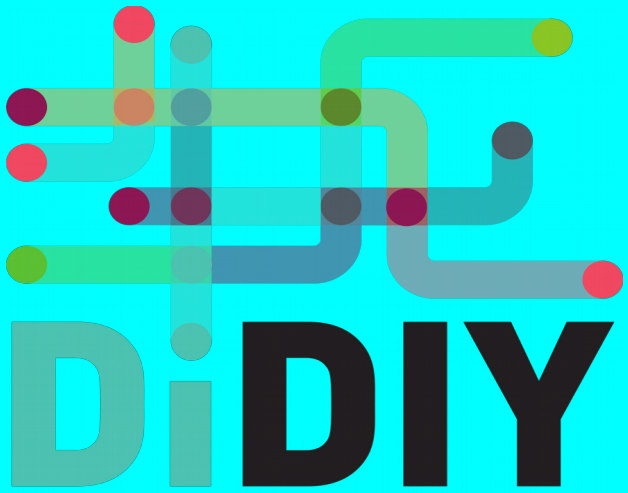

DiDIY

DIGITAL DO IT YOURSELF

Guidance e-Manual

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Preface, and disclaimer

This document is a **draft, preliminary** version of the official Digital DIY Guidance Manual that the DiDIY Project will publish at the end of June 2017. It is **only** shared with the participants to the DiDIY Final Conference, as just one more tool to help them follow the conference itself, **actively** participate in it, and make the most of the associated workshops on Production and Education.

Please understand that the differences between this version and the final one may not be negligible. For example, this text still lacks, among other things, a comprehensive list of resources that help the reader to know DiDIY even better; it also doesn't include yet more real-world examples, or explicit mentions of some policy guidelines about Digital DIY, not officially published yet. Last but not least, the text must still undergo the final, comprehensive review by the whole team of the DiDIY Project.

All these limitations notwithstanding, we feel that this draft already gives an adequate, if not final, overview of the main

issues, risks and opportunities associated with Digital DIY, and of what will be necessary to do at all levels, to maximise the benefits of Digital DIY for European Society.

Finally, please note that your feedback about this draft is **very welcome!** It is both our wish and our duty that the final manual reaches, and is immediately usable by, as many readers as possible, not just academics, and other specialists! Please help us to improve this draft, sending your questions, doubts, suggestions, critiques, etc by email to didiy@didiy.eu.

Happy reading,

the DiDIY Project Team

Introduction

Note: *This manual is a product of a research project of the European Union (EU), and as such its first intended application is inside the EU itself. However, the authors consider almost all the contents and conclusions here presented as valid and relevant also outside the EU.*

Do It Yourself (DIY) is a long-standing phenomenon, characterized by individual activity to create, repair, and modify objects. It typically occurs outside of companies and without the support of paid professionals. People engage in DIY sometimes with economic justifications, but also driven by personal satisfaction, interest in customization, or social reputation. In a context of industrialisation, that separated producers and users, DIY is a means for individuals to recover their autonomy by the productive and creative use of their skills and time.

Information and Communication Technology (ICT) is widespread today, embedded in computers, smartphones, 3D

printers, home automation systems, etc, changing the role of DIY and the way DIYers operate. To designate this emerging socio-technological phenomenon of DIY enabled and reshaped by digital tools we coined the term "Digital Do It Yourself" (DiDIY).

DiDIY is a complex, rapidly evolving socio-cultural phenomenon, which presents both great opportunities and significant risks for Europe. On one hand, DiDIY is potentially dangerous, both for the environment and for public safety, as well as for the economy, at least for certain business models. DiDIY may also worsen some social divides, or create new ones, and it already is practically impossible to stop. At the same time, DiDIY may greatly increase individual and collective well-being, and help European citizens to acquire some of the skills they need in a digital world. In doing so, DiDIY may create many economic opportunities and promote active citizenship, while making the European society more resilient, and playing a key role in realising sustainable futures for Europe.

The DiDIY Project (www.didiy.eu), run from January 2015 to June 2017 by a Consortium of seven partners from several EU countries, has studied the nature and potential long term effects of DiDIY. This manual presents the main findings of the Project

and discusses what may be done in order to exploit the more lasting, sustainable, and socially relevant opportunities of DiDIY. Each of the main issues is introduced in the simplest possible way, with real-world examples. Detailed analyses of the same issues are in the official public reports of the DiDIY Project, all freely available online (www.didiy.eu/project/results) with open licenses.

Who should read this manual

DiDIY is relevant to all citizens, to the point that, as you will see later, we also suggest that everybody should acquire some "basic DiDIY knowledge". This said, this manual is primarily, but not exclusively, aimed at the following categories, with the purpose of presenting them why and how to deal with the opportunities and the risks of DiDIY.

Policy and decision makers: DiDIY makes new opportunities and threats emerge, from the job market to healthcare, and from education to environmental protection. Therefore, EU, national, and regional lawmakers and public administrators, and in general all decision makers both in the public and private sectors will be obliged to deal with DiDIY, each according to their roles and responsibilities.

Teachers: schools, teachers, and educational systems as a whole are facing an unprecedented pressure. Demand for updates in

the content of the traditional school subjects and educational methodologies is increasing from all directions. Digital literacy, which includes DiDIY, has been acknowledged as a fundamental component of education: in a digital, globalised society it is necessary that citizens are able to keep developing their attitudes and learning new skills throughout their lives. In this context DiDIY, which allows an innovative approach to both STEM and other subjects, may help adequately prepared and supported teachers to exploit flexible and affordable technological tools in project-based education.

Business and NGO/public managers: in several sectors of the economy, DiDIY may generate new ways for companies to generate value, for their customers and their employees. This may greatly increase both competition, and opportunities of collaboration among businesses. DiDIY will also change how organizations work internally. Access to DiDIY may give every employee, or member of any other structured organization, more concrete opportunities to work by her/himself, or in semi-autonomous teams, with creative and innovative approaches. This will change the tasks and responsibilities of workers,

creating more occasions and challenges for internal cooperation and coordination inside each organization. Therefore, the roles that will need to change more will be those of managers, given that they will have to manage a workforce which may, and sometimes should, be much more independent than in the past. Managers will need both more of traditional soft skills, like communication and negotiation, and whole new hard skills, like knowledge of DiDIY technologies.

Trade union representatives: trade unions are already in crisis, due to the combination of globalisation, automation, and other forces. Many of their traditional themes have lost relevance, from safety, stress, and alienation in the workplace, to definition of working hours, roles, and career paths. This is forcing unions to face troubling questions, also about which categories of workers they should defend and whether collective representation is still needed. The diffusion of DiDIY outside and inside companies will only accelerate this change. On the other hand, DiDIY will provide many concrete opportunities to create or preserve jobs, for example by making it easier to retrain workers, or to create entirely new types of companies and cooperatives: trade unions

may play a very important role in the development of such initiatives.

Craftspeople, artists, and creative workers: DiDIY gives many more occasions to many more people to fully exploit their creativity and be rewarded for it than in the past, at the same time also exposing them to more competition. However, such changes do not occur simply because new technologies exist: all those creative people need to be aware of the nature and opportunities of DiDIY to actually take advantage of it.

Makers: environmental protection, education, making a positive socio-economic impact are key concerns of many DiDIY-related organisations and individuals. It is also in the interest of makers to remove some of the bureaucratic obstacles that today constrain their activities. However, in order to make those activities more economically sustainable and more beneficial for all society, makers should also engage, both locally and nationally, in long-term evangelisation and policy-making. This manual offers some background and proposals for all makers interested in such activities.

Digital Do It Yourself: definition and main facts

What is DiDIY

Do-It-Yourself (DIY) is usually characterized by individual, not-for-profit activity, which occurs outside of companies. People engage in many, wildly different kinds of DIY, for different reasons: money savings, personal satisfaction, interest in extreme customization, social reputation, need of independence and self-reliance. Digital DIY (DiDIY) is a complex phenomenon that is already everywhere and continues to grow. It consists, in most cases, in non-professional fabrication or control of physical objects, that is made possible by tools that are:

- directly operated by some software, instead of a human being;
- much cheaper and simpler to use than they were even a few years ago. Growing online communities, and support services,

further lower the technological and psychological barriers for DiDIY newcomers.

DiDIY is both something that someone:

- **does**, that is an activity of production, modification or maintenance of objects or services; in this sense DiDIY is *objective*, and manifests itself as tools, products, structures of collaborations, etc;
- **has**, a mindset, and then a producing and consuming culture; in this sense DiDIY is *subjective*, and manifests itself as motivations, competences, social contexts, etc.

This means that, while DiDIY could not exist without digital technology, at its core it remains a sociocultural, economic, and psychological phenomenon.

The dual nature of DiDIY also means that it cannot restricted to hobbies and individual, non-professional activities: DiDIY activities and mindset also make it possible, for groups of employees or individual professionals, from dentists to cabinet makers, to build custom tools for their work.

Main features of DiDIY

- **DiDIY enhances and extends human capabilities.** By replacing manual dexterity and labour with the capability to use software, and software-driven hardware tools, DiDIY can enable more people to do more things. With 3D printing, for example, even people who cannot use a chisel may become sculptors.
- **DiDIY is ubiquitous**, because it is based on software, which is extremely flexible. Any tool that is controllable by electric signals can be controlled by software. Software, in turn, can process designs and instructions of every conceivable sort. From a strictly technical point of view, the only limits to manufacturing something in DiDIY fashion may be the cost of machines and raw materials.
- A crucial feature of DiDIY is the **automation** of conversion from *bits* (designs and knowledge) to *atoms*, that is physical objects, without intermediate steps, or constraints due to human limits like lack of time and/or skills. Even the opposite conversion, that is data (bits) gathering from the physical world (atoms), is equally automated by digital technology. We

proposed to call “ABC” this "Atoms-Bits Convergence", to indicate that it creates a new alphabet of knowledge. By means of ABC, DiDIY brings some characteristics of the digital realm (duplication and communication at near-instant speed, unlimited copying, etc) to the unregulated activities in the physical world that have always been typical of DIY.

- The practical consequence of the previous point is that DiDIY is very difficult to regulate, because it **cannot be really stopped, nor limited:** in digital networks like the internet, preventing the spread of digitized designs or documentation, or that of software, is almost impossible.
- At the same time, and for the same reasons, DiDIY is often open and collaborative: the internet can transform the Do It Yourself into a (digital or not) Do It Together (DIT), or Do It With Others (DIWO).
- DiDIY is much more than 3D printing, and high-tech activities! Some of the most relevant, long term consequences of DiDIY may come from its impacts on primary needs (food, clothes, shelter, etc) and uses of traditional raw materials like wood, food or textiles, with technologies different from 3D printing.
- DiDIY touches both basic, personal rights (safety, privacy,

equal opportunities, education, etc) and public issues like pollution, ethics, and economic growth.

DiDIY challenges and opportunities

Wide diffusion of DiDIY challenges several institutions and basic norms of society, but also creates new ways to solve pressing social problems. This section describes the main areas in which these challenges and opportunities arise.

Safety, ethics and laws

In some extreme cases, DiDIY may be very good, if used to reduce pollution or quickly test new medical therapies, or very dangerous, if used to produce weapons or drugs. The reason is that DiDIY greatly increases the concrete opportunities for everybody to produce every kind of physical objects, or misuse, even involuntarily, existing ones. DiDIY, that is, makes it easier to physically hurt themselves or others, or to violate other people's rights in ways not possible otherwise (e.g., fabricating keys to enter somebody's home, or using drones to spy on them). In a

society where DiDIY is really, practically accessible to everybody, these opportunities may make some laws impossible to enforce, in practice. In some cases, the arrival of DiDIY may invalidate altogether some basic agreements and values, like the foundations on which gun control stands today. Eventually, a situation like this can force society to redefine what is right and what is wrong, and consequently to redesign laws and other norms, rather than just "upgrading" them. For example, today's gun control laws in most of Europe are, by and large, considered just and needed by large part of the population, even if they are much more stringent than, for example, those in the United States: the majority of EU citizens considers it right to not allow a private citizens to own assault rifles, or similar weapons. If, because of DiDIY, it became really easy to self-produce those weapons (but this, as we will see, is not likely), and if the number of crimes committed thanks to those weapon increased significantly, this would likely cause most citizens to rethink what they consider right or wrong, as far as gun control is concerned.

Eventually, DiDIY may also question the very processes, and goals on which the creation of laws and regulations is based today. In some cases, that is, "regulating" DiDIY may be as simple

(relatively speaking...) as setting new conventions about where to move the already existing barriers between what is legal and what is not. In others, the only solution may be to figure out entirely new decision criteria, and obtain social agreement for them.

Existing business and innovation models

Today many companies, and behind them whole business models, depend on some combination of artificial incompatibilities, or scarcity and on planned obsolescence. As examples of these models, we may quote incompatible phone chargers, or ink cartridges for printers. By making production of adapters and spare parts easier, not to mention that of whole new chargers or printers, DiDIY can constitute a big threat for the manufacturers of those products. Companies that adopt other business models, instead, may have more chances to succeed, just *because* of DiDIY. This topic is discussed in more detail in the next section of this manual.

Separation between (mass) producers and customers

DiDIY creates both new opportunities and threats also because it makes the distinction between users and producers of artefacts much fuzzier, and much more variable from time to time, than it has been in the last century. Many of today's laws, liability and insurance policies, environmental regulations, codes of conducts and whole service industries, starting from advertising, are all built upon a rigid, clear-cut separation between mass producers and consumers. Widespread diffusion and social acceptance of DiDIY practices will weaken that separation.

Unnecessary complexity

DiDIY exposes, possibly more than most other factors, what we may call the "peak complexity" of the current legal and social systems. All over Europe, small business owners in all sectors complain about the costs and other burdens placed on them by several layers of regulations, often written with only big

companies in mind. DiDIY, considered as the practical possibility to produce and manage many more objects autonomously, will further decrease the socio-political acceptance, as well as the economic sustainability, of those constraints.

Participation and personal responsibility

DiDIY makes it easier, for single individuals and whole communities alike, to self-organize and be more independent, at different levels. On one hand, this is a useful capability for protecting individual freedom, building new, more resilient communities or transforming existing ones in the same manner. On the other, the opportunities for self-reliance provided by DiDIY may decrease, rather strengthen, social cohesion. Thi problem may be even more serious, if only certain segments of the population can actually practise DiDIY.

A distinct, but related issue is the fact that many DiDIY activities produce objects whose designs are nobody's exclusive property, and may also be legally changed, and reused in uncontrollable ways, by many more people.

One of the consequences of these issues is that DiDIY requires

that every individual accepts more individual responsibility for their actions, and maybe less protection from others (e.g., less product liability than today) than what they would be in a society based on centralized, strictly controlled mass production.

The main, long-term effects of DiDIY

In the previous section, we have seen the main features of DiDIY: now, what would their *concrete* effects be, at a large scale, and in the long run? How would work, welfare, personal life... be in a society in which practising DiDIY, or at least having access to "DiDIY-like" services had become as commonplace as making a photocopy, or taking a picture with a smartphone? In such a society, even if DiDIY were only practised in the same ways as today, its sheer volume might create more problems than benefits, if not supported by adequate education and regulation.

DiDIY will contribute to change how individuals study, work, cooperate, express their creativity, solve problems. In general, DiDIY will change how individuals and groups deal with the physical and non-physical goods and infrastructures of the knowledge society. At the social level, the flexibility and ubiquity of DiDIY will interact with the ethical, environmental, social, and

economical pressures that Europe has been facing since several years, and that would exist even without DiDIY. As a result, DiDIY will have growing effects on crucial fields like safety, privacy, security, healthcare, human rights, education, employment, environmental and consumer rights, innovation. Some of the main positive and negative consequences are described with practical examples in this section.

Sustainability and quality of life

In every field, the internet enables creative individuals and groups to find inspiring others who share their passion, and reach together new levels of creativity, imagination and opportunity. Together with the internet, DiDIY gives more people an opportunity to express their creativity, and create new custom relationships between them and physical objects. This can have great positive effects on their general well being and quality of life, as well as sustainability for the whole society.

Where modern societies are often built on an ethos of disposable consumerism, DiDIY highlights the power of fixing and remaking goods. 3D printing and other technologies enable people to

create the "spare parts" which will make something work again, or to develop innovative solutions to make things usable in new ways. Even before that, DiDIY enables people to build, or buy, only what they *really* need, only when *they* really need it.

DiDIY can help societies all over the world reach the UN Sustainable Development Goals 11 ("Sustainable Cities and Communities") and 12 ("Responsible Consumption and Production"). More in detail, DiDIY can become a key way for local and sustainable solutions to environmental problems to be innovated, implemented and managed, through the combination of *global* knowledge and best practice with *local* resources and making. Of course, without adequate awareness in individuals, and adequate support from institutions, DiDIY has the same drawbacks of other technologies, from safety issues to pollution: many raw materials and microelectronics components that are widely used in DiDIY today are quite hard to recycle.

What if home appliances could last FIFTY years?

The Increvable is a prototype of washing machine that comes as an assembly kit. It is highly modular, can be programmed as its user wants via a standard USB port, and is specifically designed to last and be serviced for 50 /yes, FIFTY!) years. Strictly speaking the Increvable is not DiDIY, but an industrial prototype. However, it is a perfect example of the impact that DiDIY may have on sustainability, and consumer rights. If Open Source appliances were designed by DiDIYers from scratch, with the same criteria, they or their spare parts may be legally produced on demand, everywhere, by everybody with the right skills and machinery. This would greatly reduce both the total cost of those appliances, and the amount of WEEE (Waste Electrical and Electronic Equipment) waste generated by households worldwide. To know more about these scenarios, read "L'Increvable: A Digital DIY washing machine" (www.didiy.eu/blogs/lincrevable-digital-diy-washing-machine).

Privacy

Some uses of DiDIY also pose a threat to the right to privacy. DiDIY gives more concrete opportunities, to more people, to build, or get access to, data collection devices of many kinds: from drones and spy cameras to IoT devices that control home automation systems, or record people movements.

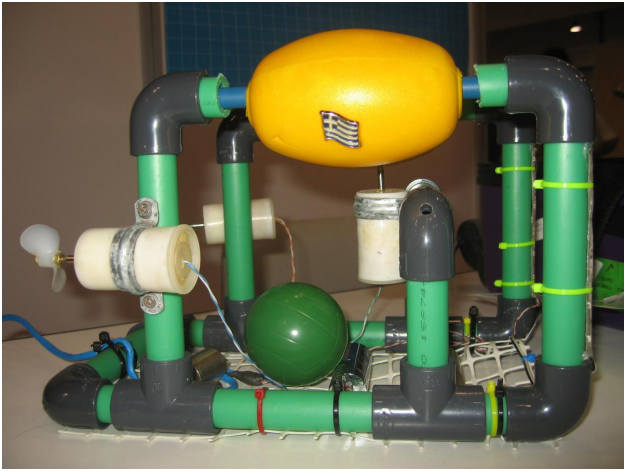
Education and research

DiDIY greatly facilitates the production of prototypes and other artefacts to be used in educational contexts. Giving students the opportunity to work on their own projects using DiDIY tools helps them develop early various skills that can be of great value later in life: not just design and engineering skills, but also a positive attitude toward sharing, problem-solving, critical thinking, collaboration, and a sense of initiative more generally. DiDIY can also be an excellent way to learn about, and practise, environmental sustainability and the idea of repairing rather than consuming.

Exposure to DiDIY might help add an exciting element, as well as

a more hands-on feel, to the teaching of STEM (Science, Technology, Engineering and Mathematics) subjects, which can sometimes seem arid.

DiDIY enables "learning by making"



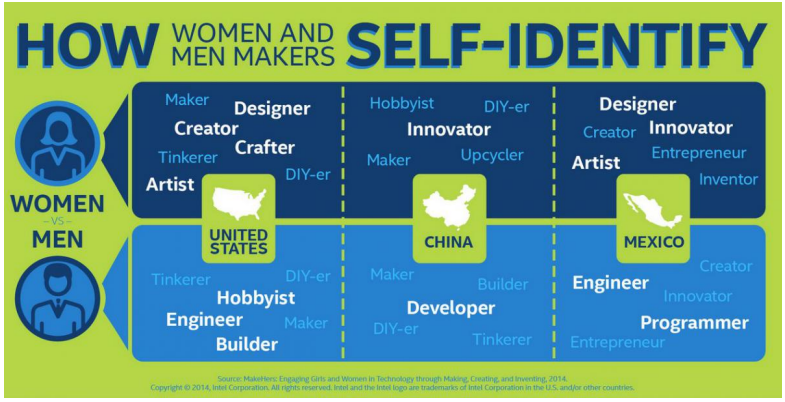
With proper preparation and support of teachers, DiDIY makes STEM learning STEM (as well as many other subjects!) less arid, and stimulates, among other things, the problem-solving and design skills of students. For some real-world examples of how this may happen, read how some Greek students built the

DiDIY underwater robot vehicle (www.didiy.eu/blogs/how-some-greek-students-built-their-very-own-didiy-underwater-robot-vehicle) shown in this photograph, or how others in Italy created DiDIY warming "body wraps" (www.didiy.eu/blogs/arrhenius-digital-diy-body-wrap-warms-you).

DiDIY could attract more members from underrepresented groups, and empower students with disabilities to create themselves the objects they need in their everyday life, and to better integrate in their class.

On the negative side, there is first of all the danger of idealizing the impact of (new) technologies on educational outcomes. Giving too importance to DiDIY may lead to neglect traditional manual skills (craftsmanship) that for some students may be more appropriate, and lead to more job opportunities. Providing merely technical training on how to operate 3D printers or laser cutters, but not awareness of the environmental impacts of the underlying technology, would just create one more source of unnecessary waste. As an extreme example, if all learning were to be assessed by reference to the production of physical artefacts, then one may conclude that subjects like history or languages do not involve any true learning!

Are non-DiDIYers "less valuable humans"?



"I am not a maker. In a value system that is about creating artifacts, specifically ones you can sell, I am a less valuable human."

This is just one of the concerns caused by the whole value system associated to making (even in education, and only partially related to gender, that are expressed in the "Why I am not a Maker article summarized in this DiDIY blog post "Are non-DiDIY-ers less valuable humans?" (www.didiy.eu/blogs/are-

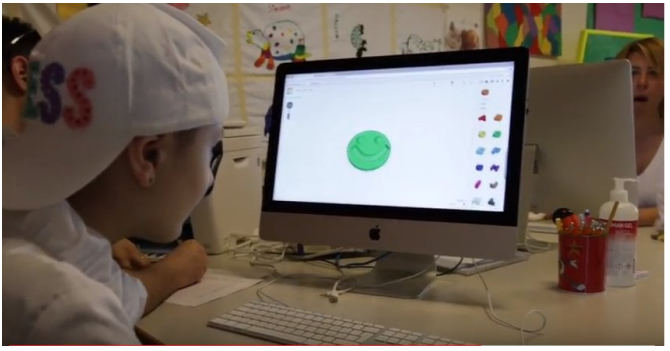
non-didiy-ers-less-valuable-humans). The infographic comes from an Intel report (iq.intel.com/report-shows-maker-movement-natural-entry-girls-women-technology).

Finally, we need to be aware of two more risks, which in fairness are present in *any* proposal to reform education: one would be the implementation of "one size fits all" approaches; the other, the possibility that "throwing" DiDIY to schools may maintain, if not aggravate, some educational inequalities and divides: this may happen because of language barriers (much DiDIY documentation is only available in English), or because of lack of concrete access to, in this order: properly trained teachers, adequate machinery or broadband connectivity.

DiDIY may have similar effects, and for the same reason, on scientific research. Many communities are already exploiting DiDIY for research purposes. DiDIY in research allows both professional and amateur scientists to have access to the equipment and data they need at a much lower cost. If these initiatives will be adequately supported (with the caveats described in the final part of this manual!), they will broaden participation in scientific research. This, in turn, especially if coupled with best practices of the Open Access/Open Data

communities, will facilitate the pursuit of audacious research projects that might otherwise have struggled to find support.

DiDIY facilitates learning for ill, or special needs children



Children affected by leukemia can meet almost nobody, and only touch sterilized objects. This makes it impossible for them to participate in practical activities.. unless they have access to DiDIY, like the child in this photograph, from the Policlinico Hospital in Rome: thanks to 3D printing, she can build what she wants remotely, and use the result, because it is easy to sterilize plastic. DiDIY activities like robotics, instead, can help disabled children to "blend" and participate with the others, more than they would have done without the robot as a "catalyst". Both these cases are described with more details in the DiDIY blog (www.didiy.eu/blogs/digital-diy-inside-hospital-course and www.didiy.eu/blogs/didiy-robotics-makes-all-children-work-together).

Product safety and liability

DiDIY makes dangerous stuff easier to make, and ordinary stuff easier to misuse. Widespread DiDIY manufacturing may bring huge benefits to society, from reduced waste and pollution (DiDIY spare parts?) to support for new art forms, or more effective teaching methods. But self production of objects that may directly hurt people, be they weapons or, much more likely, unsafe furniture or car parts, presenting objective risks that should not be overstated but cannot be ignored.

The real problem here is that DiDIY challenges the very definition of what a product is at all levels, from legal to marketing, as well as the very concept of product liability. The latter is a consequence of the so called "duty of care", which is a legal obligation to adhere to a standard of reasonable care when manufacturing and selling products. The advent of DiDIY, however, problematises this issue, by enabling many more individuals to make products that may be unsafe. The distributed, collaborative manufacturing typical of DiDIY typically is not certified and tends to be non-market: therefore, it does not necessarily follow the same quality standards of mass

production. This ultimately has consequences on how we all think about product responsibility and risks.

Unregulated production of dangerous objects

Technically speaking, DiDIY makes certainly easier than it was a few years ago to produce very dangerous products, from undetectable weapons to explosives, drugs, prosthetics and assorted pathogens. Due to the distributed, private nature of DiDIY, the manufacturing and, in most cases, even the usage of those products would be almost impossible to prevent, detect, and stop.

The first thing to point out, in order to put this threat in the right perspective, is that, while DiDIY greatly facilitates them, these activities do not really need DiDIY to happen. European regulators are already facing the challenge of what has been called "legal highs": private individuals with the relevant skills devise new drugs that they synthesized in laboratories outside Europe, and then legally imported. Gun control is in a similar

situation: today, even in Europe, getting a conventional weapon by legal or illegal means may still be much simpler and convenient than manufacturing one, even with DiDIY. Above all, there has never been the need to use DiDIY to engage in personal fabrication of firearms and other deadly weapons.

There is NO need of DiDIY to make lethal weapons

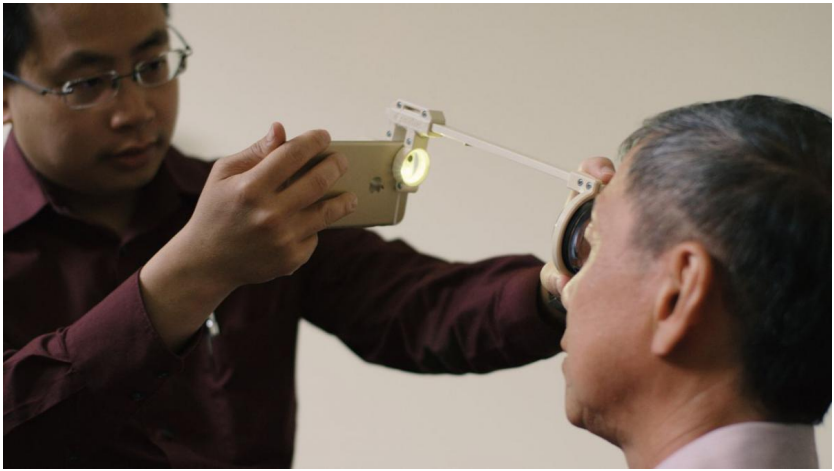
The home made composite pistol from the 1993 movie "In the Line of Fire" (left), together with the crossbow made with magazines and toys featured at Terminal Cornucopia (right) (terminalcornucopia.com) remind us a very important point: strictly speaking, there has never been need of DiDIY to make lethal weapons.

Medicine, biology and body enhancement are other troublesome areas. As we mentioned in a previous section, DiDIY research in fields like medicine, or biology, could lead to independent development of new compounds that might hold significant therapeutic or enhancing promise. Products of cutting-edge research such as 3D bioprinters can be used as DiDIY tools for both therapeutic purposes (organ transplantation, home printing of customized drugs) and non-therapeutic ones, in particular human enhancement. Professional athletes, soldiers, and biohackers are three major examples of social groups that are likely to take an interest in the use of such DiDIY tools for enhancement purposes.

On one hand, all these developments would be good for society. On the other hand, it is obvious that the unregulated testing, distribution, prescription and usage of these classes of DiDIY machines and products would still constitute a serious problem.

Smartphones in arms

Body hacker Tim Cannon is reported to have had a computer "the size of a small smartphone" implanted into his forearm, "without the aid of anesthetic or a licensed doctor". DiDIY let's people do this, as well as greatly extending the number of people who may discover the next life-saving drug, or build completely customized prosthetics and other medical devices not available with other means, like this 3D printed eye examination kit:



The ethical implications of DiDIY in medicine and biohacking are discussed in the DiDIY report titled "Ethical issues in Education and Research" (www.didiy.eu/public/deliverables/didiy-d4.6.pdf). The eye examination kit and similar DiDIY solutions for healthcare are described in the post "Glimpses of the future impact of DiDIY in healthcare" (www.didiy.eu/blogs/glimpses-future-impact-didiy-healthcare).

Less or more jobs?

Globalization and non-DiDIY application of ICT have already destroyed millions of jobs worldwide, and will continue to do so. Whether the same factors will create more new jobs than they destroy is difficult to say. The DiDIY research has observed that there is no agreement on this. The overall contribution of DiDIY to employment over the coming years is equally uncertain and open to debate. It will depend on many contingent factors such as the pace of technological development and the quality and cost of the future, more or less home-made DiDIY products.

Technology often creates new job opportunities in places very far from those where it destroys them. On this respect, DiDIY is no exception. DiDIY is usually cheaper, but above all much more flexible, than mass production. For these reasons, DiDIY may be just what many companies could use to reshore productive activities that are now the only source of (relatively) well paid jobs in developing countries. If, for example, DiDIY-based manufacturing of clothes took hold in "first world" countries, it would jeopardize jobs for around 50 million women worldwide, with devastating effects on their economic independence,

particularly in very poor countries like Bangladesh. Those people would also be very likely unable to exploit the new job opportunities created by DiDIY in their home communities. Even in developed countries, jobs created by DiDIY may not offer the same salary levels of the past.

These are serious concerns, that cannot be ignored, or dismissed outright as Luddism. They should, however, be evaluated without forgetting a basic point: millions of jobs are being already destroyed anyway, by globalisation, automation, and other application of technology which are all top-down and centrally managed, that is the very antithesis of DiDIY. This process will only get worse, in the short term at least. In this context, then, the main question is not if DiDIY makes this trend even worst. The main and real question becomes, instead, if and to what extent DiDIY can be a powerful tool to **counteract** the loss of jobs that would occur anyway. Some of the ways in which this may happen are presented in the next section.

Of course, there is one big, open issue here, which affects everybody from youngsters just entering the job market, to senior workers who lost their job after decades: how many of those people will be able to quickly take advantage of those

opportunities, that is: how hard will it be for them to acquire the necessary DiDIY skills? Some answers to this question are provided in the final part of this manual.

More risks and opportunities for businesses

When it comes to businesses, their opportunities and the relations among them and with their own employees, DiDIY can be both a positive and a negative force. Some experts believe that the DiDIY applications of 3D printing and other digital technologies will help companies to restructure and recover from the crisis, much more than damage them. Others are more pessimists. What is safe to say is that, in the foreseeable future, more companies every year will adopt low-volume, distributed DiDIY manufacturing, be it 3D printing or other technologies. Strictly speaking, these should *not* not count as DiDIY, but as "real work", that is for-profit activities performed by professionals, inside companies. If that were not their main activity though, those would be *companies* doing DiDIY. In any

case, the same activities will both demand, and cause, an ever increasing availability of DiDIY skills and low cost machines. This, in turn, may create huge challenges and opportunities.

To begin with, the rise of DiDIY may have a radical impact on supply chains: it will allow businesses to manufacture, and customize locally, spare parts that they previously would have had to ship from distant locations, thereby allowing them to cut down transportation costs and to respond faster to consumer demand. This strategy would apply in many fields, including custom-made, 3D-printable pills and other medicines, that may be produced on demand, straight from their raw components, in properly equipped and operated pharmacies.

This will carry benefits for consumers but also for the environment, for example because of reduced harmful emissions due to transport of goods. The impacts on jobs worldwide have been already explained in the previous sections. For entrepreneurs and business executives, this situation will mean both more opportunities for success, and greater competition. In addition to the challenges (and opportunities) created by mass customization and supply chains disruption, DiDIY can damage existing businesses in several ways, both illegal and legal.

The illegal treats consist mostly of illegal manufacturing of counterfeit products or spare parts. Most of the companies already operating in many sectors of the economy, from healthcare to entertainment, share a very clear position about their Intellectual Property Rights (IPR): strong protection of such property, through legal instruments like copyright, patents, and trademarks, is deemed to be necessary to encourage inventors, authors, artists and, of course, investors, to invest in the process of creation. Without such protection, other could copy or otherwise imitate the intellectual work without incurring the costs and efforts of creation. This would make creative professionals unable to expect adequate financial compensation for their efforts, thereby undermining a crucial incentive to engage in such pursuits. According to industry estimates, even without DiDIY, IP violations as counterfeiting and illegal copying (the so-called "piracy") are costing thousands of jobs in European countries.

It is very challenging to quantify the added contribution by DiDIY to these problems. What we can say is that IPR violations via DiDIY are unlikely to wreck entire industries in the near future. The technologies enabling DiDIY would still need to improve before anything of the kind can happen. But the

possibility that such a scenario comes true in the longer run should be borne in mind.

In the meantime, many thriving DiDIY communities like Thingiverse, or the whole movements of Free/Open Source Software and Creative Commons, already show very clearly that, as a minimum, the industry position that absence of strong Intellectual Property protection stifles creativity is not valid in many cases: creativity can thrive even without the need for exclusive protection of ideas, industrial designs and creative works.

Besides, regardless of the validity of today's positions in favour of strong IPR, illegal copying and hacking of existing products may not be the biggest attacks from DiDIY to creativity and innovation as we know them today. At least in the medium and long term, the greatest risk for *existing* artists, designers, corporations, and in general all commercial interests based on monopolizing creativity and innovation, may come from the nature itself of DiDIY.

When copying objects becomes as easy as making photocopies

*What happens when **everybody** can make 3D digital copies of any physical objects, including ones they produced **themselves**, then share the copies online, so that everybody else, anywhere, may build **physical** copies, thanks to DiDIY? This is not an hypothesis, but a real world change that has just started to happen. The picture above shows some of the thousands of real objects already 3D-scanned and digitised, and then shared online in the database (www.didiy.eu/blogs/large-dataset-objects-shows-relevance-didiy-project).*

It is quite likely that most products and practices of DiDIY will happen without any IP infringement, or entrepreneurial drive for innovation. How should or could society, from individuals to insurance companies, handle the risk that market demand for industrial, "designer" products, be they clothes or tractors, shrinks without any counterfeiting or other IP violation?

What if demand for "original", commercially branded products, decreased not because more consumers can make or buy illegal copies of those same products thanks to DiDIY but because, thanks again to DiDIY, they have more, fully legal alternatives? What if, that is, they use DiDIY to design and make, for themselves or for profit, unique products, or just to clone products in the public domain that satisfy their needs? Traditional corporations will still be able, in order to maintain their market positions, to use advertising, and the capability to offer extra services unsustainable for small companies. However, they will have to do it in a much more challenging landscape. In a nutshell, DiDIY makes branded products much easier to copy, but at the same time, and maybe just for that reason, it may make them much less sexy.

One way to cope with this for traditional brands would be "on-demand" and "distributed" manufacturing, allowing their customers to customize prior to order, and shop locally. Strictly speaking, not even this would not truly count as DiDIY, unless customization is substantial. This "mass customization" strategy might actually provide a buffer for industries in the face of competition from DiDIY, and at the same time stimulate more people to try DiDIY themselves.

Let's now look at how DiDIY may change businesses, or any other organization, *internally*. The starting point here is the fact is that DiDIY changes the nature of work, a well as the skills and resources needed to do and manage it. By exploiting the availability and ease of use of DiDIY tools, organisational roles typically dependent on experts (internal or external to the organisation) can carry out, autonomously, innovative practices.

Traditional, for-profit businesses, typically require both large upfront investments, and centralized structures to maintain full ownership of some product, including, as already mentioned, strong IPR protection.

DiDIY skills and mindsets, instead, employ low cost tools and, possibly, Open Source designs, which do not have the same

requirements. In Open Hardware communities like the ones around the Arduino microcontroller, for example, the burden of R&D is shared between various members. As the designs are shared under non-exclusive conditions, anyone can engage in the production and sale of the products resulting from these designs.

All this means (and, in cases as Arduino, already proves) that DiDIY allows companies to experiment with many way to *cooperate*, rather than just compete, both with other companies and with their own customers. Even better is the fact that DiDIY makes it easier to create, and above all keep sustainable, new *types* of companies. This often, but not necessarily, happens through open business models, direct business-to-business cooperation, or clustering of several small organizations, both for- and not-for-profit, that can offer sophisticated products or services to their community.

In all those cases, by sharing DiDIY designs, knowledge and services directly through digital platforms, companies can collaborate even on complex, structured activities, from research and development to internationalisation of their products. Business models like these may prove more resilient than traditional ones, and thus help counteract the loss of jobs in

traditional companies, in Europe and elsewhere.

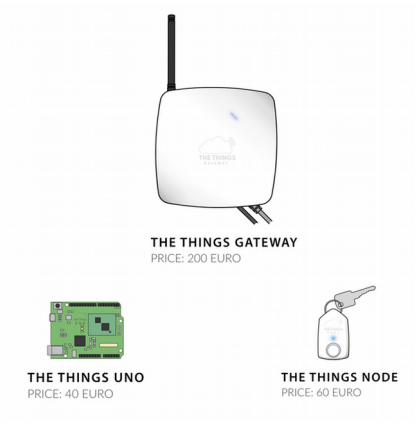
Infrastructure hacking

DiDIY hardware platforms like, to name just the most popular one, the Arduino microcontroller and its countless sensors and accessories, let their owners build devices that automatically monitor their surrounding "environment", whatever it is, and interact with it. Such devices may be built and used individually, in one's home, or set up by a community, to serve a whole neighbourhood, or even wider areas. Weather stations, community-owned urban wireless networks, robots, systems for home automation, burglar detection, garden watering, energy generation or real-time traffic monitoring... are just a few examples of what one may find in this class of DiDIY products.

DiDIY may, in fact, greatly support, or even extend, the so-called "Internet of Things" (IoT). As far a we are concerned, IoT means all the products and services created by adding remote control, monitoring and data exchange capabilities through the internet, to virtually every object that runs on electricity, from anti-theft cameras to parcels, car accessories and home appliances. With

DiDIY, millions of these devices would be designed, configured, and installed without any centralized, industrial-level quality control, and without relying on "security through obscurity" that is on keeping designs secret, in order to not expose their flaws or weaknesses to criminals. On one hand, the possibility of attacks to these devices, and the amount of actual damage, may be much bigger if they were DiDIY devices. On the other hand, DiDIY in this field would very likely consists of self-assembly and configuration of a large variety of Open Source software and hardware, all with designs that everybody can audit, test, and modify. Large deployments of many devices of this kind, all with different components and configurations, may make the overall system much more resistant to automated, large scale attacks. Besides, the DiDIY IoT devices would likely suffer less than their industrial counterparts of mutual incompatibilities and planned obsolescence.

TTN, The DiDIY network that "connects things"



The Things Network (TTN) (thethingsnetwork.org) is an initiative to build a distributed wireless data network for connecting "things" to the net, fully owned and controlled by its users. Its main characteristics are that it is completely Open Source, and low cost (in October 2015 the cost of a node was approximately 40 Euros). The basic building blocks are Arduino boards, and the LoRaWAN standards (en.wikipedia.org/wiki/LoRaWAN). TTN is a great example of city infrastructure designed, built and managed entirely via DiDIY. To know more about TTN, read "A Digital DIY, Commons based, IoT data network (www.didiy.eu/blogs/things-network-digital-diy-commons-based-iot-datanetwork).

Active citizenship, self governance, and community building

DiDIY is an extremely varied phenomenon, but at least two of its characteristics are always present. To begin with, greatly facilitates highly decentralized, non-profit production of goods geared towards the needs of individuals and of small communities alike. In the latter case, DiDIY gives those communities the possibility to manufacture together more of the products that they need locally, by downloading designs from the internet, out of a relatively small number of different raw materials. Such communities may therefore fill their needs relying on much simpler, and more sustainable, supply chains (as long as internet connectivity is granted, of course). Networks of DiDIY hackerspaces and tool libraries can be used as educational and support services for such programs, if properly supported and coordinated by local public and private stakeholders. In addition to local administrators, this first feature of DiDIY makes it a powerful tool also for all the non-profit groups whose goal is sustainable self-development of the local community, or mutual economic support among their members.

Just like individual DiDIYers, these groups put utility value before exchange value in the goods or services they produce, and for this reason some of them are already using DiDIY to accomplish their goals. It has been said that that groups doing so will redesign politics, if they already aren't.

The second common characteristic of DiDIY is that its practice is greatly facilitated by familiarity with, and active participation in, distributed online communities. This means that, besides providing more resources for environmental and economical sustainability, pro-DiDIY policies may also stimulate and facilitate other ways to engage in active citizenship online.

In summary, community-level DiDIY needs more self-governance to work better. But self-governance initiatives find in the same DiDIY more ways to make their mission concrete, that is even more concrete reasons, for more citizens, to participate in them. In parallel, DiDIY makes people practice a skill that they can reuse in self-governance, that is familiarity with online platforms for collaborative work and citizens participation. Combined, these two facts may challenge existing power and organization structures from the bottom. Whether this is a risk or not for the communities involved, is something that heavily

varies from case to case, but it surely is a trend to watch, and experiment with, in the next years.

How DiDIY can revitalize struggling cities

The Maker Movement has attracted the attention of the USA National League of Cities, which published the infographic above, because of the role it may play, together with public libraries, in the (re) organization of work and economic growth of struggling cities. A summary of why and how this could happen is available in the DiDIY blog post about new life, and higher revenues, for struggling cities (www.didiy.eu/blogs/digital-diy-can-give-new-life-and-higher-revenues-struggling-cities).

Rural recovery and sustainability

The many struggling urban or rural areas of EU countries, or any other country for that matter, deserve a special place in this manual. Many of the digital technologies promoted by the "Smart Cities" movement, and already popular in urban centres may bring even more benefits in those areas, all across Europe. In the same areas, however, the current centralised, market-focused applications of those technologies may be much less feasible and sustainable than DiDIY-based ones.

Solutions of the latter type may help those communities to leapfrog some stages of development (or economic recovery) in the same ways as they were able to adopt mobile communications. Using DiDIY approaches, each rural community may autonomously build its own personalised infrastructures and services, to solve its own actual problems, with the smallest possible effort and expenses. This would help that community to become more resilient and connected with the outside world, but on its own terms, without losing its identity by assimilation or depopulation.

It is important to point out that it is not necessary, in order for a

rural community to pursue those goals, that every single farmer to practise DiDIY: rather, what is needed is that each such community as a whole, or network of neighbouring communities, has enough skills and material resources to provide DiDIY services to their members, for example, local rural Fab Labs, skilled local residents, etc.

How to deal with DiDIY

Overall, the positive and negative consequences, described with practical examples in the previous section, will require both individual education, and adaptation of existing laws, or social norms. Only in that way the whole of society will benefit as much as possible from DiDIY, while minimising the associated risks. But in practice, what should be done to achieve such a goal?

Let us summarize some points, before providing some answers to that question. In most cases, DiDIY does not employ any innovative, or even state-of-the-art technology. We may even say that this is exactly what makes DiDIY both so powerful and, in some cases, dangerous. In fact, what DiDIY does, and the main reason why it is relevant, is to change *ease of access* to personal, unregulated manufacturing, by making it easier to practice, and much more affordable. This is no small thing, because how easily something is accessible matters a lot for both practice and regulation.

For these reasons, DiDIY may be cause of concern in broadly two areas: challenges to rights (especially IP and consumer rights) and physical risk (in particular product safety and legally limited artefacts like weapons). The research of the DiDIY Project has shown that, in most cases, current EU laws may be either already adequate, or at least better than most proposed alternatives, to deal with those concerns. The main results of that research are synthesized in the rest of this manual: after some general suggestions and proposals, there are also more specific guidelines for the main stakeholders: decision makers, public administrators, educators, company managers and, of course, Makers.

Do not overreact, or overregulate

DiDIY could bring great benefits to society, from more business opportunities to more resilient cities, and reduced environmental footprints. Wider knowledge and practise of DiDIY would also promote, and should be required as part of, STEM literacy. It is important to avoid overreacting to any potential risks when crafting public policy in this field. Some means that would

theoretically be effective against illegal or harmful uses of DiDIY also would, very often, imply massive surveillance and criminalisation of a large part of well-intended DiDIY makers. For the time being, there are more reasons to encourage, rather than contain or thwart, the diffusion of DiDIY. Countermeasures only after ascertaining that the latest available evidence, as well as a careful analysis of the foreseeable costs and benefits, warrant doing so.

Accept that it's almost impossible to limit DiDIY

The previous paragraph warns that forbidding or severely limiting DiDIY would involve simply forfeiting its many potential future benefits. Other perspectives may lead to very different answers. Even those answers, though, should not propose regulations that are impossible to enforce, something that may be often be the case, when DiDIY is concerned.

The main point to keep in mind here is that any attempt to preventively limit the capabilities of DiDIY manufacturing tools

and software is going to be useless. For example, programming a commercial 3D printer, or any of its parts, to effectively recognize, and consequently refuse to execute, the design files of weapons, or weapon components, would be like setting up automatic searches for the same files online. Even if those files were not encrypted, that is almost unrecognisable, such searches could really succeed only if there were a really limited set of 3D printable weapons, that is a really limited, and thus easily recognizable, set of design files for such weapons. In practice, things would be even more complicated, because digitally manufactured guns are assembled from any number of smaller parts. The real problem, however, is that it is impossible to program both 3D printers and the software for digital design, in any way that would prevent the use of those tools to design and build from scratch (parts of) other 3D printers and design software, free from the same restrictions.

Distinguish between producing and sharing information, and actual manufacturing

DiDIY does increase the risk that people can self produce, without any traceability or control, lethal weapons, drugs and equally dangerous products. But punishing the mere *possession* of the corresponding design files seems to have too many drawbacks at all levels, from ethical concerns to practical enforceability, so that more negative than positive effects, in practice, would be produced. Punishing the (re)distribution of such designs may also create dangerous side effects (e.g., be used as pretext to set up or strengthen online censorship systems) and have the same practical limits of forbidding illegal file sharing (it is worthwhile to remember that with drugs liberal approaches to regulation have not automatically led to any significant increase in their use).

Really great prudence is needed in regulating this specific activity, and in no way it should be treated, in and by itself, as an offence as serious as the actual DiDIY manufacturing of

weapons. The *actual* DiDIY fabrication (regardless of usage) of weapons, instead, may be covered by the same laws that already regulate or forbid such activities, and the same applies to the actual *usage* of DiDIY weapons. Possibly, the same laws may be extended to cover research purpose, or use of the weapons only in authorised facilities, or by registered users. This is a path of policy making that deserves further analysis.

When feasible, restrict / monitor access to materials

Due to the difficulty to prevent the actual manufacturing, or to enforce prohibitions, the most feasible solutions for controlling unsafe manufacturing and illegal uses of DiDIY weapons, drugs etc. may be the imposition of appropriate controls over some materials that are necessary for their production or use, but can hardly, or cannot, be digitally produced themselves. As an example, in the case of digitally made guns, the best candidate for such a component would be ammunitions. That would still not be a bulletproof solution, because ammunitions may be

produced with DiDIY. Even gunpowder may be produced "at home", *without* any DiDIY at all. However, with those constraints an actually dangerous object would be much more time consuming and harder to produce, and securing illegal or hard to obtain components that would still be needed may help law enforcement thwart such endeavours.

Note on Biohacking

Biohacking is a field that deserves special consideration, because it may been defined as any combination of these activities:

- experiments with genetic material, free from standard norms;
- Do It Yourself biology and life science, with tools equivalent to those of professional labs;
- modification of biological systems – usually, but not exclusively, the human body.

With respect to DiDIY tools for biohacking are concerned, the conclusions of the DiDIY Project are that they should be prohibited only in specific contexts and under specific sets of assumptions. No general presumption against such uses of DiDIY

seems defensible, in light of both the various potential benefits of the use of those tools (even for enhancement purposes), and of the importance of respecting individual autonomy as long as it does not encroach on the rights of others. As far as drugs, doping, food go…The main concern raised by both therapeutic and enhancement uses of the relevant tools is safety. The main, if not the only feasible way to protect people from the harm they might inflict on themselves is inform them of the consequences, so they can make informed decisions. If we are concerned about the harm they might cause to others, trying to enforce a prohibition on certain interventions might be both justified and feasible in controlled contexts like competitive sport. Further reflection is desirable regarding the exact implications of doctors professional duties when it comes to dealing with requests for medical services (e.g., surgery) from people, like body hackers, who are not guided by genuine medical needs.

Make DiDIY-related insurance easier

Many applications of DiDIY may be a boon for the economy, by keeping many small companies economically viable, or by enabling the creation of new companies. Therefore, it could be advisable to leave space to such DiDIY, even if they may create more risks, in two ways. One is proper education, to increase awareness of risks and how to avoid them; the other is creation of a regulatory and insurance framework that helps to minimise the risks of DiDIY practices, at least for third parties. A situation like this presents serious challenges to insurers, but also big opportunities, if properly regulated and supported. Some insurance companies have already started to study these scenarios, but they still seem a minority, and need more support, or at least encouragement, to enter this field. Another path for the insurance sector to explore is whether individual DiDIY designers may subscribe to some form of collective liability insurance scheme, if insurance companies provided it.

Promote universal, basic DiDIY knowledge

All the research of the DiDIY Project confirm an assumption made in its original proposal: "*The positive aspects of DiDIY can bring widespread, long term advantage to society only if as many citizens as possible, from today's students to displaced workers, know at least its real, main general characteristics and potential.*" Education *about* DiDIY may take place and be supported, **locally**, without any central coordination, "one-size-fits-all" approaches, or big budgets. But it is **very** important that such education is provided to all citizens. Schools may, and whenever possible they should, possibly partnering with local makerspaces, help young people learn to engage in DiDIY responsibly and ethically.

Every citizen, however, should reach what the DiDIY Project has defined "basic DiDIY knowledge". The main characteristic of such knowledge is that it does not need at all to include any technical skills for actually practising DiDIY in person, in any form. The basic DiDIY knowledge that every citizen should have

is not about being able to personally self-build, configure or use any DiDIY machine or component, from Arduino microcontrollers to complete 3D printers or laser cutters.

By basic DiDIY knowledge, instead, we mean a general, but correct knowledge and understanding of the risks and opportunities of DiDIY in the several fields discussed here, from ethics to the impacts on jobs and the environment. Of course, the first groups to acquire this basic knowledge should be educators, lawmakers and public officials in charge of applying regulations to DiDIY activities.

Exploit DiDIY for social cohesion and subsidiarity

Of course, DiDIY knowledge should be accessible to everybody: women, immigrants, senior citizens, and other marginalized/disadvantaged group should **not** be excluded, and often addressed via dedicated programs, to get equal opportunities of access to DiDIY.

At the same time, getting *whole* local communities "ready" for

DiDIY may be a great opportunity to increase social cohesion. Since DiDIY is still very new for the great majority of the general population, learning and practising it *together* may be one more way to fight social tensions and divides. Of course, which approach works better is different in each situation, but we suggest that the general idea is worth considering: dealing with, or learning about, something that, in a sense, may be perceived as equally unknown and "threatening" by all members of a group, *no matter how different they are*, may unite those people. Of course, whenever trying this idea, care must be taken to ensure that *all* the involved people may participate in the same way (as just one example, they should be able to use documentation in the local language).

On the same topic, it is important to note that initiatives along the lines of "bringing a 3D printer in every home" may end up working *against* social cohesion (and other things too). This risk is discussed in more detail in the "assisted DiDIY" section of this manual.

Speaking of cohesion: a note about gender parity

The World Economic Forum (2016, p. 38) mentions that "in STEM education, women currently make up only 32% graduates across the world". In the developed world, only 25 per cent of employees in the technology sector are women (Lee & Stewart, 2016). We have also seen that online controversies such as "Gamergate" have revealed an abusive and misogynistic online culture which is likely to dissuade women from seeking work in this sector.

It is certainly necessary to guarantee *equal access* for women to DiDIY technologies, spaces and communities, in and outside schools, both as a support to pursue STEM studies and careers, and as one more tool for personal well being and economic independence. But in addition, it is important to have *role models* and to push for greater engagement to overcome the stark gender disparity.

Engaging tools such as LittleBits (littlebits.cc), developed by female entrepreneur Ayah Bdeir and used in this Project in library-based creativity workshops, appeal to both girls and boys

and can help to disrupt the traditional association of electronics and technology with male students.

Clearly, gender issues within DiDIY exist in the context of gender issues in society and culture more generally, so a more holistic change is needed. Nevertheless, careful promotion of DiDIY for all may help to lead change in the currently unequal fields of digital technologies.

Using DiDIY to go beyond stereotypes.

*Digital DIY empowers everybody to go beyond stereotypes and make something that **really** fits their actual interest, priorities and needs. As an example, the photograph shows the "smartphone for women, conceived by women", designed by Christina Cyr and Linda Inagawa. Thanks to DiDIY, they were able to go way beyond the usual "pink it and shrink it" approach adopted by many mass manufacturers trying to appeal to women. For details, see the corresponding post on the DiDIY blog (www.didiy.eu/blogs/didiy-smartphone-women-conceived-women).*

Facilitate "assisted DiDIY"

Besides access to knowledge about it, there is one kind of access to DiDIY that is necessary to provide, if DiDIY is to become really commonplace, and bring the greatest possible benefits to society as a whole. We are talking of what we may call "assisted DiDIY".

Work to grant access to DiDIY is needed, but not necessarily in the sense of, for example, funding a Fab Lab in every school, or any variant of "bringing a 3D printer in every home". Expectations that the *majority* of people could or should, in the foreseeable future, start 3D-printing whatever they need directly at home aren't realistic. Efforts to turn everyone into a DiDIYer (or, for that matter, into a software developer) may do much more harm than good, in the long run, if nothing else because they would increase consumption, and waste, of energy and raw materials.

There are plenty of people who may really need, sooner or later, something obtainable only with DiDIY, but will never have the right combination of time, technical skills or physical capabilities to do it entirely by themselves. Very often, even if they had it,

they may simply not have enough *extra* money, or space at home, to spare for equipment that may not be used any more after the first time. Today, this category of people constitutes the great majority of the population, and this state of things is very unlikely to change in the foreseeable future. But this is not a reason to deny those people the benefits of DiDIY.

It is important to acknowledge that, while online 3D printing services like Shapeways or Sculpteo already exist, they constitute an adequate solution only for a *minority* of those people, , at least in their most common current forms. They are only usable (only in a handful of languages!) by people who can also use the appropriate design software, and online payment systems.

All the other people we just mentioned, instead, would need some amount of direct, face to face assistance from an expert, to design and make something with a 3D printer or CNC mill. Even more frequent would be the cases in which the same people could benefit by just outsourcing the design and fabrication work to experts, if it just were affordable.

The conclusion is that discouraging, by ad hoc taxes or other means the use of DiDIY tools or of services like 3D printing

bureaus, by taxing them more or less heavily, would be harmful not only in terms of innovation, fair business competition, or providing digital skills to citizens. It would also strengthen, if not create a serious digital divide, making the benefits of DiDIY affordable only to some people.

"Assisted DiDIY" and, in general, any sharing of DiDIY machinery and other resources in community-based "DiDIY service centres" should instead be encouraged, for several reasons. Such centres would not only increase social cohesion as previously discussed, by giving everybody equal opportunities to benefit from DiDIY. They would also contribute to reduce waste and pollution inside their communities, and create relatively qualified service jobs. Jobs, that is, that could not be outsourced, and would also constitute a basis on which people may build their professional careers.

Rethink Intellectual Property

The issue of IP rights is probably the most contentious, whenever DiDIY is involved, and the one where a balance is most difficult to strike. There are concerns that "counterfeit piracy becomes a

mainstream, non-commercial activity in a world of 3D printing" (www.hastingslawjournal.org/wp-content/uploads/Depoorter-65.6.pdf). But it is doubtful that current law is fully in the interest of society and whether enforcement itself, assuming it were possible, would not result in significant negative results. Even before the DiDIY Project, it had already been argued that that "traditional, litigation based enforcement" of IP rights against DiDIY "ineffective and possibly counterproductive". In general, the coming of DiDIY should serve as an occasion to re-think what IP rights are for, and whether some of them have gone "over the top" and need reform such as to serve social needs.

At the practical level, outlawing all acts of copying a commercial product using DiDIY techniques like 3D scanning and digital fabrication, even for personal, non-commercial purposes would be as hard to enforce as the prohibition to share digital music. In any case, it could do nothing to counter the competition by *lawful, that is original and Open Source*, DiDIY products.

Even creating new, specific taxes on DiDIY equipment, raw materials or services, in order to protect IPR of existing companies would stifle, to a greater or lesser degree (depending on how heavy those taxes would be) the potential benefits of

DiDIY for the sake of artificially preserving certain professional sectors.

The next two subsections describe a few ways to rethink IPR, strike a balance between those rights and the need to promote DiDIY for sustainability and social development, and support alternative approaches to

Support IP exemptions

DiDIY activities tend to be for private, non-commercial use (sale of self-made objects is always an option, but this typically is not the original intent). Many IPR legislations include exemptions for such uses, in particular in copyright, design rights and patent rights. Trademarks are infringed by use in the course of trade of the same mark on similar goods. When there is no trade at all, these should not be applicable. These exemptions could be strengthened to encourage DiDIY activities, extending the life and usefulness of physical products and contributing to a more sustainable planet. In the same spirit, new exceptions may be made commercial activities like 3D printing spare parts of many products.

Support business models not based on strong enforcement of IP rights

Current IPR systems are only partially fit to protect commons based approaches, as free/open licenses are generally based in copyright, which can protect the shared works only partially. Traditional, exclusive IPR protection like patents requires parties to request permission to contribute to the adaptation and further development of hardware designs. This hinders collaborative development, and often innovation too. A growing number of communities sharing their intellectual and creative DiDIY efforts under non-exclusive, free license arrangements shows successful alternatives to the traditional exclusive IP licensing arrangements already exist.

Open business models combine shared knowledge (free and open licensing), collaborative making and circular economy with revenue, as well as production models and networked or participatory governance.

The research of the DiDIY project has shown that DiDIY provides one more reason to support these kinds of business models. Practising DiDIY and sharing the related knowledge

openly allows for different ways of making more projects economically viable, reducing waste and protecting consumer rights. The reason is that, while digital designs can be replicated and compete (legally, if they are Open Source!) against the original work, at the same time this possibility forces the project to listen carefully to the needs of its users and present more socially aligned, sustainable models. In order for this to happen, however, it is necessary to promote open technical standards, that maximize interoperability among products, and thus promote real innovation, and minimize waste.

Make certification easier, and more affordable

Today, in several EU countries, the letter of local laws and regulations is such that Fab Labs and makerspaces often do not install certain machines, or fully exploit their capabilities. When this happens, almost always it is due to two distinct reasons. The first is that the certification of many machines needed for DiDIY, or created themselves via DiDIY, would cost (much) more than

the machines themselves. The other is that it would be too expensive to make the whole *work environment* around those machines comply with all the relevant safety codes, at least for certain services. The two most important ones of such services are educational activities for schools, and retraining courses for artisans and manufacturing workers, that can be officially paid, or otherwise supported, by employers, or with public funds.

This greatly limits the concrete capabilities of those Fab Labs and makerspaces to help the general population to enjoy the benefits of DiDIY. With lighter, more reasonable constraints, instead, it would much simpler to, for example, invite school classes, to show students the wonders of DiDIY, retrain workers, or rent machines to artisans who may only need them a few hours per week.

The basic reason why this does *not* happen yet as often as it could, all across Europe, seems to be the same everywhere: both safety codes for working spaces and certification procedures for machinery were written only for high-volume, full time manufacturing facilities. In those contexts, very strict constraints to limit pollution and risks of accidents are both justified and affordable. In a Fab Lab which, instead, may take several years

to process the same amount of plastic, metal and other materials that a manufacturing plant uses in one month, the same constraints make much less sense.

It is therefore important, in order to give as many people as possible access to DiDIY, to develop simpler, and more affordable certification procedures and safety codes for the usage of DiDIY machines. The managers of Fab Labs, makerspaces and similar organizations should be actively involved, from the beginning, in the development of those new regulations.

Product safety

At least as important as the safety of DiDIY machines, workspaces and procedures, is the safety of their *results*, that is the safety of any object manufactured by DiDIY. There are several ways in which such objects may be less safe, if not outright dangerous, than industry-made ones. First of all, the design themselves may be defective, leading to production of objects not fit for their intended use (fitness for a particular purpose or use are typically disclaimed: see for example the CERN Open Hardware license: www.ohwr.org/licenses/cern-

ohl/v1.2). The performances (including safety) of different copies of the same design may be more different, or vary differently over time, than it happens with objects produced on traditional assembly lines. Low quality designs may also yield products that are hard to dispose or recycle properly.

How to make sure that people are not hurt, or hurt others, because they manufactured some unsafe DiDIY product, maybe starting from some design found online? In theory, several solutions are possible.

Adequate warnings are already provided, in most cases, by the authors or distributors of DiDIY design files.

A first strategy could be to not do anything beyond that. Just mandate that websites offering DiDIY designs make it clear that they offer no quality or safety guarantee about the designs they host. People demanding extra guarantees could still have them on other websites, if there is enough demand for them.

A second solution may consist of demanding responsible codes of conduct for the users and contributors of the repositories, and consequently demanding/accepting that quality control is delegated to the users themselves. This, more or less, is just what already happens on websites like Thingiverse, Amazon or

TripAdvisor. Websites hosting DiDIY designs, that is, may be required by law to have such a peer control system in place, and then put designs voted as unsafe offline, downgrade them, or take other steps, like banning their authors. Such a solution would interfere as little as possible with the current, totally unregulated forms of design sharing. Unsafe designs, however, would be recognised and put offline only *after* they have caused some damage, or proven otherwise defective. Besides, these solutions do nothing to help people make informed decisions regarding which files, and which manufacturing procedures to use.

Official clearinghouses, that would guarantee the safety of the DiDIY files they host, and accept only files that also come with clear manufacturing instructions, could be set up in addition to unregulated repositories. This would restore some balance between innovation and consumer safety. It would make assigning liability easier (more on this in the next section), and guarantee that unwilling users of defective files would get compensated for any harm resulting from them, if getting compensation from the actual creators of the designs were not feasible.

One problem with this model, of course, is who should fund these clearinghouses, and how. If they relied on paying per download to cover their costs, they may not collect enough funds. Very likely, many of the files that they would host would have Open Source licenses, as it is customary in the DiDIY community. But those licenses let anybody redistribute the files, legally and without paying any fee, on their own websites. In practice, though, this may not be a serious problem: people may buy those digital files from the clearinghouses anyway, just like they continue to buy digital music from services like iTunes, instead of downloading them through file sharing (which is *not* always illegal, by the way, even for "All Rights Reserved" files: it depends on local legislation and whether it is for personal, non-commercial use or not).

In any case, all the solutions above share two limits. The bigger one may be that it would not be feasible, assuming that it were right of course, to *force* all DiDIY designers to only share their DiDIY designs online on such websites.

Second, and more serious, is the fact, that unlike digital music, DiDIY design files are not the final product. More often than not, the factors that may make a DiDIY object (or its fabrication!)

less safe than an industrial one have nothing to do with the quality of its design files: those factor may go from errors in the assembly and configurations of the DiDIY machines or their software, usage of raw materials that are unsafe, or at least unfit for the intended use (e.g: non food-safe plastic for manufacturing of kitchen tools).

In short, and as banal as it may seem, it is certainly possible to demand some guarantees on the safety of DiDIY products, and it should be done. According to the DiDIY research, the methods described here likely are the most feasible, and the ones with the least harmful side effects. But it should not be forgotten that DiDIY may offer the same levels of guarantee of traditional mass production only if it worked, from beginning to end, in the same way. Only, that is, if certified designs were always and only manufactured by: loading by certified operators into regularly tested certified machines; using certified components and raw materials; strictly following certified procedures. But this something that no variant of "do-it-yourself" activity can, or *wants to*, guarantee, by definition: do-it-yourself is *exactly* what people do when they can't get what they need by mass production, or by working in that way.

Product liability

The rise of DiDIY poses significant challenges for current European laws on product liability: we suggest that while these challenges do need to be taken seriously, an aggressive response at the legal level is not called for.

Introducing measures that would increase the liability of the creators of such products would almost certainly stifle innovation in this field, and the corresponding benefits for society. For example, the EU's Product Liability Directive includes an exemption clause for those who are manufacturing or distributing items in a way that does not represent their "business". Removing that exemption would force such sellers to face potential liability costs that they might not be in a position to absorb. This would rapidly lead them to end their activities, together with any benefits these might have brought to users.

Eventually, several forms of creative DiDIY can be expected to ultimately produce items that will be covered by existing European regulations on safety and liability. But what could be done now, to provide and enforce some form of liability? Here are some thoughts, provided as bases for more in-depth

discussions.

A less harmful way to extend some form of liability to hobbyist sellers of DiDIY products may be the micro-sellers proposal, made for the USA by N. Berkowitz, of creating a separate category and legal standard for 'micro-sellers'". Berkowitz describes micro-sellers as "the sellers that are not in the best position to spread or absorb the losses and do not have superior bargaining power over their customers"). If this scheme could be adapted in the EU, it would avoid the drawbacks of the other proposal, while still allowing to assess each case on its own merits. Nevertheless, a solution like this would still mean that some victims of injuries from DiDIY products would be unable to claim compensation.

The clearinghouses hypothesized in the previous section may be subject to strict liability, as they would have the resources necessary to bear the costs of full liability insurance, as a traditional business does. Liability insurance could also be offered to customers as option for an extra fee, as it happens with travel insurance on low-cost flights. This is another sector, in addition to those already described, in which "DiDIY insurance" should be made easier.

Guidelines for the main DiDIY stakeholders

The previous sections of this manual have shown why and how it is necessary to "manage" DiDIY, in order to maximize its positive outcomes of DiDIY for society, while minimizing the related risks. The final part contains some *initial* guidelines for the main groups whose active contributions would be, at least in the short term, the most crucial ones. The list below is by no means complete, however. Besides IPR advocates, there are many other stakeholders that, according to DiDIY research, should participate actively to this work, as soon as possible. They include, but are not limited to: teachers, trade unions, NGOs working on environmental and social development issues and, finally, doctors and healthcare providers.

Decision (law, policy, ...) makers

Existing rules need to change, or at least to be validated again, to cope with DiDIY. This needs to happen at all levels, from EU directives to national school or professional regulations and city

building codes. The concrete challenges are so different, both at different levels of government and between different regions or cities, that only two, very broad guidelines for decision makers are presented (again) here.

To begin with, do not underestimate the positive contribution that DiDIY can give to fight unemployment, pollution, and in general the current socio-economic fragility of many communities. DiDIY makes it easier, and possibly less expensive than other means, to concretely practise subsidiarity, that is *"the principle that decisions should always be taken at the lowest possible level or closest to where they will have their effect"* (dictionary.cambridge.org/dictionary/english/subsidiarity).

The other general guideline is to involve from the beginning all the stakeholders. Only in that way it will be possible not only to achieve the best compromise among all conflicting interests at stake, but also to prevent loopholes. As one extreme example, a full opening of makerspaces to learning or "artisans" activities may unwittingly provide legal ways to open and operate sweatshops, or exploit child labour.

Public Administrators

We have already seen why, and how, Public Administrators, especially at the city/region level, should take advantage of DiDIY to reduce pollution, and create jobs. Their reasons to support and actively promote DiDIY, however, don't stop there. DiDIY can also improve the creativity, culture and generally the well being of whole communities. More in detail, facilities for making can enhance community engagement, the ability of a community to learn, and can foster skills ranging from specific work focused technical capabilities, to creative problem-solving and creative confidence building. For this reason, the processes of DiDIY have been already adopted by cultural organisations which are trying to re-orient their activities toward more hands-on and generative processes. For example, libraries and museums are now incorporating maker spaces within their walls, so that they can become places where new knowledge and things are invented and made, rather than where already-existing things are merely exhibited.

Here are a few practical guidelines to make all these things happen.

1. Provide spaces and connections! consider creating spaces and facilities for making in library, museum, school, and other civic developments. Listen to all the local stakeholders, create occasions for them to talk with each other, and involve all of them in decisions around, and implementations of, DiDIY projects and services since the beginning.

2. Remove obstacles: Reduce the friction between makers attitudes and bureaucracy.

3. Go for sustainability models, not just business ones: Acknowledge and actively support also the parts of the DiDIY communities and philosophy that do not aim to become part of traditional economy and markets. Promote and support (even helping them to get insurance, when needed) business-to-business services to companies, Coops, NGOS…working in that way. If possible, directly *partner* with them, at least with those that offer "assisted DiDIY" to your community. Programs like Fab Market, or FabCity in Spain are already providing that kind of services. Local administrations should support them/help local versions to experiment/ as much as they can!

4. Know and demand OPEN best practices: demand that all the

organizations above follow established Open Data best practices. This will contribute to the maximum transparency and accountability of their operations, but also, in many cases, increase the economic return from certain activities (e.g., data on public transportation collected by a recycling cooperative may also be useful to a Fab Lab, to figure out which kind of waste they may reuse in their DiDIY projects).

5. Don't look just at 3D printing! 3D printing is, without doubt, an extremely flexible and powerful technology. In certain communities, however (see Section on Rural Areas), other technologies and services may bring more practical benefits, at lower costs and in less time. There is plenty to choose from, from DIY sensor networks to public Tool Libraries with good internet access.

6. Reuse! Before acting, look at what other administrations like yours are already doing. While and after acting, document and share publicly all the procedures you developed, and all the problems, and solutions, that you encountered.

Educators, education policy makers

Current educational practices neglect certain categories of students and certain aptitudes like hands-on skills. The introduction of DiDIY activities (such as building robots and other similar artefacts using DiDIY tools, in the context of a Fab Lab or a makerspace) in compulsory education can enrich the curriculum and teach valuable new skills to children. The introduction of classes focused on DiDIY-related activities, by means of makerspaces inside schools or, much better, of cooperation with *external* makerspaces, equipped with state-of-the-art digital devices, is a trend to be promoted.

Proposals to ditch traditional teaching methods and standardized testing to focus instead entirely on principles like DiDIY and learning by making should be considered with caution, in light of the recent mixed evidence (e.g., PISA results) regarding the impact of the introduction of technology in schools.

We recommend a more nuanced approach, that would respect individual differences in educational needs and preferences between students, promote DiDIY in suitable sectors of

education as an experiment, and using the resulting data about DiDIY impact on educational outcomes as guide for future policy, to ensure that such policy is based on evidence rather than ideology.

Managers and entrepreneurs

With DiDIY, organizations have the opportunity, if not the *need*, to introduce new practices in human resource management and organizational development. The interdependence between digital technologies and workers does not imply just the destruction of jobs due to automation. Applying Digital DIY in business contexts allows workers who use technology competently and autonomously, while taking care of new responsibilities, to experience job enrichment. Consequently, HR managers should:

- introduce new practices in the process of personnel selection that recognize and reward Digital DIY mindsets as engines of change;
- support education, learning and continuing professional development which will enhance, together with the same

mindsets, collaborative and entrepreneurial traits in employees.

The research by the DiDIY Project on work and organizations provides more detailed advice on these topics, together with real-world case studies. Several workshops ran by the Project also highlighted the need for companies to enter into direct contact with Fab Labs, makerspaces, hackerspaces, etc, i.e., places which enclose the spirit and the attitude of DiDIY, to make all this happen.

Makers

A whole society cannot move towards DiDIY without the help of those who already practise it today. Both self regulation, and collaborative, bottom-up proposals by European DiDIYers are absolutely necessary to guarantee that EU and Member States laws and regulations (which will be issued *anyway…*) will maximize the social benefits of DiDIY, rather than fighting it.

It would be a serious problem, if not enough DiDIYers did not actively participate, on a more or less regular basis in the long-term community and policy making activities proposed by this

manual. We offer the following suggestions as support for this task that is now facing them.

- Do not assume that everybody that should benefit of DiDIY (that is, eventually, *all* citizens!) may, or should ever become a regular contributor of some DiDIY community or even design and make personally every DiDIY product they may need.
- Make your Fab Lab indispensable for its surrounding community, by explicitly taking responsibilities in it, trying to support a wider range of people and projects of all types, from art to environmental recovery.
- Advocate the creation of local businesses, cooperatives or other organizations that offer "assisted DiDIY" services, and provide specific training and support for them.

Conclusions

DiDIY is already everywhere, it keeps growing, and is here to stay. However it may still change, and start working, in ways unpredictable now: further reflection, research and open discussion on the matters presented here will be surely needed in the future. This phenomenon, however, needs to be actively supported now. We hope that the explanations and advice in this manual will help the whole society in the first steps of this path, and wish you all...

Happy DiDIY!

The DiDIY Project

The **DiDIY Project**, active from January 2015 to June 2017, was carried out through a multidisciplinary team (www.didiy.eu/project/people), by an international consortium of seven partner institutions (www.didiy.eu/project/partners):

LIUC – Università Cattaneo (IT, www.liuc.it), a university established in 1991 by the Industrial Association of the Province of Varese

University of Westminster – Communication and Media Research Institute (UK, www.westminster.ac.uk/camri), a world-leading centre for media and communications research

Ab.Acus srl (IT, www.ab-acus.eu), a company whose mission is to design and develop technologically advanced products and services

Manchester Metropolitan University (UK, www.mmu.ac.uk), the largest campus-based undergraduate university in the UK, with an emphasis on vocational education and employability

Free Knowledge Institute (NL, freeknowledge.eu) a hub that,

since 2007, has coordinated several international projects in the areas of Free Software, Open Standards, Open Educational Resources, Access to Knowledge

Amerikaniko Kollegio Anatolia (GR, www.act.edu), a non-profit educational institution with a comprehensive undergraduate curriculum in Business, Business Computing, International Relations and English

Politecnico di Milano – Dipartimento di Design (IT, www.dipartimentodesign.polimi.it), a scientific-technological university funded in 1863, which trains engineers, architects and industrial designers.

The goal of the Project was to produce well-grounded models and guidelines to support both education and policy making on DiDIY, intended as an ongoing phenomenon that, while surely enabled by technology, should be driven and shaped by social and cultural strategies, not technology.

You are welcome to join the public DiDIY blog (www.didiy.eu/blog) and to browse the documents presenting the results of the research activities (www.didiy.eu/project/results).

For any other information, or to know more about the DiDIY Project, please fill the form at www.didiy.eu/contact.

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Disclaimer: The views expressed in this document do not necessarily reflect the views of the EC.

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