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3D Printing and Bioplastic Waste: A Matter of Concern Explored through Actor-Network Theory, Co-design, and Critical Making

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Make: Magazine, Makers, and Maker Practice

In the mid-2000s, hands-on, do-it-yourself (DIY) maker activities such as 3D printing, electronics, and woodworking increased in popularity in the United States. Interested individuals rallied around the DIY publication *Make: Magazine*, a magazine promoting the idea that everyone can design and make (Dougherty, 2005). Individuals could become a maker by engaging in hands-on activities as maker practice. Dale Dougherty (2013, p. 7) – author of *Make: Magazine* – defines makers as individuals "seeking an alternative to being regarded as consumers, rejecting the idea that you are defined by what you buy." In short, by becoming a maker, individuals could improve their sense of self-sufficiency and independence and feel empowered making, modifying, and repairing things. Through this idea, *Make: Magazine* quickly fostered a community around the action-oriented activity of maker practice and its positioning of making as a method to counter techniques often employed by the corporate consumer industry (Mister Jalopy, 2006).

Make: Magazine's positioning of making as an alternative to consumerism has become mainstream. One oft-cited example of maker culture's extensive acceptance in the United States is former President Barack Obama's legitimisation of maker practices in his declaration of a nation-wide day of making in 2014 (The White House Office of the Press Secretary, 2014). The proliferation of these ideas has further spread through *Maker Faire* events. These maker expos began in 2006, and by 2016, *Maker Faires* numbered over 150 annually (Maker Media, 2016). Part of the popularity of maker practice was the idea of making as a new industrial revolution (Anderson, 2012), that would see a shift to innovative manufacturing processes in the home using 3D printers. Comparable to the textile industry switching from hand manufacturing methods to modern ones during the industrial revolution in the 1700s, supporters of the maker movement and 3D printing technology envisioned that designing and manufacturing objects would soon be accomplished by anyone either at home or at a community workshop with access to 3D printers (Anderson, 2012). As a result, *Make: Magazine's* characterisation of the empowered, independent maker has now spread to hundreds of countries across the globe through what is known as the 'maker movement' (Fabfoundation, 2021). With this movement came widespread use of 3D printers and other small-scale digital fabrication technology in homes, 'makerspace' workshops, schools, universities, and libraries (Dondlinger et al., 2017).

3D Printing, Bioplastics, and Polylactic Acid

The increasing popularity of 3D printing technology stems from its affordability and user-friendliness and the 3D printer's ability to manufacture objects rapidly. For context, 3D printing involves software that converts 3D models into printer instructions that take the form of horizontal layers of coordinates. The 3D printer then creates a physical object by unspooling thermoplastic filament feedstock material, heating, and extruding it according to these layer-by-layer instructions. Part of the attraction of 3D printing is the low cost, plug-and-play desktop-scale devices that produce complex objects requiring minimal post-processing such as sanding or finishing (Hatch, 2014). As a result, these devices amplify maker practices and a sense of agency and self-reliance for makers. Considering these benefits, 3D printing enthusiasts (Anderson, 2012) envisioned – somewhat inaccurately – that manufacturing would shift from large-scale centralised locations such as factories to small-scale and distributed home desktops. Problematically, a shift to domestic production using 3D printers at this scale results in a large volume of waste.

In terms of feedstock material for 3D printers, most 3D printers rely on polylactic acid (PLA) bioplastic filament. Reports produced by the 3D printer company *Ultimaker* and *Filaments.Directory* – a comprehensive 3D printing material catalogue – state that over 75% of devices use PLA filament (Filaments.directory, 2019, Ultimaker, 2018). An alternative to its fossil-fuel derived plastic counterparts, bioplastic refers to plastics that biodegrade more readily (Australasian Bioplastics Association, 2019). Bioplastics such as polylactic acid can be bio-based – made using plant matter such as corn, sugarcane or other kinds of biomass (Australasian Bioplastics Association, 2019). However, this results in the problematic assumption that PLA filament is sustainable and compostable (Carlota, 2019).

For bioplastics such as PLA to effectively break down requires processes and specific composting conditions that are networked to effectively dispose of waste (Australasian Bioplastics Association, 2019b). Hypothetically, bioplastics such as PLA can be recycled and composted but are often not due to gaps in design and waste recovery networks. Some waste recovery organisations, such as *Veolia's Earth Power* waste management facility in New South Wales, accept clearly identified Australian Standard AS4736 bioplastic for composting. Yet even if PLA meets the standard for composting, only some facilities are equipped to manage this waste stream (The Author, 2021). When recycled, bioplastics are often challenging to differentiate from traditional plastics and are documented as contaminating this waste stream (Vidal, 2008); therefore, *Veolia* recommends decreasing PLA use (The Author, 2021). Thus, bioplastics are rarely recovered and usually sent to landfills like most plastics produced.

Actor-Network Theory: Material Semiotics, Generalized Symmetry, and Matters of Fact/Concern

To interrupt the individualism and account for the importance of more-than-humans in design networks – and by extension maker practice, I draw from Actor-Network Theory (ANT). Actor-Network Theory was developed in the late 1980s as a method to analyse scientific laboratory developments and attributed to sociologist Michel Callon (1986), philosopher Bruno Latour (1988) and sociologist John Law (1987). According to Law (2004, p.157), Actor-Network Theory is "an approach to sociotechnical analysis that treats entities and materialities as enacted and relational". In brief, ANT focuses on the fluctuating relations between human and more-than-human actants and how these relations contribute to creating societal networks. In Actor-Network Theory, more-than-humans includes what many might think of as things. For example, the term more-than-humans, recognised in ANT, includes objects, animals, organisms, technology, texts, entities, or language. Actor-Network Theory is a material semiotic method of social analysis useful when analysing how relations between humans and more-than-humans are shaped (Law, 2019). ANT analyses how humans and more-than-humans are moulded by their relations with other actants and by the semiotic meanings each of these actants bear. To better understand the concept of material semiotics, Law (2019) suggests first identifying the human and more-than-human entities. Law (2019) then suggests noting how each of these material entities intertwines and relates to one another.

In Figure 1, I apply Law's theory (2019) of how human and more-than-human actants relate to other actants through actions, discussion, alliance, or contestation. As a material semiotic method, ANT supports my reconsideration of maker practice using 3D printing technology as networks of continuously shifting interactions and negotiations between humans and more-than-human materials, ideas, tools, texts, processes, and technologies.

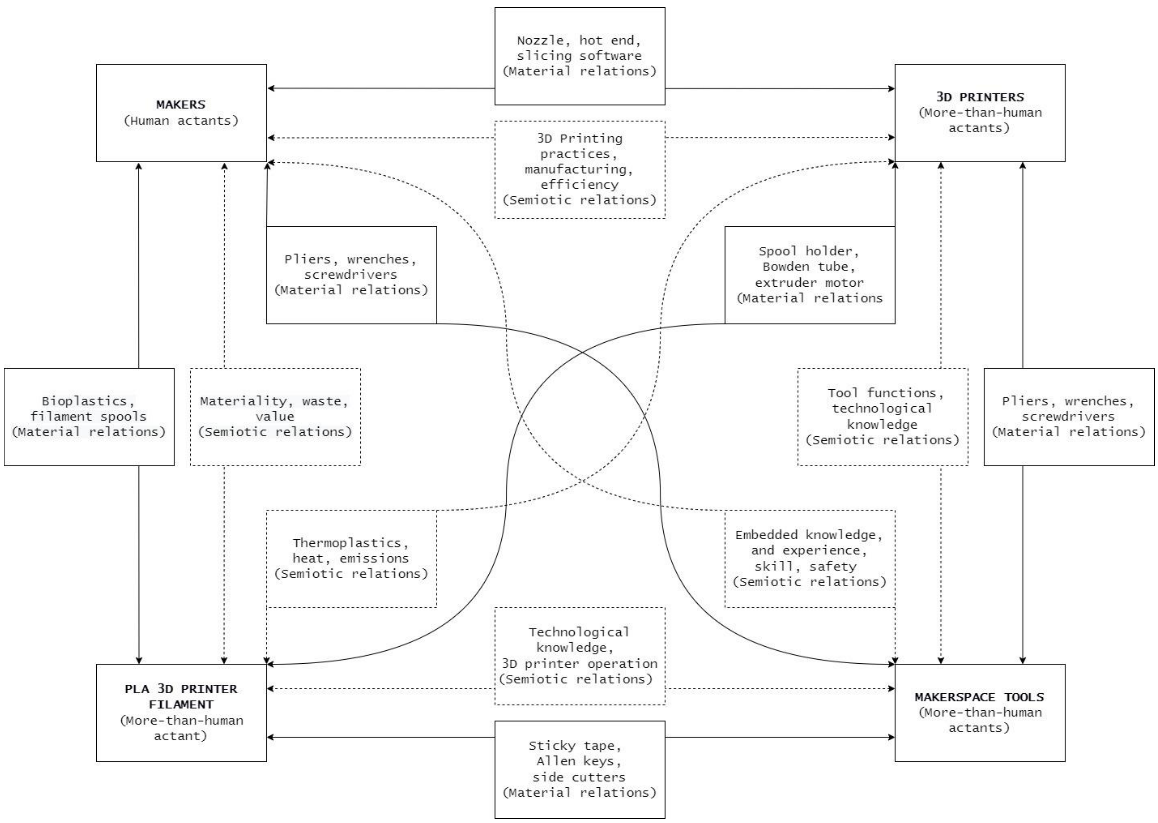

Figure 1: Material Semiotic Relations in a 3D Printing Actor-network

I draw on three key ANT concepts: 'generalized symmetry', 'matters of fact' and 'matters of concern'. The first, generalised symmetry, refers to the impartial terminology that must be maintained by ANT users when tracing and describing the relationships in networks (Michael, 2017). For example, the term 'actant' in Actor-Network Theory does not provide a preferential term to humans or assume human's superiority over nonhumans (more-than-humans) in networks (Latour, 1996). Instead, an actant in ANT refers to anything that acts, interacts with, or is acted upon by something else in a network (Latour, 1996). During ANT analysis, there can be no predisposition towards either humans or nonhumans (more-than-humans) (Callon and Latour, 1981). Moreover, an actant's potential to act within a network must not be presupposed regardless of if they are human or nonhuman (more-than-human) (Law, 2019). This is because agency stems from humans and nonhumans (more-than-humans) material and conceptual relations with other humans and more-than-humans in the network (Michael, 2017).

The second and third concepts are 'matters of fact' and 'matters of concern'. This research examines the matter of fact understanding in 3D printing debates that PLA 3D printer filament is a sustainable and readily biodegradable material that is easily disposable. Problematically, this assumption omits the broader composting and waste recovery networks and the numerous actants involved in these processes. In contrast, matters of concern describe the composition of elements, interests, and practices producing matters of fact (Michael, 2017). For example, as a matter of concern, actants involved in creating the matter of fact assumption that PLA is a sustainable material include human makers and more-than-humans such as 3D printer companies, 3D printing devices, and *Make: Magazine*. Also involved in producing this matter of fact are the interests and practices of these actants. For example, makers often use a heuristic method to verify a 3D printed object's strength or scale when moving from a digital to a physical model. As another example, 3D printer manufacturers have a financial interest in marketing and selling 3D printers. As Latour (2008) states, matters of fact are matters of concern, however, the process of their composition is hidden from view. To challenge this matter of fact understanding of PLA as a sustainable material, I reconsider it as a matter of concern; a network of relations between human and more-than-human actants. Considering PLA as a matter of concern reveals the actants' interests and interrelations in this network. In addition, it illustrates the complexity of waste recovery networks and highlights the urgent need for viable disposal options for PLA bioplastic material. Reframing matter of fact assumptions around the sustainability of 3D printing with PLA filament as a matter of concern opens this issue to questioning – in the hope of avoiding long-term ecological ramifications.

Co-design and Design Things

My research draws from the participatory Co-design methods linked to Pelle Ehn (1988) to bring Actor-Network theory into the field of design. First used to improve workers' sense of agency and involvement in the design process, Co-design was developed in Scandinavia between the 1960s and 1970s (Ehn, 1988). Contemporary Co-design retains its foundation as an inclusive, democratic design process as summarised by Co-design researchers Cristiano Storni, Thomas Binder, Per Linde and Dagny Stuedahl (2015). For example, Co-design reframes outcomes of design practice as relational entities rather than as isolated design artifacts and outcomes (Storni et al., 2015). Co-design opposes the notion of designers as the heroic, central figure in the design process as it simultaneously problematises the idea of participation (Storni et al., 2015). By this, I take Storni et al. (2015) to mean Co-design is critical of presumptions around who or what participates when designing and delineations between designers, researchers, and users.

Drawing from Actor-Network Theory, Co-design resists the Western tendency to ascribe agency to individual people (Storni et al., 2012), meaning that objects and technology are not only recognised as equally active, agential participants but are also acknowledged as essential in relational networks of design. Lastly, Co-design is critical of the Modernist designer/user dichotomy (Storni et al., 2015). This criticism is because Co-design aims to alter the focus on end-users in traditional human-centred design and challenges how to design for publics and broader issues of concern together (Binder et al., 2015). Connecting Actor-Network Theory through Co-design are hybrid forums – spaces where human and nonhuman (more-than-human) stakeholders assemble to debate pertinent issues (Callon et al., 2009). These spaces engage stakeholders such as experts in the field, government officials, consultants, and everyday citizens to assess issues and matters of public concern (Ehn, 2008).

Figure 2: Biorecycling Machine
Photograph by: Carine Thévenau

A Critical Making Project: Biorecycling Machine

To support my exploration of abstract Actor-Network Theory concepts in a more approachable way, I draw on critical making as a method capable of blending scholarly concepts with hands-on making activities and discussion. The term critical making was first conceptualised by Matt Ratto and Stephen Hockema in the late-2000s (2009). Critical making is a participatory workshop method uniting two disconnected modes of inquiry. They describe the first, critical thinking, as abstract, explicit, theoretical, internal, and individualistic (Ratto and Hockema, 2009). They describe the second, making, as something often considered to be material, hands-on, embodied, external, and outward facing (Ratto and Hockema, 2009). Although critical making is typically process-oriented, with design artifacts only serving as evidence of the critical making activity, my interest aligns more with key critical maker Garnet Hertz (2016, para. 8) who views critical making as “useful in reintroducing a sense of criticality back into post-2010 maker culture: to un-sanitise, un-smooth and re-politicise it.”

Subscribing to these definitions, my critical making project, *Biorecycling Machine* (Figure 2), prompts makers, citizens, and stakeholders to engage with the matter of fact issue of 3D printer waste disposal as a matter of concern. Addressing the issue of 3D printer waste, *Biorecycling Machine* leverages the biocompatibility of PLA with the human body and using the invasive qualities of the tattooing process, proposes human actants inject PLA into their body to enrol in actor-networks of recycling. Since PLA is a material used extensively in medical applications including drug delivery systems, sutures, screws, and implants (da Silva et al., 2018) why not inject PLA microplastic particles into human actants? If PLA polymer ink could be deposited into a human actant's intramuscular tissue, hypothetically, biorecyclers would first turn PLA 3D prints into a fine granulated powder, mix it with saline and inject it using a sterile tattoo needle. Upon entering the body, biological recycling begins as the PLA is metabolised by enzymes (more-than-humans) into lactic acid, carbon dioxide, and water before excretion (Fattahi et al., 2020). Although this is a speculative recycling device, enrolling discarded PLA plastic into the actor-network of our bodies addresses the growing demand for mechanisms and processes to dispose of bioplastic waste. Drawing on the concept of 'design things', *Biorecycling Machine* reframes the issue of 3D printer waste as a matter of concern by making visible the relational networks of humans and more-than-human actants involved in networks of waste disposal and deprivileges the body as separate from ecological networks in nature.

In Australia alone, 2.5 million tonnes of petroleum-based plastic waste are produced every year, with 84% going directly to landfills (Australian Bureau of Statistics, 2020). To mitigate this waste dumping, bio-based, compostable plastics such as polylactic acid are on the rise and projected to replace a significant portion of the plastic material created by the petrochemical industry in the near future. Continuing in the footsteps of petroleum-based plastics, new bioplastics such as PLA are being rapidly produced before designing and implementing a viable large-scale system to dispose of this material safely.

Biorecycling Machine is a speculative version of the petrochemical industry's "reduce, reuse, recycle" campaign introduced in the 1970s (Young, 2020) that shifted the responsibility of plastic waste from the producer to the consumer. With this provocation in mind, this device promotes engagement with questions around the sustainability and biodegradability of PLA material. It prompts makers and users of 3D printers to reconsider the assumptions and ideas around sustainability embedded in the 3D printing technology they use and how this relates to the things they produce using 3D printers. For example, what might this device tell us about problems surrounding 3D printing with

PLA and other bioplastics or networks of waste recovery? Suppose makers were responsible for recycling the 3D printed waste they produced. Would it prompt reconsideration of things such as the value of 3D printed objects, the speed at which they are made, and what networks are involved in recovering these materials after their disposal? Through Actor-Network Theory, Co-design, and critical making, *Biorecycling Machine* aims to mobilise debate around 3D printer waste disposal by reframing this as a matter of concern, highlighting how human bodies and the waste we produce are biologically and chemically connected to the expansive networks and processes in nature.

Conclusion

In conclusion, this research reports on the development of a practice-based research experiment titled *Biorecycling Machine* that draws on Actor-Network Theory, Co-Design, and critical making. The key issue discussed was the theoretical sustainability of the commonplace 3D printer filament polylactic acid and how it often ends up in landfills due to gaps in design and manufacturing networks of composting and recycling. Through Actor-Network Theory, I have illustrated how design and maker practice networks need expansion to acknowledge the importance of more-than-humans in making, 3D printing, and waste recovery. I have also illustrated how Co-design supports the understanding of my practice-based research as relational ‘design things’ rather than merely solitary design artifacts. I illustrated how assumptions around PLA material’s sustainability as a matter of fact in 3D printing debates can be interrogated and reconsidered through critical making. Finally, PLA’s sustainability – when viewed as a matter of concern – reveals the broader networked interrelationships between the humans and more-than-humans that together construct this issue. Ultimately, this research questions problems around PLA’s sustainability with the aim of avoiding long-term environmental consequences.

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