10-2016

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Recommended Citation

Neely, Erica. "The Risks of Revolution: Ethical Dilemmas in 3D Printing from a US Perspective," *Journal of Science and Engineering Ethics* 22(5), 1285-1297. doi: 10.1007/s11948-015-9707-4 (2016)

The Risks of Revolution: Ethical Dilemmas in 3D Printing from a US Perspective

Erica L. Neely

Abstract: Additive manufacturing has spread widely over the past decade, especially with the availability of home 3D printers. In the future, many items may be manufactured at home, which raises two ethical issues. First, there are questions of safety. Our current safety regulations depend on centralized manufacturing assumptions; they will be difficult to enforce on this new model of manufacturing. Using current US law as an example, I argue that consumers are not capable of fully assessing all relevant risks and thus continue to require protection; any regulation will likely apply to plans, however, not physical objects. Second, there are intellectual property issues. In combination with a 3D scanner, it is now possible to scan items and print copies; many items are not protected from this by current intellectual property laws. I argue that these laws are ethically sufficient. Patent exists to protect what is innovative; the rest is properly not protected. Intellectual property rests on the notion of creativity, but what counts as creative changes with the rise of new technologies.

Key words: 3D printing; additive manufacturing (AM); ethics of technology; intellectual property; safety

Introduction

In 2006, two open-source 3D printers came out: Fab@Home and RepRap. (Mertz 2013) Since then, a community of hobbyists has emerged that parallels the community surrounding personal computers in the 1970's. Much as with the personal computer, public imagination eventually caught up, and people have started paying attention to the promise of this extraordinary technology. Thus while it is not a new technology, additive manufacturing (or, as it is more commonly known to many, 3D printing) has come into its own in the last decade.

One of the things to note about additive manufacturing is that it works differently from most of our other manufacturing techniques. Standard manufacturing is subtractive: it takes a raw material and "subtracts" whatever is unnecessary for the object desired. For instance, this occurs when material is punched with a shaped die – we cut away the unwanted material and our object remains, just as a child might cut dough with a cookie cutter. Additive manufacturing works in an opposing manner: in its basic form, additive manufacturing builds up objects, layer by layer, from raw materials.

As Huang, Liu, Mokasdar, and Hou (2013) discuss, there are a number of different technologies for additive manufacturing. One common version works akin to an inkjet printer. When we print a document, we send a file to the printer which causes the printer head to move back and forth across the paper, depositing ink in the right spaces to create text, pictures, or whatever else the file dictates. A 3D printer works similarly: a file tells the printer where to deposit materials, but the print heads generally contain either a liquid material or a powder which is heated to barely over its melting point; the material solidifies soon after being deposited. By making multiple passes, the printer can deposit layers of material, thus gradually building up a three-dimensional object.

There are thus three main elements to additive manufacturing. First, one must have a file, generally from a computer aided design (CAD) program, to serve as a plan for creating the object. Second, one must have the raw materials for the object, such as powdered plastic or metal, to put into the printer. Third, one must have a 3D printer capable of handling the raw material, since different printers are able to handle different materials.

While theoretically a printer could build an object out of almost any material, at the moment there are some strong limitations on what they can do. For instance, as Berman (2012) notes, the array of materials that we can print in is currently much more limited than the materials we can use in traditional manufacturing. Thus, a great deal of the research involved with additive manufacturing is in trying to extend the process beyond plastics, which it handles fairly well, to metals (Harris 2012) and other substances. However, the promise of 3D printers is staggering: they would allow anyone with access to the right hardware and software to create objects in their home, without a need for centralized production.

The flexibility of 3D printing is the key to its revolutionary potential. One advantage 3D printers have is that they allow us to manufacture things we otherwise could not. For instance, Stemp-Morlock (2010) discusses objects which involve printing with multiple materials; when dots of hard and soft materials are printed in special patterns, the material actually gets thicker when stretched. Furthermore, there are geometries that we cannot manufacture with traditional methods due to tooling constraints but which can be created through additive manufacturing; a tube with an interior honeycomb structure would be an example of such an object. Similarly, particularly in fields such as bioprinting we are seeing the use of 3D printers to create directly in biological materials, something which is utterly impossible for traditional manufacturing. (Fischer 2013; Thilmany 2012)

Another advantage of 3D printing is its ability to provide customization of manufactured items. One of the major limitations of our traditional factory-based model of manufacturing is lack of customization: using centralized manufacturing we can make many copies of the same design cheaply, but we cannot customize them efficiently. This is not terribly surprising, since much of the cost in this kind of manufacturing is in creating the dies that are used; the money is recouped by using those dies thousands of times. It is thus not cost-effective to create a truly customized product, although companies do try to offer some degree of customization by making parts that can be assembled in various configurations. (Berman 2012) However, with 3D printing, it is no more expensive to create a completely customized version of an item than the standard model; the only difference will be in changing a few of the file parameters. (Petrick and Simpson 2013)

In terms of design, consumers have two options when 3D printing an object. One option is that a consumer could visit a site like Thingiverse (http://www.thingiverse.com/) and download plans that someone else has created; she then could use those plans to print an object on her own device. Another option is that she could both design and print an object herself. In either case, the 3D printer has removed the need for another agent to do the direct manufacturing – it puts the manufacturing power in the hands of the end user. If she desires an object, she can manufacture it; this is true even without having much specialized knowledge (at least if she relies on someone else's plans) and with only a relatively small investment in equipment. Moreover, she can make the number she needs, as and when she needs them, to the specifications she desires.[1]

[1] To be fair, there are a number of limitations on our current ability to do this – some objects are simply too large and/or expensive to manufacture at home, some materials cannot currently be used in additive manufacturing, and so forth. I discuss further limitations toward the end of this paper, but my point holds for an ever growing number of

While hugely promising from a technological standpoint, 3D printers also raise some ethical questions; these will only become more pressing as the technology spreads. I will focus on two pressing ethical dilemmas raised by this technology. First, I will consider safety issues, touching briefly on the issue of being able to print dangerous objects such as firearms at home and moving on to a more detailed discussion of providing consumer protection from poor designs; most of our traditional controls on products rely on manufacturing assumptions which will no longer apply. Second, I will discuss concerns about intellectual property arising from technology which would allow a person to scan an item and create a copy of it using a 3D printer. Since manufacturing regulations vary, I will focus on the United States as a case study; however, the general outlines of my argument apply more broadly.

Ultimately I will argue that our safety constraints will need to be modified in order to protect consumers adequately; as a society we generally believe consumers deserve protection, which should not change simply because we have a new technology. I believe that current intellectual property protection is sufficient to safeguard the creative aspect of companies' designs; I argue that the new technology forces companies to become more innovative rather than granting them wider protection. I conclude with some thoughts about future directions for 3D printers, both in terms of promise and limitations.

Issue One: Safety

One important ethical issue for 3D printing involves how to ensure the safety of 3D printed products.[2] Currently our product safety regulations depend on centralized manufacturing. Products are tested and certified as safe; factories are then inspected regularly to ensure that their products are (within acceptable margins) identical to the product that passed the original safety inspection. This relies on having a centralized location to inspect and on the idea that, if functioning properly, the machines will make identical copies of the original product.

This model will not necessarily hold in the future, however, since one of the main appeals of 3D printing is the ability to manufacture what you need at home; the manufacturing machinery is thus dispersed throughout the population. Moreover, the quality of the printed products can vary greatly, even if created by the same plans, because the machines vary. If there is a shop with a single 3D printer, then it may be possible to inspect that one piece of equipment; it is not clear how enforcement would occur for home users. Thus while it might be possible to regulate 3D printed items if they were centrally created, it is more difficult to regulate items if they are produced by home users.[3]

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objects that a person could desire; it does not seem absurd to think that this will be possible for at least a great many objects in the future.

[2] Note that one can also consider safety questions that relate to a product and its use; those sorts of issues are less likely to be affected by changes in manufacturing process, however, and thus will not be considered here.

[3] Indeed, this is one of the current problems facing 3D printers; while there is great potential to use them to create spare parts, for instance, those parts must conform to relevant safety standards. (Petrick and Simpson 2013) Just as we cannot regulate the safety of "do-it-yourself" activities that people undertake at home – and thus there is always the risk that an overly ambitious person might injure him or herself with a circular saw – so too we will have difficulty regulating 3D printed objects produced by home users.

Rather than regulating physical objects, we could turn to regulating the software instead. 3D printers function by manufacturing an object according to the specifications provided in a design plan. These plans are frequently shared online; indeed, there are a multitude of sites which promote the sharing of plans among creators. One way of addressing product safety would be to try to control the sharing of created plans; we thus would attempt to prevent unsafe plans from being distributed or sold.

However, there are concerns with this approach. We have not been terribly successful at regulating information online. In the United States, attempts to use the Digital Millennium Copyright Act in order to restrict the pirating of music and film online have met with a lot of resistance; there are still many sites that traffic in the illegal distribution of such files. Indeed, Daniel Castro (2013) discusses this issue in the case of “the Liberator,” which is a fully 3D-printed gun. When the United States government requested that its plans be removed from websites, some sites complied; however, the plans were still available elsewhere, such as on The Pirate Bay.

Our ability to stop the distribution of files thus seems to be fairly poor, particularly when combined with jurisdictional concerns. Since the internet is transnational, it is difficult to regulate its content. In the absence of international treaties, we are probably limited to attempting to regulate content on sites hosted within our country’s borders. Since users can simply go to other sites, this is unlikely to be effective.

Stepping back from the legal and pragmatic issues, there are wider philosophical questions about whether we should try to regulate such plans or whether such attempts are overly paternalistic. For instance, one could claim that consumers have the right to download plans and try them out without government interference; essentially, this is an expression of individual autonomy. While some plans, if followed, may cause a threat to personal well-being, we allow risk-taking in other areas of life; if people can pursue extreme sports without government prohibition, why impose regulation on personal manufacturing?

One possible objection to this would be that we regulate the creation of certain types of items, such as firearms, already. Hence we do not believe that people have a right to any type of object without restriction. The philosophical justification for controlling the printing of guns and their components stems from a more general limitation on autonomy. Colloquially, we claim that your right to swing your fist ends at my nose; more formally, your autonomy does not extend to infringing on the autonomy of others. Weapons raise concerns due to their potential to cause harm to others. Yet this is less an issue of safety, one might argue, than one of security: we are not concerned that the firearm might be unsafe for the user, but that it threatens the security of others.[4]

Surely, one might argue, this kind of concern does not apply to the vast majority of 3D printed items which are not security threats of this kind. Yet these problems are not immune to safety concerns, since one can ask how competent are we at determining the safety of potential designs and products. At the moment, individuals do not need to be able to judge the safety of most

[4] Note that concerns about security and 3D weapons extend beyond issues of 3D printing guns (Jensen-Haxel 2012) to larger-scale issues such as using 3D printers to create biological or chemical weapons (Mattox 2013).

manufactured goods themselves; there are centralized processes for testing objects, as well as procedures for recalling objects if something slips through the testing process. These processes, however, will not work well in the home printing environment.

The potential for 3D printers lies to a large extent in their flexibility – while current technology constrains the size and materials of objects in home printing, in the future we will likely have far fewer restrictions. At that stage, a person could conceivably print a chair or a car seat or a pressure hose for their scuba diving equipment; these are not restricted items in the sense that firearms are, yet they are subject to regulation: chairs should not collapse under small amounts of weight, car seats need to adhere to stringent guidelines to protect children, and scuba hoses need, at the very least, not to collapse under high amounts of pressure.

These regulations, however, apply to goods manufactured for sale to consumers, not those created by an artisan for his own use; if a woodworker builds a chair which collapses when he sits on it, he has not harmed anyone other than himself. Perhaps, then, this should be extended to 3D printed goods: if a person creates something to her own specifications, she is essentially accepting the risk that she may have designed poorly. This would be one way of extending autonomy rights to the situation at hand.

One problem, however, is that often a person is not creating something to her own design; she is using a design developed by someone else in order to create her object. This design may have been created by someone with a good understanding of engineering or it may have been created by someone with very little understanding of engineering. Creating an unsafe design is not, in and of itself, unethical; many conventional products likely had design flaws to begin with, which is what testing and design revisions are expected to correct. However, distributing an unsafe design raises ethical issues.

Clearly there is ethical fault if one knowingly attempts to pass an unsafe design off as safe; in this case, the person is being deceitful. However, in some cases it seems likely that a person will design something which appears to be safe, distribute it thinking that is safe, but simply be incorrect about its safety.[5] How do we deal with this sort of situation?

One response would be to say that a consumer bears all of the risk; essentially by choosing to download and print a particular design, she consents to any possible harm. However, philosophers generally hold that consent is only valid under certain conditions, such as being uncoerced and informed. There is a question of whether the consent given is, in fact, informed. At the moment, I suspect that it is – much of 3D printing is experimental in nature, and the communities of users likely realize that there is a degree of risk inherent in trying out various designs.

However, the situation is different once this form of manufacturing becomes prevalent. In this case, the designs are not taken as experimental, but as a basic way of receiving consumer products. In general societies have not assumed that consumers are capable of determining the risk of a manufactured product. For instance, in the United States, the Consumer Product Safety Act (1972) states that

[5] In our normal manufacturing processes today, this is what leads to product recalls.

> [the] complexities of consumer products and the diverse nature and abilities of consumers using them frequently result in an inability of users to anticipate risks and to safeguard themselves adequately.

In essence, this argues that products and the people who use them are sufficiently varied that we cannot assume that users are able to assess the risks of particular products. If this is the case for ordinary manufactured products, it should also hold for 3D printed ones.

Of course, selling 3D printed products is not necessarily a problem. If the products are still being centrally manufactured in factories which use 3D printers, say, then all of our current procedures will work well. We can fairly easily ensure that consumers are not exposed to any greater degree of risk than they are at present, since the main change comes in the type of machine used to create the object; we have not changed the method of distribution, in this case, but merely the kind of machine.

Problems arise when what is being distributed is not an already-manufactured product but rather a design consumers use at home in order to print a product themselves. In this case, applying safety standards will be more difficult because, currently, designs are not typically subject to government inspection – manufactured goods are.[6] However, since as a society we have concluded that consumers cannot reasonably be expected to assume all the risk for manufactured goods themselves, presumably that holds also for products which are 3D printed at home using an acquired design.

A possible reaction would be to argue that government oversight is unnecessary because design communities will, in essence, self-regulate by rating different designs; Castro (2013) offers some thoughts about the promise of self-regulation. A user could then depend on the ratings, with the belief that a community would ultimately reject (or vote down) those with failings. While it might be possible that such a system could work, I have some reservations about its ultimate effectiveness. One problem is that almost any ratings system can be circumvented; it is difficult to ensure that ratings are given in good faith by unbiased reviewers.[7] Moreover, since different people have different criteria for designs, it is not clear how meaningful the ratings would be; a product may be wonderfully functional but a reviewer may penalize it for its aesthetics or vice versa. This could perhaps be solved by having different ratings for different features; there would thus be a score card for each product, not a single rating. However, unless those people who do the rating had some kind of knowledge as to how to test the products, safety ratings might still be unreliable.

The biggest issue, however, involves trust. Even if those doing the ratings within a particular community are experts in their field, how do others know it? Under our current manufacturing practices, standards and inspections are carried out by people with certain qualifications who are verified to have those qualifications. On the internet, anyone can claim to be a Ph.D. in

[6] This is not entirely true if, for instance, one is designing a bridge – in such a case the plan is going to be thoroughly reviewed. However, most products manufactured for home use require the inspection of finished products, not designs.

[7] See, for instance, the controversy over ratings on Amazon.com.

engineering with 20 years of experience. Yes, it will be difficult to maintain the deception but it is not impossible, at least in public imagination. As such, I believe that it will be necessary to involve a standards body of some kind, whether governmental or through a professional organization; a plan could be certified by the Institute of Electrical and Electronics Engineers (IEEE) or the American Society of Mechanical Engineers (ASME) or whatever body is appropriate for the particular design.[8]

While we cannot prevent all risk to consumers, if we have established a certain level of risk as unacceptable in our society, then we cannot ethically ignore the ramifications of moving to a system of manufacturing which may cross that threshold. If 3D printers are to replace traditional forms of manufacturing, then the risk level to ordinary consumers increases dramatically unless there is some way of ensuring the safety of particular designs. While I do not wish to stifle the innovative potential of 3D printing and design, some measure of consumer protection must be extended, whether in the form of government regulation or certification by professional bodies.

One question this raises, of course, is whether all plans would have to be certified, or whether plans simply have the option to be certified; the latter possibility allows people to choose plans that have not been rated if they wish to take that risk. I believe that the best blend of autonomy and safety is to require that plans which are commercially available be inspected by some authoritative standards body. For one, this solves a pressing issue of who would pay for this inspection – if the plans are being sold, then any cost of inspection will be part of the company's overhead in developing the plans; the cost can then be passed along to the consumer. In practice, a plan which is freely available is unlikely to be submitted for certification because there is little financial incentive to do so. Unless the author of the plans is using something like a shareware model, where users are not required to pay for plans (but are encouraged to), it is not clear how an author would recoup money spent on certification. Requiring all plans to be certified thus seems overly restrictive – one of the core strengths of the 3D printing movement is the degree of innovation which it encourages; requiring all plans to be certified risks stifling a large part of the revolutionary potential of the technology.[9] Having some plans be certified raises the potential that people will choose plans unwisely, but it seems a more reasonable balance of autonomy and safety concerns. We can ensure that people have expert opinions available to them – if they choose to exercise their autonomy in a way that ignores or overrides those opinions, that is their choice.[10]

<u>Issue Two: Intellectual Property</u>

Another ethical issue involving 3D printers concerns intellectual property. At the moment, it is fairly difficult to reproduce most objects that have been created in a factory; to do so would require a similar manufacturing set up, which means that companies are most likely to face a

[8] Or perhaps there could be some neutral body like Consumer Reports or Underwriters Laboratories who did standards tests for plans.

[9] Assuming it were possible to enforce such a rule, that is – my suspicion is that uncertified plans would still be shared, just less openly.

[10] Note that there will still be some safety issues due to the fact that different machines produce slightly different objects using the same plans, since some of them manufacture to higher standards. This, too, would need to be addressed eventually, perhaps by certifying particular combinations of plans and printers: we could say that if you print plan X on printer Y then it meets the necessary standards.

threat of unauthorized reproduction from other companies, not from individuals. However, this changes with 3D printers and scanners.

There are two relatively easy ways to recreate an object using a 3D printer. First, if you have a copy of the relevant CAD file, you can simply print it out using your own equipment. This is something companies can address by protecting their files; if a person has an illicit copy of the file, then that can be treated as theft, just like for any other file. Unfortunately, there is another method of reproduction that avoids this sort of obvious theft. Using a 3D scanner, a person can scan an object and create their own plan for how to print it. This file can then be saved and used to reproduce the original object.

While this method does not involve stealing a particular file from a company, many are still concerned with whether this infringes upon the intellectual property rights of the original company. If so, then this technology has opened the doorway for a plethora of law suits, although pursuing those law suits might be tricky; trying to find individuals printing single copies in their homes is likely going to be impossible unless those individuals then distribute either the copies or the plans they have made. One of the complications of this is that there are different forms of intellectual property protected by law, and of course the law varies by country. I will focus on the United States as an example of the difficulties, following the discussion by Weinberg (2010) of types of intellectual property and their likely protection; I will then consider the philosophical issues in play with respect to intellectual property.

There are four kinds of intellectual property that could be relevant: copyright, patent, trademark, and trade dress. Copyright is probably the kind of intellectual property which is most familiar to a general audience, since it exists automatically and pertains to photographs, texts, and other common forms of creative expression. With respect to an object, copyright applies to the artistic or decorative elements of an object; an object itself is only subject to copyright if it is intended to be a sculpture or purely decorative. As such, assuming the item is not a sculpture, the decorative element of an item could be copyrighted, but the rest of the item is not; if you altered your plan to omit the copyrighted element, then the object could be legally reproduced.

The patenting of an invention is a process that has to be undertaken by the inventor or his/her agent; it must be applied for, and the invention must exhibit some degree of originality and not be obvious. Many manufactured or produced objects are not patented, although particular parts of them may be. As such, you will not necessarily be violating a patent by scanning a common object, unless that item or a part of it has been patented. In the United States, patent protection is all embracing, however; whereas copyright law contains an exception for fair use, patent law does not. Thus those objects which are protected by patent will likely be protected completely.

Trademark refers to a manufacturer's mark, and exists mainly to designate something as authorized; it exists to protect the consumer from illicit copies. Assuming that a person is creating something for home use, trademark protection does not apply since presumably she will be aware that she 3D printed it – there is no way to deceive herself, so she does not require the consumer protection of trademark. If the object is being distributed, and thus there is some concern about deception, that can easily be addressed by simply omitting the trademarked image or symbol; the rest of the object can be printed without infringement.

Trade dress refers to the packaging of a product being an indicator to the public of its origin; the classic example would be the iconic silhouette of a glass Coca-Cola bottle. Once again, this is unlikely to apply to a person printing something for home use. However, it may be more tricky if the object is going to be distributed; this could be a way to protect certain design elements, if they are taken to be crucial to the brand's image. The matter is complicated by the fact that trade dress cannot be claimed to be inherent in a design; it has to come from a secondary source. For instance, if there is a marketing campaign to associate a particular design image with a company in the consumer's mind, then this is an attempt to create trade dress. As such, a company cannot simply design a product and claim trade dress at the time of design; it would happen after the fact.

In the United States, therefore, intellectual property rights may not be threatened simply by scanning an object and recreating it; unless it is protected by patent, it is not clear that any of the other forms of intellectual property protection would apply. Other places may provide more or less protection. For instance, Bradshaw, Bowyer, and Haufe (2010) note that, in England, there is an exception to patent protection for non-commercial personal use; hence even a patented item would likely not be protected from this form of reproduction.[11]

While a company can protect their own CAD files and seek to have them removed if they appear on websites, there will be enforcement issues; reputable sites may remove illegal plans, but the plans will undoubtedly still exist on other sites, just as illegal copies of films and music do. Moreover, if a new plan is created by someone else via a 3D scanner and freely distributed, then it is less clear whether the company has any legal right to stop this. We may ask, however, whether this distribution is wrong in a philosophical sense; to do so requires us to consider why we protect intellectual property.

In general, our desire to protect intellectual property seems to stem from a belief that intellectual effort should be rewarded, just as physical labor is. If you create a sculpture, then part of what you created is the idea behind it, not just the physical form; as such, we hold that mental labor should be protected as well as physical labor. Just as I cannot steal your physical sculpture without causing moral harm, I also cannot create a copy of your sculpture, as you have put intellectual labor into the design.

One of the key motivations behind this protection seems to be to reward creativity and innovation. Yet, of course, what counts as creative or innovative changes over time – the use of perspective was hugely innovative when it first arose, but it is a standard artistic method now. Similarly, as technologies change, the standards for innovation change as well; the first home personal computer was hugely innovative, but to make an innovative home computer now would require additional creativity.

As such, it may be that we have reached a point where designing a physical object is not sufficient to count as particularly creative. If the object is particularly artistic, we might recognize that. If creating it involves new manufacturing techniques that cannot be easily

[11] There may be other exceptions to patent protection under UK and European law, such as reproduction for educational use. However, a full treatment of the laws in other countries is beyond the scope of this paper.

copied, then that will almost certainly be eligible to be protected. Yet it may simply be that, as a society, we do not think that manufacturing a common object is deserving of protection; a person or company must do more to count a putative invention as being innovative.

Companies, then, would need to focus their efforts elsewhere to keep consumers – having the initial idea would not suffice. It might be possible to market it better than competitors, or to instill one's brand with cachet; people will pay extra for a purse with a Chanel logo on it, or a phone with an Apple logo on it. Similarly, it might be possible to have a better finishing process. Right now, goods come out in a rougher form than in traditional manufacturing processes; it could be that post-production processing adds value that is not easily duplicated, resulting in a kind of hybrid manufactured product. Or companies may move to designs which are not easily replicated by additive manufacturing processes; perhaps this is where the future of innovation lies, at least for corporations.

Philosophically, this is where my sympathies lie. As times change, so too do criteria for innovation; we must adapt laws and ethical understandings to reflect current abilities. Thus while I anticipate a future of legal wrangling over intellectual property, I believe our current laws do not need drastic extension. Typing is no longer a specialized skill requiring experts with training; so too for creating objects using certain technologies. If the only thing that makes your object distinctive is that no one else had the technology to create it, then it becomes outdated as the technology spreads. Truly distinctive innovation can be protected by patent; the rest is fair game.

Concluding Thoughts

While I have focused on the problems I see looming in the future of 3D printing, many opportunities also arise from the technology. For instance, small companies and individuals are already using them to innovate in new ways; the ability to print prototypes and try out inventions is a boon to many small inventors. Hence 3D printers can spark creativity, not simply be used to copy the designs of other people.

Similarly, there is a vast potential of uses for these devices, particularly in the field of medicine. Researchers are currently working on organ fabrication (Fischer 2013), printing up copies of tumors for surgeons to investigate, without having to operate on living patients or rely on cadavers (Banks 2013; Thilmany 2012), and creating custom prosthetics (Banks 2013). Furthermore, there are many other potential creative uses. People have created 3D models of calculus visualizations for blind students; they also modeled the flooding from Hurricane Katrina in real time to better plan rescue and evacuation attempts. (Raths 2014) The future possibilities seem almost boundless.

Having said that, there are a few limitations which must be addressed. One promising aspect of 3D printing is that it may have a positive effect on our environmental impact, since it allows us to cut down the supply chain by printing objects as they are needed; similarly, additive manufacturing is less wasteful of raw materials than subtractive manufacturing. (Huang, Liu, Mokasdar, and Hou 2013; Nowak 2013) Nevertheless, long-term environmental impacts have not been studied, and must be considered. Similarly, many 3D printers are limited in the size of objects they can print, as well as what materials they can use; while 3D printing has expanded from plastics to certain kinds of metalworking – and even into using biological materials – there are still many other materials we cannot currently work with. (Berman 2012)

Despite these drawbacks, 3D printers will likely be key to the future of manufacturing. As such, we must consider the ethical issues inherent in the adoption of this new technology. It is striking that one of the first 3D printed items to receive a lot of media attention was a gun; the possibility of printed weapons seems to have captured public imagination, and we certainly must address the security ramifications of this technology. Yet most items that are 3D printed will not face these kinds of security issues nearly as much as they will face safety issues – a fact which is frequently overlooked but must be addressed. Similarly, we face threats to intellectual property, stemming from the ability to copy items in a new fashion.

With respect to both of these issues, I believe that the key is balance. The safety issue must balance autonomy and consumer protection; the rights issue must balance intellectual property and innovation. Neither of these conflicts is new. What is new is the pressing nature of these questions in a novel arena, one where current thought and law does not easily apply. I have argued that with respect to safety, we may have to move away from regulating objects and towards certifying specific plans. Intellectual property, however, seems adequately protected; the times are changing, and companies must do so as well. Neither companies nor philosophers can afford to become complacent in the face of such revolutionary new technology.

Ethical Impact Statements

This article does not contain any studies with human participants or animals performed by any of the authors. Informed consent was obtained from all individual participants included in the study.[12]

Acknowledgements

A version of this paper was presented at the CEPE/ETHICOMP 2014 meeting in Paris, France. I am grateful for the helpful comments received by people present at that presentation, as well as the peer reviewers and editor of this journal. My thanks also to Clif Flynt, Rebecca Newman, and Bill Roper for answering certain questions on engineering practice.

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[12] It seems odd to include an informed consent statement when there are no studies with human participants involved in this paper – as I stated in the previous sentence – but it seems to be required, so I have included it. Either that sentence or this footnote (or both) should probably be removed upon publication.

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