation to verbal communication between just two parties, without leaving records behind. Among the unintended consequences of widespread uses of telephones was the emergence of flexible forms of social organizations that could speedily coordinate transactions across national and continental boundaries. Despite its inherent privacy, the telephone facilitated the emergence of international corporations and increasingly vicious military excursions.

The radio followed the telephone but built on the asymmetry of newspaper publishing: one-to-many communication. In 1931, Albert Einstein heralded the radio as a democratic medium, serving everyone. However, because radio transmissions required costly technology and could operate only in government-regulated frequencies, the radio served totalitarian governments in Nazi Germany and the Soviet Union. In the United States, the radio and later television served as the medium of spreading commercial and political interests. Scholarly research that defines communication in terms of media effects legitimizes these consequences.

Facebook was designed for friends to stay in touch, something that the mass media could not provide. It adopted some interactive features from conversations but soon mushroomed into a profitable business of connecting huge numbers of people, labeling them "friends" though most had never met in person. Facebook required contributors to have names, but provided no means of authentication. Virtually all social media platforms limit posts to short messages and comments. Some messages go viral, other are not responded to. The creativity within social media is almost as in conversations, with freedom to post nearly anything. However, coupled with the anonymity of participation, that freedom has the unintended consequence of leaving outrageous comments, invalid claims, and hate-speech unchecked. Moreover, the brevity of

messages favors relatively shallow concerns, and their speedy dissemination and ability to mobilize large populations of users can lead to volatile expressions of public opinions and actions. For example, the Iranian uprising and the Arab Spring were fueled by social media, created hopes for political changes, but could not deliver any.

The abovementioned designs were inspired by perceived limitations of conversations, and spread widely for providing recognizable benefits to individual users, but their common use caused unimaginable public discourses to emerge. Designs introduced in less public discourses follow similar patterns.

By adopting various designs exemplified above, all discourses develop specialized vocabularies to create and maintain discourse-specific realities. Some of their terms refer to routine and institutionally regulated practices, for example, calculating, copying documents, bookkeeping, generating and analyzing data, validating information, and making collective decisions. Discourse communities tend to be open to replacing such routines by tools that their practitioners can handle. Calculators have been around for a century. Copying machines and printing presses replaced copying documents by hand. Analytical software replaced lengthy hand calculations, and PowerPoint presentations made drawing on blackboards obsolete. Everyday devices that could share computational processes found themselves bundled in mobile phones. All of their apps are tools that replace routine practices.

However, the more successful designs do not merely replace routinely performed behaviors, they expand human abilities. Search engines are designed to scan thousands of documents for a reference. Optimization algorithms run warehouses, air traffic, and newspaper publishing. Authors of scientific work are asked to submit their articles on Web sites tied to nearly automated systems that produce journals with only minimal human supervision. All so-called mindless or rule-governed jobs are good candidates for replacement by computational devices that are designed to perform them faster, more reliably, and cheaper, and to do more than what humans could. For example, trained bank tellers are being replaced by automatic teller machines (ATMs), designed to be continuously available.

One of the unintended consequences of replacing human behavior by designed algorithms is the constraints they encourage on the ecological diversity of human ingenuity. For instance, computer content analysis software tends to be billed as able to extract content from texts without the use of costly and notoriously unreliable human coders and analysts. Being impressed by the speed and volume of texts that such software can process and unable to judge how it does it tends to shift the researchers' concept of content from what careful readers can discern to what the software produces. Blindly trusting such computational results sows doubts about human abilities and dismisses as divergent text interpretations that may well be validated in conversations. The enthusiasm about "big data" exemplifies surrendering human judgements to the results of computations. Another example is the Diagnostic and Statistical Manual of Mental Disorders (DSM), which forces therapists to use its vocabulary in order to be paid by their patients' insurances. Alternative concepts of mental functioning that do not fit DSM's definitions are effectively removed from psychiatric discourse. To pursue them anyway has a good chance of being considered unprofessional, perhaps even grounds for malpractice suits. Whenever one relies on algorithmic or rigidly designed replacements of human intellectual competencies, insightful, rare, unconventional, and novel interpretations are likely to be dismissed as deviant, and removed from the prevailing discourse.

Another consequence of such replacements is diminished control by human agency. For instance, the discourse of artificial intelligence (AI) is dedicated to design mechanisms whose intelligence equals or exceeds that of humans. AI's project has not succeeded but is producing responsive automata that exceed human abilities in a few dimensions and can be implemented to work with little or no human supervision: robots, driverless cars, automated online shopping, and high-frequency trading (HFT). HFT algorithms are designed to respond within milliseconds to small changes in financial data and reap profits well before human traders are able to notice what is happening. The participation of HFTs in trading securities, however, has also increased the volatility of markets beyond human imagination, and is considered the probable cause of the 2010 "flash crash"—which ruined several otherwise sound corporations. These uncontrollable and, for some corporations, fatal consequences have led to demands to outlaw HFTs altogether. In this case, the delegation of human agency to a designed artifact is at least being questioned. Most artifacts—designed, assembled, and installed with good intentions—set ecological processes in motion whose social consequences may surface only in a distant future that will have forgotten its past.

While design is indispensable in keeping a culture viable, it also feeds differences into ecologies of artifacts with ramifications beyond good intentions. The ethical imperatives to not debilitate communities that had no voice in a design, and to self-critically examine the design discourses of the culture in which they are practiced, challenges designers to face the complex ecological consequences of their interventions.

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Keywords

Artifacts; Computation; Conversation; Discourse; Ecology; Innovation; Institutionalization; Interfaces; Products; Social Constructivism; Stakeholder Networks; Technology

Author bio

Klaus Krippendorff is Professor of Communication Emeritus at the University of Pennsylvania's Annenberg School for Communication. He is a past president and an elected fellow of the International Communication Association (ICA), elected fellow of the American Society for Cybernetics (ASC), the American Association for the Advancement of Science (AAAS), and the Society for Science of Design Studies, Japan. He has published widely on theories of communication, conversation, cybernetics, content analysis, social science methodology, and the design of cultural artifacts. His current scholarly interest centers on the consequences of language use, specifically on the discursive construction of social, technological, and material realities, and, with the lens of a critical scholar, on the possibilities of emancipation from burdensome social or political constructions.