Social Construction of 3D Printing

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On my honor as a University Student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments

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Introduction

This paper is an examination of the lack of sustainability in the 3D printing market. It examines the groups, conflicts, and future of this segment through the context of the STS framework Social Construction of Technology. This examination also showcases three potential technological responses to deal with the explosion of plastic waste produced from home 3D printing. Additive Manufacturing is the broad parent category that encompasses 3D printing; it is a term to describe manufacturing techniques where the material is added one layer at a time. Historically, manufacturing has been done by the assembly of smaller parts, by casting metal or plastic, or by subtractive manufacturing. Additive manufacturing is often more sustainable than traditional manufacturing methods, so the existence of a wasteful form of additive manufacturing is an oddity. This paper discusses additive manufacturing and its orientation towards sustainability in contrast with the waste problems in the 3D printing market. The paper finishes by describing how SCOT provides a framework to understand the success of a technology over other technological solutions and ties this into the three potential technological responses.

Social Construction of Technology

The STS framework behind this paper is explained first. In its essence, *Social Construction of Technology,* or SCOT, is a framework that deals with the development of technology in the context of society and helps with understanding which technologies succeed and why. In explaining the importance of SCOT, Bijker states: “the success of an artefact is precisely what needs to be explained” (p.406). Much of Bijker’s paper uses the evolution of the bicycle to show how a SCOT can explain the evolution of an object. Now, the following important concepts of SCOT will be covered: relevant social groups, interpretive flexibility, problems and conflict, stabilization, and closure.

SCOT – Social Groups

First, a core idea of SCOT is that for all artifacts there are social groups that attach different meanings to the artifact. Specifically, a social group is one group of people who share the same meanings and feelings toward an artifact (Bijker, 1984, p.414). Basic groups include producers and consumers but more complex groups and subgroups can form; Bijker emphasizes, “the key requirement is that all members of a certain social group share the same set of meanings, attached to a specific artefact” (p.414). Bijker further gives examples of other social groups that formed for the bicycle, which are not the basic producer and consumer: male and female users. Specifically for bikes, men and women were defined into two social groups due to the clothing and social attitudes at the time which affected how men and women used the bike. He also adds that this would not be the case for an object such as a “fluorescent lamp” because the usage would not vary by gender (p. 415). Social groups are important because each group has different feelings about and toward artifacts. This difference leads to interpretive flexibility which is discussed next.

SCOT – Interpretive Flexibility

Interpretive flexibility is the concept where different groups can attach different meanings to an artifact. This results in differences in how people think of, interpret, and design artifacts (Bijker, p.421). Bijker contrasts two social groups of the bike: those in favor of using air tires due to vibration reduction, and those who ridiculed it as a poor technology (p. 421). This difference shows how two groups can look at one design feature and have varied feelings about it. These varying interpretations are important as through the modern interpretation, air tires are the status quo for bikes. Something that seems completely normal and sensible now, was not so in the early years of the bicycle. The differences in meanings and interpretations naturally lead to conflict between groups.

SCOT – Problems and Conflict

The third core concept of SCOT is the problems and conflicts that arise due to different interpretations by different groups; Bijker states "a problem is only defined as such, when there is a social group for which it constitutes a problem […] The key requirement is that all members of a certain social group share the same set of meanings attached to an artefact." (p. 414). Bijker also explains that there are different types of conflicts based on which social group is viewed; he goes on to give examples from the development of the bike. On page 416, Bijker discusses the types of conflicts. There are conflicting technical requirements concerning how an artifact is designed or different designs of an artifact. For the bike, this was the speed and safety of a bike's design. Next, there are conflicting solutions to the problem through different designs that emerge. An example of this was the variety of safety bikes that emerged on the market. Finally, there are moral conflicts where some groups may take issue with a design or solution solely on moral grounds. The example given for this was whether women should ride bikes, and how would they ride them. As with all conflicts, there must be some sort of solution or compromise where the different groups agree that one particular form of the solution solves the problem.

SCOT – Stabilization

The fourth core concept of SCOT is the idea of stabilization where "a consensus is formed among more than one group" (p.424). It is the winning of one solution in a way that affects long-term innovation. An example of this is the convergence of bike designs in the late 19^{th} century. There were many designs then, but one clear winner in the modern-day due to stabilization. It is not the permanent closure of a conflict, but it is when a solution becomes the mainstream solution and opposition is nonexistent or weak enough to not generate changes.

SCOT – Closure

The final core concept is closure. Closure is similar to stabilization but it is the mechanism through which stabilization takes place. There are two forms of closure: rhetorical and redefinition of the problem. Rhetorical closure is when an artifact stabilizes due to the disappearance of problems in the eyes of the relevant social groups. Bijker explains the concept in this excerpt: "Closure in technology involves the stabilization of an artefact and the 'disappearance' of problems. To close a technological 'controversy' the problems need not be solved in the common sense of the word. The key point is whether the relevant social groups see the problem as being solved." (p.426). Bijker also adds that advertising can play a significant role in altering a group's feeling about an artifact and explains that an attempt was made by the producers of the high-wheeler bicycle to change public opinion by advertising it as perfectly safe (p.427). The next type of closure is redefinition of the problem whereby a conflict is closed because the problem has changed. Bijker's example of this is the acceptance of air tires on the bike. Originally, the air tire was meant as a solution to the instability and vibration of other tires. It was viewed negatively by the public at first, but once other tires could not keep up with air tires in terms of speed, the problem shifted to how to make bikes faster. This shift changed the problem from stability to speed and thus the air tire became the stabilized solution for bikes (p.427). This shift would not have taken place if non-air tires could keep up with air tires in bike races. The point of racing is to win and so the conflict shifted from which tire is the best to which tire is the fastest.

Next, the explanation of SCOT is used to examine the 3D printing market through the framework of SCOT.

SCOT, Additive Manufacturing, and 3D Printing

In this section, the key resource will be an article by Ford and Despeisse about additive manufacturing and sustainability (Ford & Despeisse, 2016). It is a strong research base because it covers multiple forms of additive manufacturing (AM), the benefits and drawbacks, and the effect of AM on the manufacturing world.

Social Groups & Interpretive Flexibility

As described by Bijker, the basic two social groups of an artefact are the producers and the consumers. In this context, producers are those who create a machine that carries out a form of AM. Consumers are those who would buy such a machine; these consumers can be industrial manufacturers or hobby 3D printers. In their article about AM, Ford and Despeisse claim that producers are interested in AM because the field offers new markets to explore, while consumers favor the increase in manufacturing flexibility (Ford & Despeisse, 2016, p.1574). This increase in flexibility comes from on-demand creation, reduced material use and cost, and potential for reduction in transportation costs. An example of this flexibility is a group of engineers who used the increased manufacturing flexibility to design and produce a special fuel injection nozzle that makes cargo ship engines more durable and fuel-efficient (Madelaine P., 2022). This nozzle leverages AM to produce shapes that could not be produced using prior forms of manufacturing as well as being cheaper to produce. It also can be produced closer to shipyards, even further reducing costs. Ford and Despeisse further the importance of this special nozzle by explaining: "[AM] appears to herald a future in which value chains are shorter, smaller, more localized, more collaborative, and offer significant sustainability benefits" (Ford & Despeisse, 2016, p.1573). Customization that results in reduced resource use is one of the greatest benefits of AM and one of the reasons AM is heralded as inherently sustainable. 3D printing still possesses all of these potential benefits for further sustainability. However, further examination is required to understand why even with these potentials, it is less sustainable.

Next, supply chain actors are relevant because AM can shorten the supply chain and allow products to be produced on-demand and in locations other than manufacturing plants (p.1574). However, not all supply chain actors are pleased. Certain shippers may be displeased by AM displacing business by allowing for on-site manufacturing to reduce or eliminate the need for shipping (Pearcy, 2017). Conversely, some groups can benefit greatly from the shortened supply chain. A great example of this is when NASA designed a special wrench which was then 3D printed and used onboard the International Space Station (Harbaugh, 2015). The primary purpose of this experiment was to test the ability to 3D print important tools off-world in preparation for a potential mars mission. Although this example does not specifically deal with supply chain actors, it shows a specific example of how objects can be designed in one location, and manufactured in another, hard-to-reach location. Considering that the ability to "ship" a file directly to the use-location and print it there would cut into shipping revenue, shippers are not necessarily in favor of AM. Furthermore, Ford and Despeisse explain that because AM allows for on-demand creation, not only does the need for shipping decrease, but the need for warehouses to store surplus products also decreases (p.1574). For better or worse, the net result of the shortened supply chain is decreased resource use which is good for sustainability.

Now, a specific subgroup of consumers and producers will be discussed. First, hobby 3D printers are another relevant social group because they are part of a new market that has emerged as a result of the declining cost of 3D printers. This group is a subgroup of the consumers. Ford and Despeisse explain the emergence of this segment. Due to expiring FDM patents, open-source movements, and crowdfunding for consumer-grade printers, the cost of an FDM printer drastically decreased and became affordable for an average person (p.1574). They favor 3D printing because it allows them to become self-manufacturers and rapid prototype instead of relying on the supply chain and manufacturers; they also enjoy it as a hands-on hobby where they can design special use objects as well as tinker with the printer itself ("Why Is 3D Printing Important?", 2017).

Next, two important subgroups on the producer side to discuss are the manufacturers of hobby printers and the manufacturers of 3D printing filament (Note: filament is the plastic that 3D printers heat, extrude, and place in order to create 3D objects). Both of these groups view hobby 3D printing favorably because it is a lucrative market now that hobby grade technology is affordable. These are important groups because of the role they play in ensuring affordable access to the market, however, the most significant roles of these groups will be examined in the next section.

Now, the question will be posed: why talk about all of these AM groups when the core focus is on 3D printing. 3D printing is a form of AM. AM is typically depicted as being "green." By showcasing how the majority of groups involved in AM generate some form of sustainability, the importance of the lack of sustainability in 3D printing is highlighted.

Problems & Conflicts in AM

For this paper, the primary artifact in question will be hobby-grade 3D printers, not large industrial AM machines. Despite the numerous advantages afforded by 3D printing, there are problems resulting from differences of opinions in the 3D printing (3DP) groups.

The background of the conflict is the result of the greater availability of at-home 3DP. As prices decreases, more users became interested in purchasing 3D printers, and the number of those who owned one skyrocketed (Toor, 2019). The issue with this rise is the increase in the amount of plastic waste produced by 3DP. A particular issue noted by Ford and Despeisse is that many new entrants into this market may not know or care about the environmental impacts; they also may not have the ability to mitigate the impacts (p.1575). Despite 3D printing existing as a form of AM, a critical divergence took place when consumers gained the ability to self-produce. AM is traditionally performed by a company that is producing at scale. This means the company is incentivized to reduce waste and design efficiently. There is no such incentive for individuals when filament is extremely cheap.

At a time when the world is facing a plastic waste crisis, 3D printing could prove to be a new plastic waste nuisance. Ford and Despeisse do mention reduced waste as a benefit of 3D printing, but they also touch on how failed prints generate waste. A large issue they outline is the plastic used for FDM is usually not accepted at municipal recycling facilities, so the user must find a way to recycle the waste plastic. They also may just discard the waste into a landfill. Furthermore, a survey found that more than 80% of plastic waste from home FDM printers was from failed prints (Toor, 2019). Moreover, 3D printing excels with expediting rapid prototyping, but in the hobbyist community, it is often used to print novelties and custom toys ("Why Is 3D Printing Important?", 2017). The worthiness of these prints will not be examined, but the question must be posed: what will happen to these objects at the end of life? Much like most resource consumption on this planet, many items are not designed to be reused or recycled and are discarded at the end of life.

So, what specifically is the problem? To define it clearly: the problem is that consumers are split between knowing about the reuse and recycling of FDM filament and not caring. Those that do care often find themselves unable to reuse or recycle the waste in a meaningful way. Manufacturers are not incentivized to redesign the market to reduce waste and act sustainably. Further, until recently, most filament manufacturers shipped filament on plastic spools that are discarded after use. Some users attempt to reuse or recycle these, but many still discard them (Mayer, n.d.). The main reasons manufacturers do not recycle used filament are worries over the quality of the recycled filament, the cost to transport the plastic, and the business logistics behind such an enterprise (Toor, 2020).

Looking Forward

Unlike the bicycle, this market is volatile and changing as stabilization has not occurred in a significant sense. There are a lot of different social groups involved in AM and most solve or alleviate sustainability issues except groups involved in the 3DP market. Without a group large enough to make noise about waste, this will continue to be the case. However, groups are forming to try to fix the issue of waste in 3DP. This section will examine what current methods of reuse and recycling exist and the potential paths toward stabilization and sustainability in the market. The following are the methodologies that will offer an ability to reduce waste: a circular economic model of recycling (Toor, 2019), home recycling (Ford & Despeisse, 2016, p.1579), home reuse ("How to Recycle Your Failed 3D Prints," 2019), and finally, closure by redefinition of the problem (Vidal, 2008).

A circular economic model is one where consumers buy filament from a manufacturer and ship back failed prints for discounts (Toor, 2019). The benefits of this are a reduction in the use of raw plastics, manufacturers can only accept prints from those who purchase their brand of filament to reduce sorting issues, and the user is happy because they waste less and spend less. A major potential issue with this solution is the potential for contamination to ruin a batch of filament. If a batch is contaminated with more than one type of plastic, its properties change and it is often unusable. Further, depending on the type of plastic being used, virgin plastic may still be required. It should be noted that the most common form of plastic used is PLA which following a specialized treatment is 100% recyclable without loss of quality (Ford & Despeisse, 2016, p.1581). Finally, this solution may not be fully sustainable as shipping is still involved.

Home recycling involved the purchase of a machine (or multiple machines) that crushes, mills, melts, and re-extrudes filament for the user to reuse (Ford & Despeisse, 2016, p.1579). Almost all issues of the circular economic model are solved by this solution. The issues are solved because it is then up to the user to ensure no cross-plastic contamination takes place, sorting is up to the user, and there are no transportation costs involved. The major issue with this solution is the unaffordable nature of these machines. The two primary machines available for this purpose are the filabot (*Full Recycling Setup*, n.d.) and ProtoCycler (*ProtoCycler+*, n.d.) which retail for over $14,000 and $4,000 respectively.

Home reuse is not a form of recycling but more of a form of reuse. It is where a user melts down plastic from a failed print into a special shape to become something new, or to be used as raw material in subtractive manufacturing ("How to Recycle Your Failed 3D Prints," 2019). This is reusing and not recycling because the product is not returned to its original form and is of lower quality. It is, however, the easiest and cheapest method available.

The final alternative is a redefinition of the problem. The Bijker article does discuss how groups will leverage advertising to change the opinions of others (Bijker, 1984, p.427). The most likely outcome will be that filament manufacturers make claims that their product is the least environmentally harmful, has the most recycled plastic, or is compostable. This has the potential to redefine the problem to *how to buy the filament least harmful for the environment* over *how to reduce plastic waste from hobby 3D printing.* Another unfortunate result of this is these claims may not necessarily be the truth. Bijker discusses how these claims may distort the truth (p.427) and a Guardian article discusses how PLA is marketed as a compostable product but this is only true under “industrial, anaerobic conditions” (Vidal, 2008).

Which of these solutions will win, generate stabilization, and close the problem? SCOT is a framework designed to understand the success of a technology, not predict the future. As such different scenarios will be discussed that could bring about the triumphant technology, but no prediction will be made about which technology will “win.”

First, if filament manufacturers create a method to ensure recycling batches cannot be contaminated, then the circular economic model will win purely on the power of economies of scale. It will be easier for filament producers to create a waste filament return system and give customers a discount than it will be to create a cost-effective, size-conscious home recycling machine. Second, if the cost of at-home recycling machines goes down, then this solution will win. The same urge to buy a 3D printer and become a self-manufacturer will drive consumers to purchase the machine (if it is affordable) over returning waste. Third, it is unlikely home reuse will ever see itself become the dominant solution. Melting plastic can generate toxic fumes and since the product is degraded, most users do not go through the effort. Finally, redefinition of the problem is very likely. The market is already filled with brands offering recycled filament

(O'Connel, 2020), and biodegradable filament (O'Connel, 2020). Evaluating the validity of these claims is not the purpose of this paper, but showcasing that companies are leveraging advertising sustainability to generate customers is important.

Whichever solution wins will become the go-to for filament recycling, and may even force large plastic producers to adopt similar policies for their plastic products. Through the process of stabilization, this will become normal and conflict will be closed through rhetorical closure since the conflict is no longer a problem. It is also possible that several of these solutions may be dominant for many years or even that a new solution will arise and achieve stabilization where other solutions failed.

Conclusion

In this paper, SCOT was defined, the groups of 3D printing were defined as well as the conflicts in this segment. The primary issue addressed in this paper is the waste associated with 3D printing. Since 3D printing is a form of AM, and AM is usually sustainable, why 3D printing is wasteful is a topic of interest and importance. It was argued that this waste can be mitigated through recycling. This recycling can either be a special program run by the plastic filament manufacturer or through at-home reuse/recycling of failed or discarded prints. The scenarios in which either of these solutions would win were discussed, as well as the pessimistic solution where filament producers twist the truth about the actual sustainability of their filament resulting in users thinking the problem has been mitigated and thus taking no further action. As the world drowns in plastic, one can only hope that a solution comes soon.

There is a vast amount of future work that could be conducted on this topic. The ethics behind plastic use and waste could be examined, as could the existing and potential laws and regulation surrounding plastic use. Technical work could also be done to study the affects of recycling filament into raw plastic and attempting to design such a device to be affordable. Finally, technical work could be conducted to examine whether or not regular plastic such as that used in plastic bottles can be milled and extruded for 3D printing.

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