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Contextualizing 3D Printing's and Photosculpture's Contributions to Techno-Creative Literacies

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Introduction

Autodesk CEO Carl Bass, upon the 2011 release of Autodesk's free "123D" CAD-to-3D printing software, claimed that the future of design innovation would be found not within the engineering industry, but from the ranks of creative, tinkering consumers. "There are tens of thousands of people—if not more—who want to create something," celebrated Bass, "… an unbelievable community of people who want to be making things."[1] Similar messages of the creative, even transformative potential of consumer-level additive printing technologies were echoed by TechShop CEO Mark Hatch, Lockheed Corporate Director Steve Betza, and Adidas Creative Director Paul Gaudio. "Bringing the familiar into the future; marrying the qualities of handcrafting … with the limitless potential of new manufacturing technologies," dreamed Gaudio of consumer-created product design.[2]

While there is more-than-a-little marketing speak running through these messages, it would be wrong to dismiss the above as merely CEOs glossily pitching new wares; Bass, Hatch, Betza, and Gaudio represent only a handful of a multitude of companies that appear to be tapping into a kind of consumer-creative *zeitgeist*, a cultural drive to "reclaim" a past where artisans and entrepreneurs embodied a liberated "creative class."[3] As such, energy and excitement about the possibilities for 3D printing and small-scale manufacturing clearly exist beyond industry: in non-profit and community groups offering access to community "makerspaces,"[4, 5, 6] in universities where even social science and humanities departments are beginning to offer studio-based, "hands-on" educational elements in their curricula,[7, 8] and in US government funding agencies like the National Science Foundation (NSF) and the National Endowment for the Humanities (NEH), which are committing millions to "making" efforts across the United States.[9, 10]

As Gaudio's above quote illustrates, the transformative possibilities of 3D printing—and the general public's ability to take advantage of those possibilities—are often painted in technological or economic terms: consumer-level additive technology is, or will be 1) new and 2) cheap. As science and technology studies (STS) scholars have repeatedly demonstrated over the past three decades, however, technological promises and imagined futures are never exclusively derived from their mechanical properties or market values.[11, 12, 13] Rather, technologies are born out of and into social and cultural contexts, which contribute to a shaping of the understandings and further uses of those technologies.[14, 15] The promises of technology, in other words, are always contextual.

Through a historical comparison of two additive manufacturing technologies, 19th century photosculpture and 21st century 3D printing, we will trace some of the elements of past and current cultural *milieus* that contribute to the acceptance or rejection of consumer-focused creative manufacturing technologies. Though the history of proliferated 3D printing is relatively limited, the technology seems to have gained a foothold for future success in both general consumer and industrial markets. The same cannot be said of photosculpture, which—despite its similar technological properties, successful public demonstrations, and promises to liberate users' creative potential—was scorned by art critics and investors and was, in short order, relegated to a footnote in history.[16]

This paper will argue that one major social factor that differentiates the success of 3D printing from the failure of photosculpture is the changed ontological relationship between "art" and "design" from the 19th century to the 21st, including, importantly, the different fundamental goals of techno-creative literacy as mastery versus as experimentation and play. While photosculpture was damned by its contemporaries for its intrusion of mechanical processes into the "human" practice of art making, removing the capacity for mastery, 3D printing exists in a cybernetic world[17] where the boundaries between mechanical and human labor in the design process are more blurred, and play is encouraged. Thus, though photosculpture was dismissed as being unable to truly capture aesthetic "beauty" or creative "genius"—fundamental properties of artistic mastery—3D printing needs only to afford the ability to be "more creative." In an odd way, the rhetoric of 3D printing, particularly its ability to further galvanize a burgeoning popular creative movement, may be successful because of its lack of the ontological burden of art. In other words, because 3D printing does not have to strive to *be* art, it is free to do educational and critical work *beyond* art. We draw out some of the implications of this comparative history for technological literacies—both in terms of public engagement with technology and in terms of engineering education reform.

The Photosculpture Process

Photosculpture was developed in Paris by François Willéme in the early 1860s. Willéme's personal design documents first show sketches for a "mechanical sculpture" device in 1859, and by 1861 Willéme had filed two patents of his process.[18] Willéme, who had professional training as a sculptor and had conducted experiments with early photography, envisioned a device that could dramatically reduce the labor-hours and costs associated with the production of sculptures, particularly of busts and reliefs. At the time, self-portraiture was seen as a symbol of high socio-economic status; the production of a painting or sculpture could take months, and the costs of the artisanal labor, to say nothing of the props and wardrobes that were often made specifically for one *to be painted in*, were astronomical.[19] While by the 1850s photography had begun to make two-dimensional portraiture more accessible to the burgeoning *bourgeois* population, the commissioning of sculptural work was still firmly the domain of the elite.

Willéme's photosculpture process leveraged photography in order to rapidly prototype clay busts. The subjects who desired a sculptural portrait were seated in the center of a large, circular room, which was capped by a clear glass dome. From where the subject was seated or standing, 24 chevron shapes, like those on the compass of an illustrated map, extended outward on a circular dais. Each chevron served as a guide for the placement of a photographic plate, which was mounted behind a circular wall that surrounded the dais. The wall had 24 circular cutouts that served as the portal for light from the subject's room onto the photographic plates; each portal was covered by a curtain or slide, and the slides were all mechanically connected to one another.

At a "certain sign,"[20] an operator would simultaneously expose all of the photographic plates, and about 10 seconds later, would re-cover them to freeze the captured image. This process resulted in 24 pictographic, trans-planar “slices in the round” of the subject in the center of the room; effectively an early form of low-resolution 3D scanning. At this point in the process, the subject’s role in the production of the sculpture was effectively over—quite a change from the hours or days of sitting that a figure model could expect to endure in a traditional sculpting studio.

The 24 trans-planar slices were then projected, one by one, onto a screen using a magic lantern.[21] Artisans and shop workers would trace the outline of the silhouette, using a mechanical device that would carve the contours into a piece of clay. Rotating the clay and repeating the process 23 times resulted in a mostly-defined bust that featured a photographically-exact representation of the subject. Workers in Willéme’s shop would add final touches to the bust, mostly in order to smooth out the gaps in-between the 24 carved slices, and often to cast the sculpt in a layer of bronze. Importantly, these final markings imprinted upon the sculpt by human hands were one of the few moments where human hands were seen as having material agency in shaping the bust, a point of heavy critique of photosculpture as an art form, particularly by the British and French critical press.[22, 23] Historical accounts differ, but the entire photosculpture process, from photography to final casting, was said to take anywhere between 18 hours and 4 days[24, 25]—a radically shortened amount of time compared to the 2 to 6 months required by traditional methods of sculpture. By the end of 1866, there is evidence of the existence of or planned investment in at least four photosculpture studios across France, England, and the United States.[26]

The Response to Photosculpture

The photosculpture process was cheap and fast, making sculptural portraiture accessible to wide swaths of the *bourgeois* class. Technically speaking, photosculpture also afforded a mechanistic method of producing portraiture that was more mathematically and anatomically exact than could be achieved by the traditional “sketch-and-mold” methods of sculpture. These factors led to general praise of the photosculpture process by its clients; Willéme’s studio, as well as its offshoots in France and America, was relatively economically successful for the first few years.[27]

Critical success, however, did not follow the initial positive consumer response to the photosculpture process. Despite initial praise in *Le Monde* by art critic Théophile Gautier (who himself was employed by an investor in photosculpture),[28] critics in France largely derided the photosculpture process. The critiques levied against photosculpture were twofold, and sprung from the permeation of machine agency throughout the photosculpture process. The first critique was that the objects created by the photosculpture device were *too accurate*, and therefore did not strive to achieve the artistic sublime. The second, and more damning, was that the use of daguerreotype photography to capture the initial impression of the to-be-molded subject eliminated the need for artists to do initial sketchwork, which was considered by French critics to be the moment at which individual artistic vision and style were most pure and untamed, and most necessary for artistic mastery.[29] Let us take each of these critiques separately.

While the photosculpture process created geometrically-faithful representations of its subjects, critics bemoaned the lack of “genius” the device allowed its artists. Paul de Saint-Victor writes of the “soullessness” of the sculpts in 1866:

> These small portraits have neither life nor intelligence. They remind of *homunculi* manufactured by alchemists, stupid runts that could not be given a soul…. The body of the model in the photograph will always be deficient when trying to achieve a more complete and harmonious form. In making a god or nymph, a genius or a heroine from literature, the sculpture must ascend beyond the human model to achieve its rightful rank. (Translated from French by the authors)[30]

By capturing an exact likeness of the model, the photosculpture could not "ascend" to the status of great art, which for French critics required the use of imagination, physical exaggeration, and artistic license. Though this may seem like a trifling critique to contemporary eyes, where portraiture is understood more as documentation than as high art, the divide between documentary and glamorizing portraiture prior to the 20th century was not nearly as wide. The goal of portraiture, in fact, was not to represent *the body*, but rather to represent *the soul*. Foreheads were heightened to denote intelligence, skin was tone-shifted towards alabaster to suggest purity of spirit, muscles sculpted more sinewy to show strength and vigor, subjects cast in imaginary locales and backgrounds that revealed not where they *were*, but where they *belonged*.[31]

Thus, the vision of the artist was instrumental in creating the representation of the "inner self" of the subject; daguerreotype photography, of course, functions in exactly the opposite manner. This leads to the second critique of photosculpture: the photographs that become the literal guide for molding the clay replace the "artist sketch" as the first step in the sculpting process. As art historian and critic Michele Bogart outlines, the artist's sketch was understood as the moment in sculpting where the artist could be most expressive.[32] Expressivity was particularly important to late 19th century art theorists, many of whom were working towards the democratized institution of arts and drafting education across both liberal and technical education. Mechanical and anatomical drawing were seen as processes that could be easily mastered: given enough training and repetition, anyone, even a machine, could learn to reproduce on paper the dimensions of an object or person. Artistic education, then, aimed to give students the skills to draw and draft, but these skills were also understood to be insufficient to create great art. The mastery of drawing was necessary only insofar as it allowed artists to deploy that mastery as a vehicle for their own creative expression. The mastery of artisanal skill combined with the *génie* of the artist created the potential for great art.

Given that the photosculpture process was thought to restrict the capacity for artistic flair or prodigy, the sculptures produced were treated more as banal objects than as high art.[33] The banal status of photosculpture would lead to its ultimate economic undoing. Artistic pieces in the *bourgeois* home were not meant to be collected as decoration; an overabundance of art "stuff" in one's sitting room could be seen as lurid. Rather, art in the home was mean to show off the owner's taste and refinement; if the piece was not generally accepted as representing "good taste" in the high art community, neither would it be valued by the *bourgeois* consumer. As the initial excitement over the peculiarity of the photosculpture process waned, so did demand, and Willéme's studio was out of business by the end of 1867, less than a decade after photosculpture's introduction.[34]

Comparing the Responses to 3D Printing and Photosculpture

The photosculpture process, and its associated promises of democratization of artistic or creative production, has much in common with current 3D printing and additive manufacturing processes, perhaps surprisingly so, given the 150-year time difference between the two technologies, each having emerged within a different professional/disciplinary domain. Although 3D printing's explosion onto the consumer market has been credited in the popular press to recent technological advances, most of the formative patents and advances in additive manufacturing are actually products of the late 1970s, with over twenty key patents registered by the U.S. Patent Office between 1975 and 1985.[35] While costs have undeniably plummeted with 3D printing, this too was the case for photosculpture relative to traditional production of busts in the 19th century. What appears to be distinct is how the technology is being received within the broader social context.

The modeling process at the heart of additive manufacturing and photosculpture is fundamentally the same: the splitting of three-dimensional objects into two-dimensional, trans-planar images. While photosculpture accomplished this by taking photographic images in the round of a subject, 3D printing relies on CAD software to "slice" digital meshes into vertical planes, which are then re-layered upon one another in physical space during the printing process. This additive process of layering is a particular technological advantage of 3D printing: because 3D prints do not require a mold to produce, additive manufacturing processes allow for the creation of single-cast objects with more intricate and diverse topologies than industrial injection-molding processes. These new kinds of solid-shape designs have already made impacts across both engineering[36] and the arts.[37]

This cross-colonization of multiple disciplines by 3D printing is reflected by themes of hybridity in the rhetoric surrounding the technology. Both photosculpture and 3D printing were contextualized as a creative hybrid of human and machine, though with very different outcomes. Where the daguerreotype and sculpting arm were seen as mechanical elements that separated the human genius of the artist from the work of art by European critics of photosculpture, the new objects made possible by human-hardware-software synthesis in 3D printing are celebrated and fetishized by industry, consumers, and academia.[38, 39, 40]

The possibilities for scientific and engineering advances to contribute to design processes were, in fact, a major goal outlined by the software development team led by Douglas Ross at MIT in 1960, whose work on CAD software would become the digital backbone of 3D printing:

> The engineer's role is the creation of systems, devices, or processes sought by society and conducive to its welfare. The process by which these substantial goals of engineering are achieved we call engineering design. The Computer-Aided Design project (CAD) is devoted to reducing the elapsed time and resources expended in completing the design process by enlisting the special powers of modern data processing – prodigious, reliable, accessible storage of information and accurate, incredibly rapid manipulation of data…. The long-term goal is automatic manufacture once the human-computer "design team" has established the features of a design. The possibility of having a computer be an active partner to the designer, to accept and analyze his sketches and perform all or a substantial amount of the necessary design calculations, does seem reasonable for the near future.[41]

This acceptance of, and even revelry in, the possibility for computing technology to replace the bulk of human labor—to become part of the "design team"—is a substantial shift in rhetoric from the bemoaning of the daguerreotype sculpting aid by European art critics.

Thus, while since its inception photosculpture had been targeted towards the direct creation of consumer products, the same cannot be said of 3D printing and additive manufacturing. The first produced additive manufacturing tools were introduced in the late 1980s, and featured stereolithographic (i.e., layer-by-layer) stacking of liquid polymer gels that were solidified using UV light.[42] These expensive and limited machines were not designed as consumer goods, nor were they intended to themselves produce scalable, market-ready prints. Rather, additive manufacturing was seen as a tool for engineering and design firms to rapidly iterate industrial designs and produce small-scale, market-testable prototypes; prototypes that would eventually be mass produced using more conventional injection-molding manufacturing processes.[43] It would not be until 2011, with the expiration of several additive manufacturing patents, the rise of a "maker culture" in consumer-class America, and the release of open-source hardware like the Makerbot that 3D printing processes would become inflected with a kind of Silicon Valley techno-liberatory rhetoric.[44]

From the standpoint of contemporary constructions of the role of additive manufacturing, however, the social goals of 3D printing and photosculpture are similar: these technologies give to the consumer class access to tools and objects that had previously been accessible only to elites. However, the imagined educational goals of 3D printing and photosculpture—not just *what* 3D printing and photosculpture allow non-experts to do, but what these non-experts *should be* striving to do with the technology—could not have been treated more differently. While photosculpture was criticized for its removal of the ability to master drafting, thereby removing the ability to invest creativity into sculpture, 3D printing is hailed as a playful entryway into building and making, where prerequisite mastery is rejected in favor of creative exploration by anyone, not least technology novices.

Conversation on the 3DPrintBoard, one of the major international, non-professional printing enthusiast online communities, often praises the ways in which 3D printing has enabled users to unleash their inner creativity precisely by *taking away the need of mastery*. In one thread alone, from late 2015, multiple users describe the boon that 3D printing has been to their multiple, yet united, understandings of creative work:

> I have very little or no artistic background/training/skills, and yet without much thought, 3d printing seemed a natural way to bring together my past skills with my new pottery hobby. It is helping me to find my "artistic" voice by allowing me to use the skills I DO have (computer/technical) to help give expression and to help me craft a physical manifestation of something I otherwise might not attempt, or which would consume too much time…. FWIW, it also helps that I've found a couple of other "practical" applications for 3d printing as well..., which at the very least helps reinforce the notion that the 3d printing activity is overall, very worthwhile for me.[45]
>
> I think 3D printing is a boon to creativity. Many people want to make things, but don't have the facilities or skills to produce anything like what they have in mind. Now, with just a computer, which most people have anyway, they can produce sculpture, crafts items, or functional parts in a variety of materials.[46]

> In my personal opinion, 3d printing is a key in unleashing our creativity. 3d printing can let you have your own unique design realized and 3d printed. The good thing is that your 3d model can be printed in various materials and you don't even need to own a 3d printer to have it printed. I've seen great breakthroughs in 3d Printing. Fashion clothes are now emerging with customized and creative designs made by fashion designers, customized prosthetic in Medicine, 3d printing food, etc. 3d Printing is about to change how the world works.[47]

> I want a powerful PC to play some computer games like WOT and NSF, but a desktop is ugly I think. So I design a structure and install all parts by my own hands. Now my PC [is] just like a modern castle, this is real creativity.[48]

For each of these users, creativity is achieved through highly individualized exploration following personal preferences, rather than by trying to achieve some kind of artistic sublime as determined by elite critics or pursuing technological mastery by following a predetermined script for skills development.

The Importance of Context

While the underlying technologies of photosculpture and 3D printing have important similarities, the social context around those technologies—and the dominant visions of how and why they are employed—has changed remarkably. 3D printing is being contextualized by multiple groups in multiple ways: government scientific agencies have painted 3D printing as a potentially transformative educational tool,[49] industry views 3D printing as affording new kinds of mass production[50] as well as new collaborations with consumers,[51] and the user-commenters above paint 3D printing as both a tool for self expression and a pragmatic home enterprise. Nevertheless, consistent across all of these framing is a rejection of the idea of mastery of prerequisite skills and a celebration of the role of individual, independent exploration and creative self-expression. Productivity (the ability to produce creative output) is reduced significantly to an underlying consumptive act—the purchase and use of a 3D printer.

In the 19th century, mastery of tools was seen as necessary but insufficient for the production of art. Despite its technological and initial market success, photosculpture—and the mastery of tools and techniques required to successfully carry it out—never reached the bar of "true art" in the larger social context of its historical moment. Now in the 21st century, in conversations of creative self-expression around 3D printing, questions both of mastery and of true art have largely fallen away and have been replaced by questions of self-guided exploration, with both cognitive and material dimensions. Aligned with the new cultural paradigm of "design thinking," creative exploration, or "serious play," replaces the logic of (disciplinary) mastery, the imperative of following step-wise processes, and rigidly hierarchical organizational structures. According to design thinking evangelist, IDEO's Tim Brown, "What *is* a prerequisite [for creativity] is an environment … in which people know they can experiment, take risks, and explore the full range of their faculties."[52]

In the case of 3D printing, many people within the contemporary context appear ready to embrace a vision of the novel technology usually held only by a technology's most passionate advocates:

- The technology can/will (and should) be widely disseminated—as widely as possible;

- The technology can/will empower users to participate in productive activities—economic, technical, social—in ways or at scales heretofore unimaginable.
- The technology can/will reduce costs of or otherwise increase access to goods (economic, technical, social) for broad swaths of the population—potentially "everyone"—so as to obviate traditional distinctions between haves and have-nots.
- In these and other ways, the technology can/will serve as an equalizing force and thereby democratize society.

Without weighing in on the veracity or sensibility of such claims, we simply note that a broad public embrace of *the potential* of 3D printing to revolutionize society is certainly likely to enhance its ability to actually manifest that potential. 3D printing has captured our social imagination; its capabilities are mapped to our aspirations.

To summarize our findings: though 3D printing and photosculpture shared similar technological affordances, and though the creation of each technology emerged from a desire to incorporate machinery to make creative output more accessible to non-elites (and non-experts), the social contexts into which each innovation emerged had direct impact upon their respective economic and social successes. Photosculpture's contextualization as a technological form of producing works of art led to its dismissal by critics, who saw little value in the objects that the photosculpture process produced or in photosculpture's potential to educate larger numbers of artists capable of sculpting likenesses of people or other objects. These critiques had a direct negative impact on the *bourgeois* desire to purchase photosculpts, leading to the ultimate economic failure of studios in the U.S. and Europe. In contrast, 3D printing's maturation has occurred in contemporary global consumer society as an access point for both industry and consumers to explore new kinds of creative and pragmatic endeavors, which has led to growing consumer-level economic success, as well as industry and academic-sector investments in 3D printing equipment and resources.

Implications for Techno-Creative Literacies

Aside from providing a general illustration that the successes, failures, and impacts of technological innovations are always guided in part by the social and cultural contexts from which they emerge, the authors see implications of this analysis for constructs of technological literacy. We argue that the case analysis of the social conditions of these technologies has two important lessons for educating "techno-creative literacies." First, our analysis highlights how the changing conceptualization of the essence of creative work—shifting from mastery of (artistic) technique to (design) exploration—opens new spaces for introducing technological literacies to non-technical audiences.

The new emphasis on experimentation, and celebration of consumer-level participation in technical making activities, reverses decades of epistemological exclusivity around technology making[53]—that only the elite few have what it takes to be "a rocket scientist." The nascent making culture appears to attract throngs of followers on their own terms and without the need for elaborate public relations strategies. Further, making culture has attracted a broader demographic range of participants than traditional approaches to STEM diversification,[54] achieving in a matter of a few years many of the diversification goals long aspired to within engineering. And this without decades of research seeking to figure out how best to convince, prepare, or incentivize young people to pursue STEM disciplines in higher education.

The embrace of tinkering in maker culture has aligned with and enhanced the desire and drive of non-experts to experiment with design and engineering practices, although these practices emerge more organically and over time than engineering educators may be used to in a traditional curriculum, where formal (analytic) "engineering literacy" education often occurs *before* material building (i.e., "application"). Nevertheless, the room for play associated with contemporary creative-technological practices has served as an invitation for average folks (i.e., not self-identified technology enthusiasts or experts) to interact with technologies in a deeper, more experimental way. By celebrating their individual agency and creativity in using 3D printing to produce *objects that interest them*, it may serve to legitimize and frame their own interests as comfortably situated within the discipline of engineering. In this light, the contemporary contextualization of "making," such as that seen around 3D printing, can and should be understood as an emerging form of public technological and engineering literacy.

Our analysis also points to a second, derivative lesson around educating for techno-creative literacies: that the hybridization of technical work and creative play around 3D printing offers a compelling supplement, if not alternative, to the mastery logic foundational within contemporary engineering education (and 19th century art). However important technical analytic "competence" may be to safe, economic, timely engineering work, the extent to which engineering education emphasizes engineering's epistemological exclusiveness,[55] its glorification of discipline and rigor over open-endedness and dynamic flexibility,[56] suggests opportunities for disciplinary cultural transformation. The easy success of making and design cultures at attracting enthusiasm and diversity among participants provides a stark counterpoint to engineering's (and STEM's) enduring struggles in this regard, despite decades of targeted "outreach." We see great possibility for the transformation of engineering epistemologies—and engineering educational culture—by better alignment with the practices of 3D printing and their corresponding making or design cultures. Using the design logic of serious play, engineering education could bridge traditional technical competence with creative exploration and individual engagement. In this way, engineering literacy would be expanded and it is likely the number and diversity of engineering students would increase.

Conclusion

The authors have argued that case studies of the initial public contextualization of two technologies, photosculpture and 3D printing, demonstrate a cultural shift in the ways in which creativity, mastery, and literacy are conceptualized in society at large. By taking advantage of the current imaginations of techno-creative practice as an invitation for play and exploration, engineering educators can both broaden the reach of their efforts to infuse technical skills training across liberal and informal education, and legitimize the kinds of making and building interests that are already present in target demographics. Engineering educators may also seek to apply these values of creativity and play back onto engineering education itself, potentially creating a more inviting and engaging environment for students of diverse backgrounds and interests.

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