D2.2 FOUNDATIONAL INTERPRETATION OF DIDIY

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Executive summary

Deliverable D2.2, “Foundational interpretation of DiDIY”, aims at presenting a content-related backgrounder and some perspectives for the development of the Knowledge Framework on which the whole Project will ground its activities. The presentation is based on the acknowledgement that the paradigmatic novelty of the phenomenon that we have called “digital do it yourself” (DiDIY) and its multifaceted nature require a cultural shift, and is aimed at identifying the multiple dimensions according to which DiDIY can be interpreted.

Under the general hypothesis that DiDIY is a kind of DIY somehow specified by the presence of digital tools, the structure of this document is: a general introduction; a section on the concept ‘digital’; a section on the concept ‘DIY’; a section on a preliminary interpretation on the concept ‘DiDIY’. Some more sections integrate this “foundational interpretation” with perspectives, that will be developed during the Project, and further references.

This deliverable is coordinated and submitted together with D2.1, “Options for the knowledge framework”, devoted to the methodological options for the development of the Knowledge Framework.

Note on contributors

This deliverable is the result of a collaborative work. While parts of the text have been discussed by all partners, and the coordination has been maintained by LIUC as WP2 leader, each section has had one or more main contributors:

1. Introduction: LIUC
2. The strategic positioning: DIY and DiDIY: LIUC
3. On digital: LIUC
4. On DIY: POLIMI
5. On digital DIY: LIUC and MMU
6. Interpreting DiDIY: from the perspective of organization and work: LIUC
7. Interpreting DiDIY: from the perspective of education: ABACUS and POLIMI
8. Interpreting DiDIY: from the perspective of creativity research and a cultural interest in making: UOW
9. Interpreting DiDIY: from the perspective of laws, rights and responsibilities: FKI
10. Interpreting DiDIY: from the perspective of ethics: AC
11. Interpreting DiDIY: from the perspective of design: POLIMI

Revision history			
Version	**Date**	**Created / modified by**	**Comments**
0.0	18/04/15	LIUC, POLIMI	First, incomplete draft, resulting from several online documents to which all partners contributed.
0.1	23/04/15	LIUC, MMU	Extensions (in particular the section on modelling) and fixes. First formal distribution to TB.
0.2	24/04/15	LIUC, UOW	Extensions (in particular the section on creativity), fixes, etc.
0.3	26/04/15	ABACUS, LIUC	Extensions (in particular the section on education), fixes, etc.
0.4	29/04/15	FKI, LIUC	Extensions (in particular the section on laws, rights and responsibilities), fixes, etc.
0.5	29/04/15	AC, LIUC	Extensions (in particular the section on ethics), fixes, etc.
0.6	30/04/15	LIUC, POLIMI	Extensions (in particular the sections on organization and on design), fixes, etc.
1.0	30/04/15	LIUC	Fixes after comments by TB members. Approved version, submitted to the EC Participant Portal.

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1. Introduction

1.1 Context and aims

WP2 is aimed at grounding all activities of this Project through a Knowledge Framework (KF) on the phenomenon that we have called "digital do it yourself" (DiDIY). The KF will be released as a sequence of three deliverables, in the form of public reports – D2.3, D3.4, D2.5, "Knowledge framework, initial / revised / finalized version" – at Months 6 (June 2015), 15 (March 2016), and 30 (June 2107) respectively.

As stated in the Project proposal, and now in the Grant Agreement (GA), the KF will provide "a common conceptual and lexical ground to the activities performed in all other WPs by integrating the different competencies of the interdisciplinary Project team, in particular by harmonizing languages, approaches and research methodologies". The sequence of KF versions will allow us "to timely update the shared framework and validate the hypotheses grounding the previous versions of the framework".

In this Project we are going to observe the changes induced by the spreading of DiDIY-related technologies and social practices, and we will try to address the core challenges in different disciplines. What is the impact of these developments on creativity and what opportunities does it offer? And how in the workplace? While in the past a product idea went through a whole range of departments before finally being developed and supplied to an end customer, now this process can be run by one or a few persons with a community around them, for much less costs and less time. What does this mean for education and research? How will the access to information and low cost tools change the quality of the learning and research work? What ethical and legal challenges will we need to deal with?

The basic hypothesis is that the KB should provide a conceptual background and context for this exploration. In turn, this document is aimed at proposing a foundational interpretation of DiDIY on which the KB can be appropriately built.

Not necessarily the KF will have to include formal definitions, and it might be instead organized as a more or less structured set of "dimensions" (e.g., the importance in DiDIY of creativity, the interest in DiDIY for self-actualization, the role of communities in DiDIY for information and knowledge sharing, ...), introduced and at least preliminarily explored because thought to be relevant to characterize DiDIY and therefore intended as viewpoints on it to be better understood, and possibly to be exploited in related decision-making processes.

Given the complexity of the phenomenon under consideration (in principle both a spatial and a temporal complexity: has DiDIY the same connotation in UK and in Italy? in Europe and China? ten years ago and today?), at least in the initial release of the KF its openness should be privileged over its specificity.

In order to identify an appropriate development process for the KF, two coordinated deliverables have been planned to be delivered at Month 4 (April 2015) (quotations below are from the GA):

- D2.1, “Options for the knowledge framework”, in which some methodological options for the development of the KF are explored, relating to “the meta-structure of the framework and its degree of formalization”, and a development strategy is identified, relating to “informal and semi-formal knowledge elicitation and description methodologies and tools” and “the set of research methodologies that will be adopted”;
- D2.2, “Foundational interpretation of DiDIY” (*the present document*), based on the acknowledgement that “the paradigmatic novelty of DiDIY and its multifaceted nature require a cultural shift spanning, with mutual dependencies, the three layers of the individual, the organization, and the society” and aimed at identifying “the multiple dimensions according to which DiDIY can be interpreted” and therefore at defining “the structure of the framework that will be then developed and validated in the subsequent tasks of the WP”.

1.2 Lexical conventions

“DiDIY”, i.e., “Digital Do It Yourself” or also “Digital DIY”, is the term that denotes both the phenomenon and this Project. To maintain at least a loose lexical distinction, we may use “digital DIY” for the phenomenon and “DiDIY” for the Project.

To denote a person engaged in DIY activities we use the term “DIYer” (or “digital DIYer”, “digital do it yourself’er” in the case of digital DIY).

To denote what a DIYer does we avoid the term “DIYing” and we use verbal forms such as “to engage in DIY activities”.

1.3 DiDIY as phenomenon and DiDIY as Project

In the proposal of this Project we introduced the term “digital do it yourself” to denote a phenomenon whose boundaries are still unclear and dynamic, and therefore such that it might be not properly defined in a sharp way. Our basic strategy to cope with this complexity – first introduced in this document and then developed in our research activities and embedded in the resulting deliverables – is to identify a “core phenomenon”, which uncontroversially would be accepted as DiDIY, and then adopting it as a basis to extend the analysis.

1.4 Terms and acronyms

GA	Grant Agreement
DIY	Do It Yourself
DiDIY	Digital Do It Yourself
ABC	Atoms-Bits Convergence
KF	Knowledge Framework

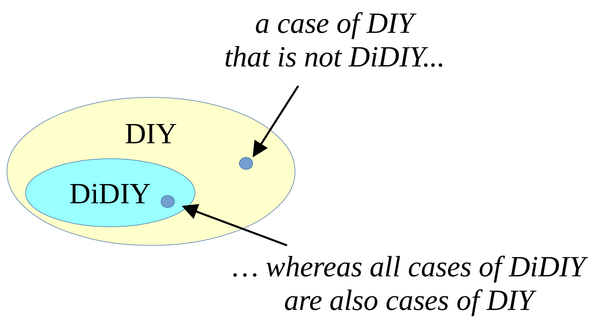
2. The strategic positioning: DIY and DiDIY

We assume that *DiDIY is a kind of DIY*.

This position has two consequences:

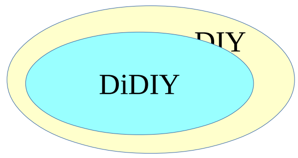
- everything that generally characterizes DIY also applies to DiDIY; hence studying DIY is useful also for DiDIY;
- not everything that characterizes DiDIY also applies to DIY; hence studying DiDIY requires identifying how the 'being digital' contributes to create a specific kind of DIY.

In synthesis:

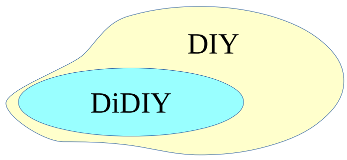


This position is compatible in particular with the possible acknowledgements of:

- a hyper-trophic role of the digital in the DIY ("DIY is more or less digital today");



- an extension of the scope of DIY because of the role of the digital ("DIY has changed with the digital").



DiDIY emerges as the systemic composition of two components, DIY and digital, which can be studied and characterized independently of each other. The digital in the DIY has multiple possible roles, e.g.:

- as a means to integrate physical and informational components ("atoms" and "bits") of entities (as in digitally manufactured objects), a situation that can be suggestively called "Atoms-Bits Convergence" (ABC);

- as the tool for creating distributed processing systems (as in Internet of Things systems);
- as the enabler of efficient online communications (as in open online communities).

These roles will be studied during the Project in their relative relevance and mutual interactions and dependencies.

In the following the two basic components of DiDIY, i.e., digital and DIY, are separately analysed, and on this basis DiDIY is finally introduced.

3. On digital

Lately the term “digital” has been widely exploited to convey a generic message of ‘being novel’. We shall avoid this trap, and maintain a specific meaning for the term: “digital DIY” is not a synonymous of “current way of DIY”. We have devised the term “digital DIY” in the proposal of this Project to denote a kind of DIY specified by some use (to be understood) of digital tools. In order to achieve a useful characterization of what DiDIY is, the concept ‘digital’ is then a critical component of our analysis and exploration.

3.1 What digital is not

Let us recall that the opposite of *digital* is *analog* (sometimes spelled “analogue”): why should something that is not analog be digital? and what is specifically the scope of these opposite features? i.e., what can be analog-or-digital? (for example, a table is plausibly neither analog nor digital)

Basing on the common understanding of the concepts, “digital” does not mean:

- ‘discrete’ (vs continuous: a clock whose hands assume only discrete positions – as in an electronic display where the angular position of each hand changes by making the hand disappear in a position and reappear in another one – is analog);
- ‘based on electronics’ (vs mechanical or something else: many electronic devices – such as traditional radios, telephones, amplifiers, etc – are analog);
- ‘related to computer-based online communication’ (vs offline computing or something else: digital computers are digital also if disconnected to the Internet);
- ‘informational’ (vs physical: many informational devices have been and are analog).

Despite this list of what digital is not, the concept is not empty, nor purely marketing-related: understanding it is helpful, if not necessary, to explain the critical role of the ‘being digital’ in digital DIY, and therefore to maintain the appropriate focus in our Project.

3.2 Digital as a strategy of coding (and therefore of communication)

Today being digital is fashionable and everything seems to be possibly digital (computers, libraries, books, marketing, etc), but the scope of the characterization ‘analog-or-digital’ should be maintained specific: digital, or analog, is *a feature of the way information is encoded by means of signs* (Frigerio et al 2013, which discusses other positions such as those cited in the References section).

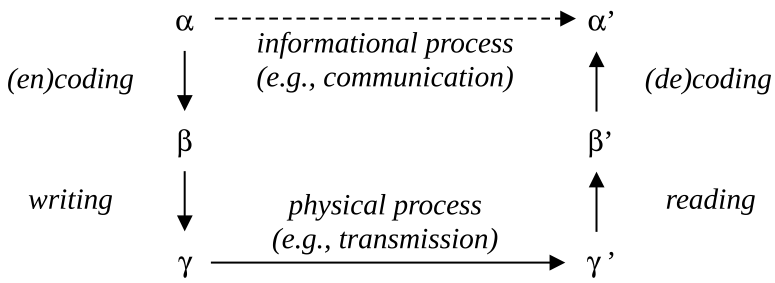
For example, let us suppose that someone is asked to communicate a number chosen from a set. There are many ways to do this, as there are many different signs by which the information, say, <number two> can be encoded:

- the digit “2”;
- the English string “t-w-o” or the Italian string “d-u-e”, in their written or spoken forms;
- the amount of two pebbles;

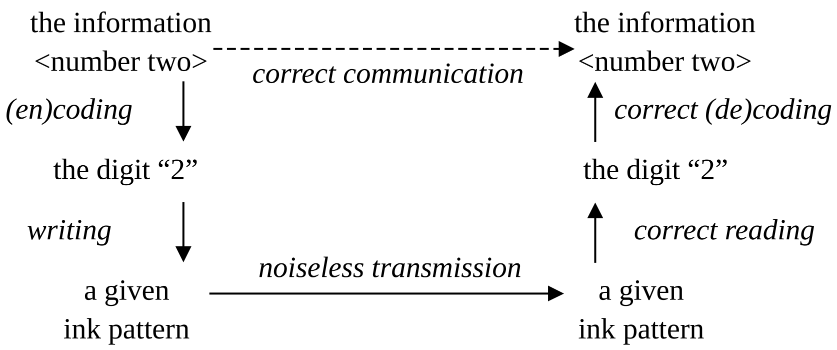
- the angular position of 2° of a needle on a scale;
- ...

All of them share the same structure, based on a sequence of:

- encoding/decoding, i.e., purely informational sub-processes;
- writing/reading, i.e., informational-physical sub-processes;
- transmission, i.e., a physical sub-process.



For example:



The main target of any information process is to design, setup, and perform the process so to suitably operate on information (in the simplest cases of communication and memorization so that $\alpha'=\alpha$). This requires a suitable encoding/decoding (so that $\beta'=\beta$) and writing/reading and then transmission (so that $\gamma'=\gamma$). In other terms, any informational process aims at producing the transformation $\alpha\rightarrow\alpha'$ but what actually does is $\alpha\rightarrow\beta\rightarrow\gamma\rightarrow\gamma'\rightarrow\beta'\rightarrow\alpha'$: to operate on information some physical transformations are required.

On this basis, encoding/decoding, as formalized by a representation function linking information entities and signs, is the focus of the analog vs digital distinction.

Let us indeed compare these ways of encoding by considering what the receiver of the sign is expected to know for decoding the sign and then recovering the information:

- in the case the information has been encoded in terms of amounts of pebbles or angular positions of a needle, all she must know is a general rule such as “the number is the amount of pebbles”, whatever the amount is; this generality is allowed by the fact that there is an analogy between the information to be encoded and the encoding sign; *these ways of coding are analog*;

- in the case of the digit “2” she must know, case by case, the correspondence between digits and numbers, and in the case of the English string “t-w-o” she must know, again case by case, the correspondence between some English terms and numbers; this specificity is required by the fact that there is only a conventional relation between the information to be encoded and the encoding sign; *these ways of coding are digital*.

Since information can be communicated only by means of signs, that are then somehow “written” on a physical system (ink on paper, sounds, etc), the encoding / decoding stage, be it analog or digital, is crucial to make communication possible. The common characterization of physical devices as analog or digital is then elliptical: a device is analog / digital because it deals with information coded in analog / digital form.

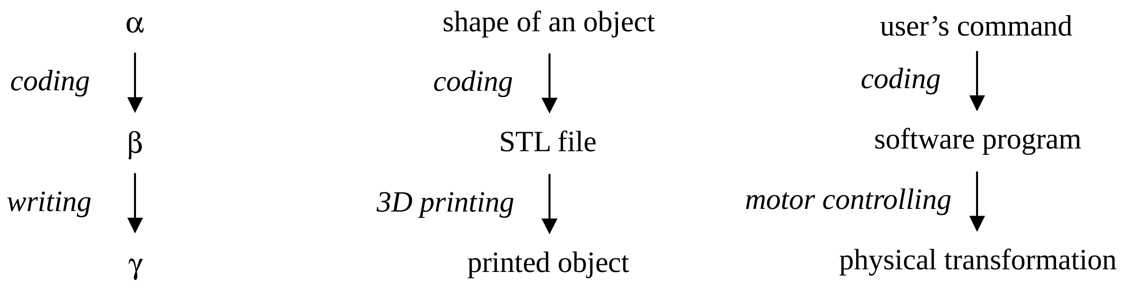
Moreover, communication can freely mix analog and digital components. For example, spoken language is usually digital (the fact that, say, a table is called “table” in English is known by convention), but it can include analog aspects, for example in the tone of voice (the louder the more important the conveyed message, and so on). In their turn, technological systems of communication have adopted both analog and digital components, as in press where text is digital but emphasis by means of boldfacing or underlining text, setting its font size, etc is instead analog.

Hybrid / layered coding is in fact widespread. Let us consider the example of the number twelve, as coded “12”, i.e., according to the usual decimal positional system. It is the example of hybrid coding: digital in the single digits (“1” and “2” denote the numbers one and two only by convention), but analog in the positional rule (“12” is different from “21” as there is an analogy between the position in the sequence and the relative value). In this sense, a number system whose base is, say, 1000, thus requiring 1000 different digits, is “more digital” than the one in base 10, and the binary system is the “minimally digital” one.

3.2.1 Actuators and sensors

The previous model of informational process, such that the transformation $\alpha \rightarrow \alpha'$ (i.e., information→information) is performed as $\alpha \rightarrow \beta \rightarrow \gamma \rightarrow \gamma' \rightarrow \beta' \rightarrow \alpha'$, can be easily specialized to cases relevant in this context, and in particular:

- information→physical systems processes, such as the operation of a 3D printer (centre diagram) or of a computer-controlled motor (right diagram):



  These are cases in which information drives physical transformation by means of actuators (3D printers, motors, ...);

- physical systems→information processes, such as the operation of a 3D scanner (centre diagram) or of a computer-plugged sensor (right diagram):

α’	shape of an object	information to user
↑ *coding*	↑ *coding*	↑ *coding*
β’	vector of 3D coordinates	data file
↑ *reading*	↑ *3D scanning*	↑ *sensing*
γ ’	physical object	physical quantity

These are cases in which information is obtained from physical states by means of sensors (3D scanners, ...).

3.3 Analog vs digital: pros and cons

Analog and digital have complementary pros and cons:

- *analog* coding is efficient and easy to implement and to learn, as it can be learned by rule, but it can be adopted only when the information entities to be encoded have structural relations that can be analogically mapped into signs (e.g., if the information increases then the sign increases) and it requires physical supports that in their turn can maintain these structural relations (e.g., if the information increases then the support increases in some sense);
- *digital* coding is inefficient and hard to implement and to learn, as it must be learned case by case, but it can be adopted also when the information entities to be encoded do not have structural relations and only requires physical supports that can maintain distinctions.

In this view, *the digital has a broader practical applicability than the analog*, and it *is entirely conventional*, being almost completely unconstrained by physical supports that is only required to be able to maintain the differences which allow to distinguish the encoded signs, as in the commonly known case of “zeroes and ones”. Through digital coding systems, information can be then easily processed, transferred, stored, etc also by means of simple and very efficient technological tools, leading to practically zero marginal costs of computation (according to the Landauer’s principle, “theoretically, room-temperature computer memory operating at the Landauer limit could be changed at a rate of one billion bits per second with only 2.85 trillionths of a watt of power being expended in the memory media. Modern computers use millions of times as much energy.” [http://en.wikipedia.org/wiki/Landauer's_principle]).

The pros and cons of the coding system are then in principle distinct from the pros and cons of the physical system adopted to encode information.

While the code can be then:

- analog, i.e., based on an intensionally defined rule: *relatively efficient implementation of coding*, since one rule conveys the entire (meta-)information on the code;
- digital, i.e., based on an extensionally defined rule: *relative independence of coding from the features of support*, that is only required to maintain distinguishable configurations,

the physical system that encodes the information is basically characterized by the number of empirically distinguishable configurations that it can assume, and whose number can be:

- a priori unlimited: it can potentially *encode infinitely many distinct information entities*, were the writing / reading resolution system infinitesimal;
- a priori finite: it can potentially *guarantee protection against error*, were the configurations encoding information entities distinguishable from each other, according to what specified by the Shannon's noisy channel coding theorem [http://en.wikipedia.org/wiki/Noisy-channel_coding_theorem].

From an empirical viewpoint – clearly the only one relevant in the present context – the important distinction on support configurations *is not*:

- *continuous vs discrete*: no experiment can assess the difference between a real number and a rational number approximating it, and whether, say, energy is a continuous or quantized physical quantity is a topic unrelated to the opposition analog vs digital;

and is not:

- *infinite vs finite in number*: no physical process can distinguish infinitely many different configurations, and since all measuring systems have finite resolution, relating analog vs digital to infinite vs finite would imply that only ideal cases could be analog, and everything would be instead operatively digital (so that, e.g., analog computers would be indeed "ideally analog" but "practically digital"),

Rather, what is important *is*:

- *whether, in the space of possible configurations, distinct configurations are sufficiently far from each other*: this crucial condition is worth a more detailed analysis.

The informational-physical sub-process of writing (i.e., $\beta \rightarrow \gamma$ in the diagrams above) is subject to the basic constraint that distinct signs have to be written as distinct configurations of the physical support, so that the complementary sub-process of reading ($\gamma' \rightarrow \beta'$) can produce distinct signs from distinct configurations. Physical systems are generally affected by influences of their environment, called "noise", and might have only a limited stability: for a system exploited as information support both noise and instabilities become critical when they produce changes in configurations, such that in the overall writing-reading sub-process ($\beta \rightarrow \beta'$) the read sign might be different from the written one, a situation that can be called of "error". The closer are distinct configurations in the space of possible configurations, the more probable is this situation of error.

In the case the number of distinct signs to be written and then read is small, configurations might be chosen that are far enough to guarantee that the probability of error is small. But when the information to deal with is complex (a long text, a picture, etc), and therefore the coding system requires many distinct signs, the probability of error in the support might become non-negligible.

Let us consider the case of encoding one colour in 2^8, as typical in grey scale, by means of a number, say from 0 to 255, and then to be required to write this number as an electric tension. With a large range of possible tensions, say from 0 V to 2550 V, a simple solution is to write the number *x* as 10*x* V, so that all changes of less than 5 V in the support do not produce any error. On the other hand, in a more typical situation of an allowed range of, say, 0 – 5 V, the distance between two contiguous configurations is 5/256, i.e., less than 20 mV: any change of 10 mV or more in the support is sufficient to produce an error. An alternative solution is then to encode the colour by means of the sequence of 8 binary digits and to orderly write each bit on a distinct tension, say, either 0 V or 5 V. The trade-off is clear: in the first case 1 tension is sufficient but the error threshold is 10 mV; in the second case 8 ordered tensions are required (x8) but the error threshold for each tension is 2.5 V (>x100). Of course, the order in the sequence is critical (01 is different from 10) but the physical support can be designed so to make the probability of swap (and therefore of related error) negligible.

This justifies why the hybrid / layered coding, as obtained through sequences of binary numbers, is so widespread today.

A note: the opposition analog vs digital is peculiarly subject to strong stereotypes, particularly related to the supposed correspondence analog = continuous and digital = discrete. A good example is “An analog signal is any continuous signal for which the time varying feature (variable) of the signal is a representation of some other time varying quantity, i.e., analogous to another time varying signal. (...) It differs from a digital signal, in which a continuous quantity is represented by a discrete function which can only take on one of a finite number of values. (...) An analog signal has a theoretically infinite resolution. In practice an analog signal is subject to electronic noise and distortion introduced by communication channels and signal processing operations, which can progressively degrade the signal-to-noise ratio (SNR). In contrast, digital signals have a finite resolution.” [http://en.wikipedia.org/wiki/Analog_signal]. While correctly emphasizing that being analog has to do with coding by means of analogy, the consequence of the assumption analog = continuous together with the acknowledgement that in practice infinite resolution is not possible would lead to the peculiar conclusion that the opposition analog vs digital only applies at the theoretical level, and operatively only digital signals are possible.

3.4 On the (claimed) novelty of digital

Hence, digital communication has nothing new, nor anyway there is anything new in analog communication. In their biological and societal evolution, human beings developed sophisticated means to communicate, in both analog and digital ways. It is interesting that analog coding is generally much easier to learn, and human beings have some analog coding directly built in: the message conveyed by a caress vs a slap is clearly analog, and it does not require any learning stage. On the other hand, while very primitive communication may be conceived as also purely analog (through onomatopoeic sounds, rules such as the more the risk the louder the shout, and so on), human beings have learned to deal with so many different and so structurally complex entities that our communication has becomes largely conventional in its coding rules, and therefore digital (while distinguishing a table from a chair by means of a sketch is analog, the English terms “table” and “chair” can be associated to tables and chairs only by a case by case convention; interestingly, some languages maintain some analog components also in verbal communication through term modifiers, for example for size: in Italian “tavolo”, for “table”, admit variations such as “tavolone” and “tavolino”, where the suffixes “-on-” and “-in-” are generic for “big” and “small” and therefore are somehow analog).

As a consequence, the possible novelty of digital is not to be looked for in traditional ways to handle information: since millennia they are already largely digital. Rather, and somehow paradoxically, what is novel in digital is justified by its low efficiency, such that until a relatively recent past technological communication (telephone, radio, television) has been mainly analog: only the widespread availability of microelectronic components has provided the large arrays of bistable devices required to make digital coding technologically affordable. As mentioned, the benefit is a practical almost complete separation between information and physical supports, that has led to a reification of information far greater than in the past: once implicitly assumed as something to be treated by humans only (“wetware”), by means of its digital coding information has become software, databases, websites, etc. What is new is then that we now have machines that are particularly efficient and fast at processing digitally-coded information: the digital computers. This opens a whole new range of possibilities.

3.5 Further considerations

Given this core meaning, the concept ‘digital’ has been spread out to information processing entities (a digital computer is a computer working on digitally-coded information), and then, by metaphor, to information related entities (a digital library is a library in which digitally-coded information is stored).

It is then apparent that there is no principled relation between being digital and being electronic: there are electronic devices that are not digital and digital devices that are not electronic. The fact the most devices for the automatic processing of information are both electronic and digital is due to the great efficiency of electronic technologies for the automatic processing of digitally-coded information. The correlation digital-electronic is really high nowadays, and therefore interchanging seems to be operatively acceptable, although conceptually unjustified.

Being decoupled from its physical support, digitally-coded information not only freely flows and can acquire autonomous individuality, but also – and crucially from the viewpoint of this Project – can be freely recombined with physical systems in the versatile options allowed by systems such as 3D scanners and printers, Arduino boards with sensors and actuators, etc: the phenomenon that we propose to call “Atoms-Bits Convergence”, ABC. Associating the concept ‘digital’ to DIY conveys these ideas.

4. On DIY

Amateurs committed to producing something by themselves (i.e., Do It Yourself or, simply, DIY) are reshaping the relationship between production and consumption. The spreading of this trend suggests scenarios in which non-professional people are, or will be, able to create artefacts. Concepts have emerged to describe this contemporary phenomenon, such as the 'new' DIY age (Hoftijzer 2009). Engaged individuals have been described as 'craft consumers' (Campbell 2005), 'lead users' (von Hippel 2005), 'professional amateurs' (Leadbeater and Miller 2004) and 'prosumers' (Anderson, in Toffler 1980). Such individuals are united by the will and ability to create artefacts that they desire and may be supported by innovative technologies (e.g., Atkinson et al 2008), networks (e.g., Leadbeater 2008) and, perhaps, companies with new business models (e.g., Franke, von Hippel, and Schreier 2006).

Although, DIY has been spotted as a major trend in contemporary society (Anderson 2012), it still deserves further research (Watson and Shove 2008), namely to understand how DIY – in particular its expansion through the use of digital technologies – may contribute to the provision of individual and social empowerment (Manzini 2003) while reducing the consumption of resources (Lorek and Spangenberg 2014).

To this end, in the following sections DIY is described first on a broader level and then with a focus on the digital DIY (DiDIY). Eventually the gaps in research are identified.

4.1 DIY and how it came about

DIY usually refers to the activity carried on by untrained people for the realization (designing and making) of a product, instead of having it done by a professional. Kuznetsov and Paulos (2010) defined DIY as any creation, modification or repair of objects without the aid of paid professionals. The outcome of this activity is eventually used or consumed by the creator or people with personal connections (e.g., relatives or friends), without the generation of direct profits. Therefore, "DIY is both a producing and consuming culture" (Edwards 2006, p.11).

The origins of such phenomenon may be traced back to the 18th century, when upper-class women were "not employed and whose role was to organize the running of the family home" (Edwards 2006, p.17). Later, in the 19th century, the bifurcation of work and leisure, generated by the industrialization and definition of working time, infiltrated the home in the form of productive leisure (Gelber 1999). Towards the end of the 19th century, America's first leisure "power tool" was launched and – especially masculine – people learned and applied manual skills as leisure, and they practised these skills improving their homes (Goldstein 2003). In the 1950 and 1960s the DIY raised again as on one side the result of unavailability of skilled workers and the increasing cost of professional work after World War II (Atkinson 2006) and on the other as a way to realize the American dream of an affordable and modern home (Goldstein 1998). During the 1950s and 1960s, "the growing interest in DIY coincided with increases in disposable income, greater leisure time, and improvements in lifestyle. It marks a confluence of a variety of historical factors: changing social and cultural conditions, developments in manufacturing technology, the importance of newspaper and magazine publishing, and even television celebrity" (Jackson 2006, p.57). In fact, Johnson, founder of the DIY Magazine, believes that three elements established the DIY in those years (1977):

- the introduction of the electrically powered pistol drill with its attachments, which reduced the efforts of sawing, drilling, sanding, etc, enabled the amateur to tackle basic woodwork and home-repairs;
- the appearance of the paint roller and emulsion paint, a water-based paint, almost odourless, that amateurs could use to cover large areas with the minimum of labour and fuss; it was something new to be able to clean brushes with water;
- third was the far-reaching decision of the Wall Paper Manufactures Ltd, founded in 1899, to make their products available to the public for the very first time through their retail outlets. And not only to make them available but to give demonstrations throughout the country to show how easy it was to apply them.

Therefore, the introduction, establishment and diffusion of DIY historically derived from a concoction of factors, including situated needs to be accomplished with financial limits, development of tools and materials, investments of spare time in leisure activities, expression of the personal identify and setting relationships with the social environment.

4.2 Approaches to DIY

The analysis of the origins of DIY provides a picture of the multitude of factors concurring to its development and tapping into anthropological, socio-technical and economic fields. However, such an investigation is still missing for understanding the DIY trend in current century. Little research has investigated the topic and a more holistic and structured study on the topic is still missing. Several are the research questions that are still missing a possible answer on the topic, especially in relation to the influence of the digital innovation, such as:

- how is DIY performed and which are the motivations for contemporary age, especially in affluent societies?
- which are the tools and media of a contemporary DIYer and to what extent the development of digital tools sustained its revival?
- which are the skills and competences of a contemporary digital DIYer?
- to what extent the spreading of Internet-based social networks and communities of practice have reshaped and supported the spreading of DIY?

Each of the questions above may require an extensive investigation to depict a specific element of DIY. However, addressing them individually risks to generate a fragmented picture of a seamless web of experiences and connections. To this end, approaches and theories depicting complex phenomena may help the definition of contemporary DIY. *Social Practice Theory* is one of the possible resources that can be used to this end and described below in relation to DIY.

4.3 Social Practice Theory for DIY

According to Warde (2005), consumption occurs in the course of accomplishing practices, which emerge from, constitute, and makes sense of “forms of bodily activity, forms of mental activity, things and their use, background knowledge in the form of understanding, know-how, states of emotion, and motivational knowledge” (Reckwitz 2002, p.249).

DIY is one of the practices accomplished in contemporary society that evolves over the time because of the active integration of both existing and new elements in practices (Shove and Pantzar 2005). The study and description of such integration of elements is the primary objective of Social Practice Theory (SPT). SPT can support the development of future scenarios for design and production fields alike (Ingram et al 2007), and in general fields interested in the environmental aspects of consumption (Røpke 2009).

Shove – one of the most well-known researchers in this field – classifies the elements of every practice into:

- *materials*, i.e., tangible resources;
- *competences*, i.e., capabilities and skills;
- *meanings*, i.e., motivations for accomplishing DIY.

Shove's theory can help to generate a systematic and structured analysis of DIY as it can highlight how new connections have been created among the elements of the practice, especially with the introduction of digital tools. Salvia (2013) analyses the components of contemporary DIY applied to reuse, repair, re-purpose and re-manufacturing in both UK and Italy. Some of the contents below describing DIY draws on the findings of his research.

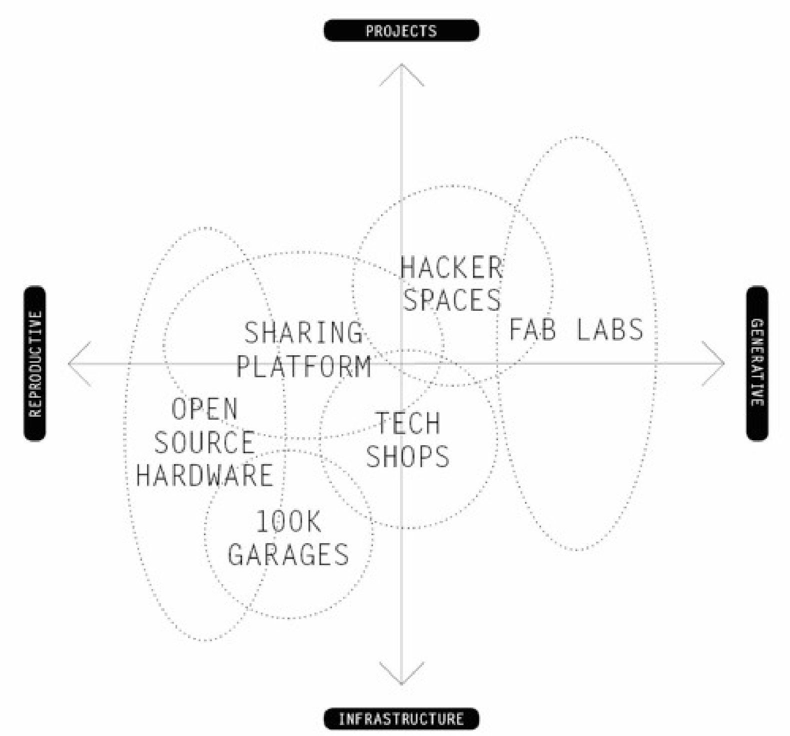
4.3.1 Materials

The first component of a practice describes the set of materials, artefacts and in general tangible resources needed to accomplish the practice. For example, Salvia (2013) identified some categories of materials, such as raw materials, tools, sources of information and spaces for both collecting artefacts and practising DIY.

Sources of information – Sources of information and in general media, such as magazines (e.g., Make [http://makezine.com] or Craft [http://craftzine.com]) and TV programmes have been considered crucial for current development of DIY (Jackson 2006) as knitting magazines and in general media for feminine hobbies were during 1920 and 1930s (Hackney 2006). Yet, several other means coupled the traditional magazine format thanks to digital tools, and web 2.0 in particular. Beyond YouTube, several virtual platforms have been set in the last decade to share and spread users' inventions and DIY output. Generally, they are characterized by a specific topic, typically technology or furniture, such as iFixIt [http://www.ifixit.com] or Instructables [http://www.instructables.com], with communities of amateurs showing how to repair electronic devices in the former case or make almost everything in the latter one.

Tools – The development of tools facilitating the production of artefacts also at basic levels of skills can be considered one of the major factors influencing the current establishment of DIY. Consumer and prosumer 3D printers (e.g., [http://reprap.org]) and CNC machines (e.g., [http://diylilcnc.org]) are plausibly equal to the power tools in the 1950s in triggering the interest of contemporary DIYers.

Spaces – Virtual and tangible places for practising DIY have been spreading in recent years. In fact. the possibility for practitioners to gather and produce, especially collaboratively, is also a major factor for contemporary, especially digital, DIY. Troxler (2011) mapped such spaces (see the Figure below).



In the last decade many DIY workshops equipped with user-friendly devices (especially the tools described above) have spread globally, under various denominations such as FabLabs, Hackerspaces, Men's Sheds, Community Garages, TechShop, etc. Generally aiming at providing facilities for self-production, these workshops offer members the opportunity to share skills, knowledge and projects with others passionate about DIY.

The practice and the possibility to collaboratively create or share knowledge is also fostered through virtual platforms, such as Fab@Home [http://www.fabathome.org] or Thingiverse [http://www.thingiverse.com]. These platforms can collect components or allow for the collaborative creation of product. Interestingly, Open Source Ecology (OSE) [http://opensourceecology.org] is a wiki platform connecting farmers, engineers and volunteers in order to develop the main parts for high-performance machinery, the Global Village Construction Set, collaboratively. In some other cases, the file rather than the object is purchased and the user sources manufacture locally (e.g., Shapeways [http://www.shapeways.com], Ponoko [http://www.ponoko.com]).

4.3.2 Competences

The second component of the practice in Shove's theory is competence. It embraces the skills required or involved in the accomplishment of the practice, typically to use the materials components described above. In the case of DIY for home improvement, commonly involve manual skills (e.g., to work wood). Digital DIY involves the capability to create and interpret also non-physical elements (e.g., CAD files).

Support provided in the form of communicating manual skills through virtual means does, however, face inherent limitations as direct feedback is generally lacking. Moreover, practitioners may be inhibited from undertaking a repair by a perception of lack of skills and competence, the latter "conventionally defined as a characteristic of the human subject [but] perhaps better understood as something that is in effect distributed between practitioners and the tools and materials they use" (Watson and Shove 2008, p.77).

Digital tools (e.g., 3D printers) tend to allow for lack of manual skills, because products can be files before being produced or other practitioners might contribute and help. Therefore such tools might enable also practitioners that might be low level skilled, thus distributing the competences (Latour 1989) between the human and the machine. For instance, companies are increasingly interested to the involvement of their customers approach in the design and personalization of the product that they will buy through virtual platforms that can be used at any level of competence. According to the business model of Consumer Customization, "a manufacturer can equip its customers with a set of tools which enable them to convert their ideas, preferences, and tastes into products. Their final, individual solutions are then produced by the manufacturer, who takes advantage of mass customization production systems" (Schreier 2006).

Skills can be acquired and trained in the places and through the sources of information presented above. In particular, online DIY tutorials have changed the way we learn new skills and techniques as well as how we share our knowledge (Dalton et al 2014).

A crucial skill often required in the accomplishment of the practice is the capability to anticipate the whole designing and production process. Therefore DIYers might need to practice a "design thinking" (Brown 2004).

4.3.3 Meanings

People's main motivations for engaging in practicing DIY ('meanings' in practice theory), such as expressing one's one identity (Campbell, 2005), feeling of being the creator of one's own products (Franke, Schreier and Kaiser, 2009), social display (Hackney 2006) or stating personal independence from consumerist society (Duncombe 1997; Kuznetsov and Paulos 2010). Wolf and McQuitty (2011) link DIY to identity enhancement through sense of empowerment, an identity as a craftsman, membership in a community of DIY enthusiasts, and the need to be unique or different from others.

In literature, Watson and Shove (2006) identified several other motivations for DIY, to be found within the family (Nelson 2004); through the maintenance of self-esteem (Woodward 2003); by means of reconstructing space and identity (Miller 1995); or in the consequences of project-definition for modes of provision (Williams 2004) and in-store purchasing (Van Kenhove et al 1999).

Hoftijzer (2009) classifies motivations for DIY as Status, Pride of Authorship; Democratizing Design/ Self-determination; Control; People have always wanted to express their creativity; Added Value by "doing" it Yourself. Atkinson (2006) determined four groups of DIY practitioners according to their creativity level and main reason for self-making, that include pro-active, re-active, essential, and lifestyle DIY.

Economic saving is a particularly recurrent motivation for practising, more evident in low-income contexts but present throughout the economic classes as a lifestyle choice (Williams 2004). Perceived satisfaction gained in the DIY practice appears to be the crucial component motivating pursuance and accomplishment of the task, regardless of the level of the individual's commitment and ability. In other words, less committed and skilled DIYers are very likely to gain levels of enjoyment and satisfaction comparable to highly committed practitioners when a task is accomplished (Salvia 2013). Therefore Salvia classified the DIYers according to their level of interest and commitment borrowing the categories defined by Sanders (2006) in studies for involving final users in the design process, i.e. doers, adapters, makers and creators.

Practitioners with higher level of commitment may more likely pursue DIY as a 'serious leisure', i.e. systematic pursuit of an amateur, a hobbyist, or a volunteer activity sufficiently substantial and interesting for the participant to find a career there in the acquisition and expression of a combination of its special skills, knowledge, and experience (Stebbins, cit in Pantzar and Shove 2005).

The others might more likely pursue the activity as a 'casual leisure', i.e. immediately, intrinsically rewarding, relatively short-lived pleasurable activity requiring little or no special training to enjoy it» (Stebbins, cit in Pantzar and Shove 2005).

4.3.4 Summary and gaps in research

Summarising the exploratory investigation of the literature above, DIY and its digitally enabled version has been defined as a production and consumption process, with a strong social connotation, where people's creativity and self-improvement through the development of new skills and knowledge are key-elements. The research requires further investigation to fully understand and map the digital DIY. Future research could address areas that might result to appear not sufficiently explored yet and summarised below. In particular, the definition of how the influence of the digital shapes the practice of DIY could be a major focus of analysis and future research could aim at intervening between in its elements of the practice above, and propose actions addressing the main actors of production and consumption, i.e.:

- users;
- products;
- contexts;
- mutual relationships.

Addressing the complexity of actors and mutual relationship in a holistic way is fundamental especially for DiDIY because technological practices are never isolated from their social or economic contexts, or from the history of previous technological practice (McLuhan and McLuhan 1992).

4.4 Some further dimensions

4.4.1 DIY and innovation

Self-production has been acknowledged as an opportunity to generate innovation. In particular, it was estimated that 80% of innovation in scientific tools have been generated by amateurs (Von Hippel 2006). Digital DIY could even accelerate this process: "Access to tools capable of turning digital designs into physical objects, coupled with the ease with which digital files can and are being modified and circulated, is bringing a third dimension to the practices of sharing, mashup and remix, and giving everyone the opportunity to not only reinvent and shape the world of bits, but also the world of atoms." (Mota 2011).

However, little has been done to map trajectories of innovation and possible effects namely on the environment.

4.4.2 Empowering the individuals and the community

DIY is seen as an opportunity for practitioners to learn, and thus empowering themselves. Knowing how to make, repair and transform artefacts has been seen also as a way to provide confidence to the DIYer about not only how things are made (thus being able to better judge the quality of purchased items) but also about themselves being able to solve everyday problems more easily in the future. In fact, the dominant paradigm of user-as-consumer gives way to alternative framings of the user as creative appropriator, hacker, tinkerer, artist, and even co-designer or co-engineer. There is an obsolescence of the notion of the "consumer" as a passive receptor of "products". They want to retrieve areas of knowledge and practice that are not universally necessary in the industrial age (personal food production, handcraftsmanship, understanding the inner workings of machines), but that bring people pleasure and purpose to know (Tanenbaum et al 2013).

On a broader scale, DIY can empower the groups on individuals, i.e., communities. For example, developing countries are typically characterized as being concerned with utility or disaster relief rather than the pleasures of making. Such hackery allows craftspeople to earn a living in a way that lets them control their schedule, express creativity, and maintain a sense of dignity. More deeply than that, it embodies a tradition of work that intrinsically includes elements of fun, sociality, and communal effort (Tanenbaum et al 2013). However, little has been investigated about the process and the effect of self-empowerment. Therefore future research could address the process of learning, acting and extending knowledge to other practice.

4.4.3 The social dimension of DIY

Contemporary DIY is often mainly considered as a social activity. It has been said that DIYers are interested in DIY because it connects them with others (Wolf and McQuitty 2011) and they might have an overwhelming focus on the role of the effects achieved through DIY in mediating and maintaining relationships between people (Watson and Shove 2005).

The spreading of physical and virtual places where people can undertake creative activities is enabling the coalescing of committed individuals who support each other in "communities of practice" (Lave and Wenger 1991) or even "creative communities", i.e., groups of people who cooperatively invent, enhance and manage innovative solutions for new ways of living (Manzini, in Bœuf et al 2006).

The establishment of the Internet, web 2.0 and social media has contributed to the spreading of groups who collaborate on a wide scale, often at a global level, for shared purposes. This is an example of commons-based peer production, whereby "large groups of individuals (...) co-operate effectively to provide information, knowledge or cultural goods without relying on either market pricing or managerial hierarchies to co-ordinate their common enterprise" (Benkler and Nissenbaum 2006, p.394). It has led to several phenomena, initiatives and communities (e.g., open source, peer-to-peer, etc) emerging with the aim of contributing to a more community-oriented society. Peer production has been envisaged as "an opportunity for more people to engage in practices that permit them to exhibit and experience virtuous behavior" (Benkler and Nissenbaum 2006, p.394).

Further research could address how the dynamics of communities and social networking are reshaping DIY and if they are bringing innovation in knowledge and practice.

4.4.4 Environmental and social sustainability

The spreading of DIY, particularly in its digital versions, risks generating unwanted rebound effects on the environment. Facilitated access to the production system by consumers could, in theory, lead to inefficient resource use and increased waste, and thus the sustainability implications of this trend are still being debated (Troxler, in Abel et al 2011; Watson and Shove 2006).

Self-designing and crafting of artefacts may still depend on systems of mass production (Watson and Shove 2008). The disruptive innovation brought about by these trends then risks being reduced to a different form of production and consumption of more goods: essentially a new form of capitalism (Ritzer and Jurgenson 2010).

The question is then how to align the current DIY design trend with sustainability targets. Research by Salvia (2013) envisaged this contemporary trend as a ‘window of opportunity’ to foster positive sustainability impacts through, for example, personal growth, community empowerment and waste reduction. The research addressed self-production as a means to prolong product lifetimes by re-using, re-pairing, re-purposing, and re-appropriating, hereafter named ‘RE-DIY’, i.e., RE-activities in DIY practice. In addition, grassroots innovations are recognized as incubators of the social change that is needed to minimise future environmental harm (O’Brien, cited in Feola and Nunes 2014). There is a growing and diverse population applying the DIY approach to the replication, repair, regeneration, redesign, or refunctionalization of products (e.g., fixers, remakers, refurbishers, customizers and hackers) (Bianchini and Maffei 2014). For example, the Restart Project [http://therestartproject.org] and ReFab Space [http://www.refab-space.org] are social enterprises that promote the extension of electric and electronic equipment lifespans by teaching and sharing repair and maintenance skills, either in their premises or during workplace events, as an empowering practice.

Further research could map good practices of environmentally and social beneficial digital DIY.

4.5 How to scale up

Digital DIY is perhaps not a mainstream practice yet. However, the spreading of such practice on a wider level might bring additional benefits. To this end, studies on transition management could help to identify levers for scaling up. In particular multiple level transition theories can help as their focus is often on the innovation brought by niches (e.g., Geels 2002, 2004). Patterns of transition may be guided by specific environmental and social criteria to general sustainable scenarios such as the one modelled by Manzini (2010) and called SLOC (Small, Local, Open and Connected) to address novel and visionary, yet viable, scenarios for sustainable design.

A first attempt to adapt the SLOC model to digital DIY may consider:

- Small: DiDIY as geographically distributed niches;
- Local: engagement of local communities, use of local resources, preservation of situated traditions and skills;
- Open: collaborative nature of contemporary DiDIY, with Open Source;
- Connected: on-line platforms for designing collaboratively (and producing locally).

5. On digital DIY

5.1 The fundamental tension: DIY as something that someone does or something that someone has

As discussed above, the literature proposes multiple interpretations on what DIY structurally is, that can be classified around a fundamental tension, DIY as something that someone (an individual, but possibly also a group, a class, a company, society as such):

- *does*, e.g., an *activity*; the creation, modification or repair of objects; a production and consumption process,

or:

- *has*, e.g., a *mindset*; an attitude; a producing and consuming culture.

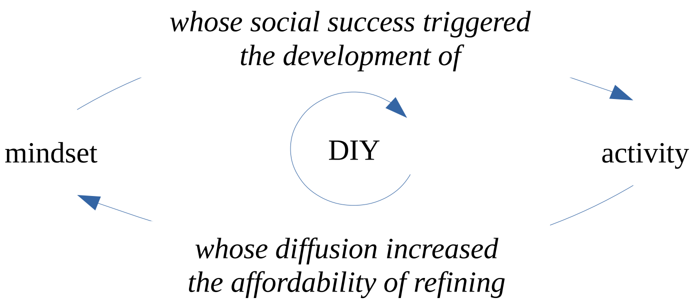
This duplicity emphasizes the complementary interpretation of DIY as:

- objective phenomenon: DIY as an activity is studied from the analysis of tools, products, structure of collaborations, ...

and:

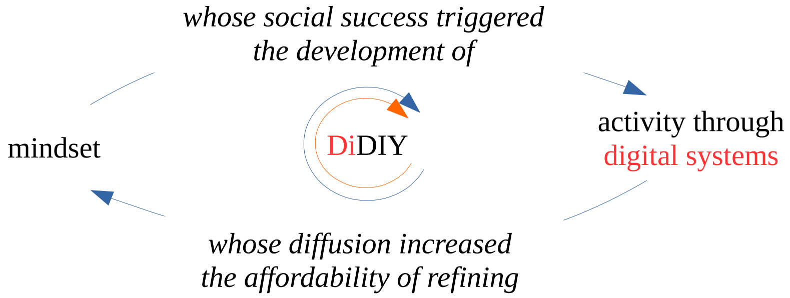
- subjective phenomenon: DIY as mindset is studied from the analysis of motivations, competences, social contexts, ...

Typically, the co-presence of the "objective" and the "subjective" components activates a positive feedback (self-reinforcing) process, thus progressively transforming DIY into a socio-technical system:



Ethical positions, individual attitudes and motivations, transformation methods and tools, etc have contributed and are contributing to make the system a recognizable phenomenon and to develop new dimensions and directions in it.

In this perspective, the diffusion of digital systems has further amplified this feedback effect:

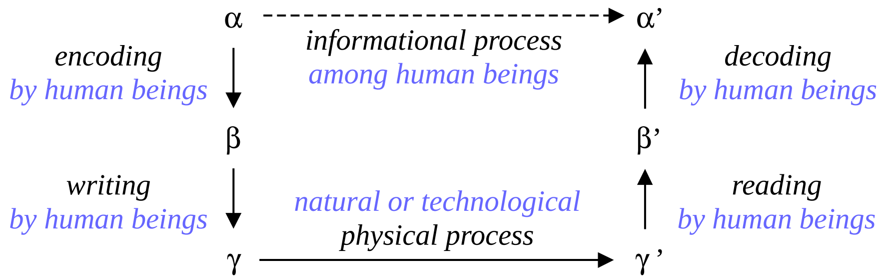


As mentioned above, in the broader picture the digital can be then intended as a means to lowering technical and relational barriers, easing the access to information, resources, and opportunities, and hybridizing the distinction between the physical and the informational.

5.2 DiDIY and Atoms-Bits Convergence

Traditionally information is statically embedded in physical artefacts, and dynamically recognized and operated only by natural cognitive agents (animals, particularly humans), according to the (implicit, because assumed as obvious) equation:

information processor = animal, i.e., wetware processor

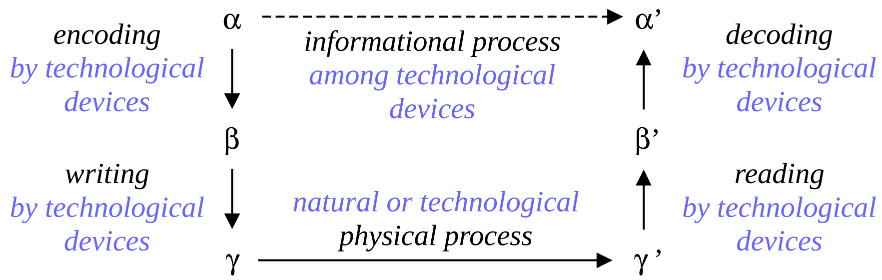


DIYers, starting from (i) informational entities (knowledge, skills, designs, ...) and (ii) physical entities (raw materials, components, tools, ...), generate new information-laden physical artefacts. The relation between information and physical artefacts (metaphorically: bits and atoms) is then at the core of DIYers' activities.

Then something changed: technological devices have been developed able to dynamically operate on digitally coded information, so that the equation has become:

information processor = wetware or hardware processor

where the critical novelty is the very existence of technological digital information processors:



that has triggered the widespread diffusion of:

- the (technological) phenomenon of communication networks (from the Internet to the Internet of Things / Internet of Everything);
- the (social) phenomenon of information shared in open formats (freely reusable digital data on everything: texts, music, images and videos, geolocalization of objects, shapes of objects, …);
- the (cultural) phenomenon of open collaboration and innovation (open source communities, IPR management via Creative Commons licensing, etc).

Communication networks, open formats, and open collaboration and innovation have been the effective breeding ground for new DIY tools, such as 3D scanners and printers and Arduino systems, which operate at the interface between bits and atoms.

This emerging scenario can be considered, in a specific sense, digital DIY, intended as DIY with a structured (instead of implicit), technological (instead of psychological) interface between the physical and the informational components of the system, where the physical process of DIY is enabled or empowered by digital tools, and this is realized both directions,

- from bits to atoms (i.e., encoding and writing, as in 3D printers and in actuators connected to Arduino boards)

and

- from atoms to bits (i.e., reading and decoding, as in 3D scanners and in sensors connected to Arduino boards).

Hence, what results from digital DIY is a new paradigm that can be called of Atoms-Bits Convergence (ABC).

5.3 Some dimensions of DiDIY

Some dimensions to present and study DiDIY have been identified, mainly through literature analysis and discussion among Project members. They are listed here with the same conceptual structure:

with respect to... there is a tension between DiDIY as only... or also...

where then the "only" position assumes a more specific, stricter interpretation and the "or also" position a more generic, looser one.

- *DiDIY and outcomes*: is DiDIY only aimed at creating artefacts, or is it also aimed at performing services?

- *DiDIY and production*: is DiDIY only related to hand made things, or is it also about the production of ideas?
- *DiDIY and professionalism*: is DiDIY only for non-professionals, or is it also for professionals who maintain their DiDIY mindset?
- *DiDIY and innovative technologies*: is DiDIY only driven by the use of innovative technologies, or is it also possible with traditional, well-established technologies?
- *DiDIY and creativity*: is DiDIY only about creative processes, or is it also for repetitive processes?
- *DiDIY and open communities*: is DiDIY only about openly sharing knowledge in communities, or is it also of individuals operating alone?
- *DiDIY and sustainability*: is DiDIY only related to the target of sustainability, or is it also unrelated to this target?
- *DiDIY and individual decisions*: is DiDIY only about voluntary activities, or is it also about activities performed to order?
- *DiDIY and routine*: is DiDIY only about non-routine activities, or is it also about activities performed routinely?
- *DiDIY and aesthetics*: is DiDIY only finalized to produce beautiful results, or is it also unrelated to beauty?
- *DiDIY and profit*: is DiDIY only about activities satisfying in themselves, or is it also about activities for profit?
- *DiDIY and timespan*: is DiDIY only about activities spanning relatively short amounts of time, or is it also about long lasting activities?
- *DiDIY and processes*: is DiDIY only focused on the processes of doing, or is it also related to the products of such processes?
- *DiDIY and open releases*: is DiDIY only about openly released outcomes, or is it also about outcomes that are maintained proprietary?

All these dimensions are presented so that the stricter position ("DiDIY as only...") would be non-controversially acknowledged as DiDIY (and maybe even "stereotypically DiDIY").

A challenge for the research activities in the Project will be to study how in the potential continuum from the stricter to the looser position of each dimension the phenomenon assumes different identities, how such identities are mutually related, and which of them should be proposed as desirable in socially-aware scenarios.

5.4 DiDIY from a modelling perspective

Looking at phenomena from a modelling perspective gives one a different and complementary view of things. One of the most productive aspects of building a simulation is that it forces you to be clear about what exactly constitutes the various aspects. Rather than dealing with a phenomenon, like that of DiDIY, as a complex whole, it divides the phenomenon up into its formal components without being reductionist, and in particular:

- *conditions and outcomes*: what are the preconditions for any events compared to what are the outcomes from them. For example, what might be the results of a new DiDIY enabling technology and what might be the necessary conditions for it to appear. A driving out of professionals from intermediary roles might be an outcome rather than an essential part of the phenomenon;
- *micro and macro phenomena*: what happens at the individual level of behaviour compared to what happens at the societal level. For example, individuals may not be aware that they form a sharing network, they are just giving and seeking advice, but the effect of the whole may be to change the widespread economic landscape and cost structures;
- *processes and structures*: societal structures (social networks, institutions, markets, laws, social norms, etc) and continually acted upon and hence changed by the individuals who act inside these (the processes). Similarly, all processes are constrained and enabled by existing structures. For example, new social norms can arise when individuals perceive (rightly or wrongly) the standard of behaviour of a community as they enter it, so they may come to expect that advice is free or designs can be freely copied. This new norm might then change the processes of design development within that community;
- *individual and collective agency*: individuals do not act alone, but often in collectives of various kinds. These will have some internal process to determine their collective action. Distinguishing what is achieved by individuals and what by groups, is sometimes crucial to understand the possibilities inherent in social change. For example, deregulatory changes in the law usually happen as a result of collective pressure, whilst new uses of a technology are usually invented by individuals;
- *built-in and emergent*; some processes are forced/built-in whilst others emerge. The limitations of accessible 3D printing technology will limit what can be done with it, that is built-in. A sharing community of people using the technology for a particular purpose (say a fashion in DIY strange facial extensions) might emerge.

In terms of these different dimensions we may start to unpick the different aspects that come together in the complex phenomena we might call “DiDIY”. Some of the elements within these different dimensions are:

- *(foreground) conditions*: the availability of a technology that enables (many more) individuals to convert a representation into an object; (later) the availability of a technology that allows representations to be automatically created from an object; the ability to easily share those representations; the ability to hand-craft new representations; previous costs and constraints that might motivate the uptake and use of these technologies;
- *(some possible) outcomes*: a collection of individuals that share representations and use these for the creation of objects that they need; a core of creative individuals that craft new representations and a penumbra of others that used these or simply make re-combinations of them; a set of shared values in that collection that makes it a community as a result of their shared interest and activity; the (partial) by-passing of professionals who used to make money by converting representations to objects or vice versa; the emergence of a new brand of creatives who are able to offer services to this new community; the weakening or even by-passing of IPR that was previously buttressed by the Atoms↔Bits conversions barriers;

- *micro-level (@individuals)*: the decisions and activities that individuals decide to enact; the knowledge and skills of individuals; the creativity and industry of individuals; the difference that the technology and community makes to the lives of individuals; the economic consequences for these individuals;
- *macro-level (@aggregate)*: the value-chains that emerge; the communities that result; the culture of these communities; the wider economic and legal impact of the activity and existence of these communities; reaction by the wider society to these communities and their activities;
- *processes*: the Bits→Atoms conversion process; the Atoms→Bits conversion process; the process of designing elements of the representations; the process of combining parts of a representation together; the process of deconstructing a representation into component parts; the process of storing a representation; the process of transmitting a representation to another;
- *structures*: the legal constraints upon action; the infrastructure that exists between individuals (post, internet, etc); the social networks that might result from the activity; value-chains that might emerge within this network; resources that might be created to support the activity (archives of representations, educational resources, etc);
- *individual agency*: whether to invest in the technology that allows Atoms↔Bits conversion; the decision making of individuals (what to transmit, make, design, scan, deconstruct, store); whether to help others to use the technology; what to communicate about the activity; (ultimately) designing the enabling technology itself;
- *collective agency*: what social norms a community suggests and maybe even enforces on itself; the laws that a society chooses to impose controlling how the technology might be used; the influence that such communities have on the wider society;
- *built-in*: the underlying cost structures behind the affordances involved in the Atoms↔Bits Convergence technologies and the transmission processes; what is possible technologically (given existing science and technology);
- *emergent*: the ‘culture’ and ‘mindset’ that characterises a DIYer that become common to a group of sharing individuals; the economic impact of the activity - including impact on IPR structures and how creativity is rewarded and encouraged; the new kinds of devices and representations that are created as a result of the network and creativity; the patterns of sharing and creation that develop; new dangers to individuals; new careers for individuals; new opportunities for crime.

These dimensions will be useful in the integrative WP where we will try to bring all these strands together again (in simulations and associated scenarios and analyses).

6. Interpreting DiDIY: from the perspective of organization and work

The fundamentals of management and organizational science have been developed and consolidated in an era structurally different from today (Dobbs 2015). Economy was mainly based on goods (atoms) and not on services (bits), economic transactions mainly occurred at the local and not international level (no globalization), the so-called first world experienced a constant economic growth. In that era technology used to provide tools supporting materials handling (atoms) and not information management (bits). From a demographical point of view, this era was characterized by a far shorter life expectancy and a lower average age of the employed population. The managerial models developed in such a context leveraged on an analytical approach, synthesized, almost ideologically, in the Taylor's model of work emphasizing specialization and a representation of organizations as deterministic machines.

Despite criticism about specific aspects (Yetton 1992; Sharp 1996; Merchant 2012), or the way they have been taught (Spender 2011), the dominant models taught as fundamentals in business schools are still the managerial classics of two decades ago, such as Ackoff's, Mintzberg's and Porter's models (Bedeian 2001) which are rooted, more or less explicitly, in the assumptions listed above.

It is at least questionable that these fundamentals, originally designed as conceptual tools to improve organizations and society, constitute as a whole a model appropriate to represent the current state of work and organizations, all the more so to project future scenarios based on disruptive phenomena like DiDIY.

Focusing on the infrastructural and social nature of DiDIY, it is worth noticing that its impact on work and organization is widespread across the industries and not merely related only to the skills of individuals. As such, this phenomenon should be observed at three different levels of aggregation or layers:

- L1: *individual* layer;
- L2: *organizational* layer (more in general: multiple individuals level);
- L3: *inter-organizational* layer (more in general: multiple organizations level).

Management science models typically simplify the complexity of these layers by flattening them and focusing on L2 (the organization) as the main subject of research. In doing so, the uniqueness of each individual (L1) is lost (or at least blurred) in the attempt of standardizing personal characteristics and behaviours and viewing people as a whole ("human resources") as a component of the organization (L2) as a deterministic machine (Melao 2000). Within the classical managerial models, L3 is seen as the "environment", i.e., the context where the organization (L2) operates facing exogenous, and often hostile, forces (Mintzberg 1979; Mintzberg 1996; Porter 1979; Porter 2008).

6.1 DiDIY impact on work and organization: main assumptions

Within the WP3 of our Project, we want to overcome the simplistic approach described above, and explicitly address the WP3 issues according a multi-layer research structure. Therefore, we assume that DiDIY provides the individual (L1) with the opportunity to exploit her unique competences and be the maker (the artifex) of the environment (physical and social, relational) where she works:

- within L2, seen as a network of relationships between individuals and objects rather than a deterministic machine;
- within L3, seen both as an inter-net, a network of networks where relationships are made among L2 entities (Lyytinen 2011; Grover 2012) and as a meta-network driven by the relationships among single individuals who operate in L2 entities (Menzel 2010).

However, this architecture is not meant to exploit the Tayloristic rooted extreme emphasis on specialization of work (analytical view). On the contrary, we assume that the understanding of such a complex phenomenon requires to use a multidisciplinary yet systemic view of organizational structures and processes.

Under these assumptions, the investigation of how DiDIY reshapes work and organization can be carried out as the study of the effects of DiDIY on socio-technical systems at all the levels of aggregation (L1, L2 and L3) and the study of the transformation processes that DiDIY activates.

An implication of this paradigmatic shift is of a linguistic nature, even before than of cultural and organizational nature. We assume that the semantics of the terms commonly used to define economic / social / technological the phenomena (well established in the previous "era") shall be put under question.

Some basic terms in the business jargon help highlighting this issue:

- "employee", which evocates objectification of human beings, slavery;
- "training", whose the etymology is from the Latin term "trahere", evocating the objectification of the learner;
- "management", from "manager", to handle, evocating the atom-based (vs bit-based) nature of organizations;
- "tactic" / "strategy", terms derived from the military lexicon, evocating the principle that interaction in the environment is based on conflicting relationships (rather than collaborative ones).

7. Interpreting DiDIY: from the perspective of education

For its very practical nature, DIY, and then DiDIY, has been and is used as a learning tool in education, from kindergarten to higher education. When students are making something, the object they create is a demonstration of what they have learnt to do, providing evidence of their learning. The opportunity to talk about that object, to communicate about it, to tell a story about it is a way to learn at the same time we teach others (Dougherty 2012). This learning strategy is one of the positive aspects of the maker movement to education that John Dewey, a psychologist and education reformer, called learning by doing approach (an example is: KitHub Designed to Empower Young Innovators, http://dmlcentral.net/blog/howard-rheingold/kithub-designed-empower-young-innovators]).

The basis for the use of DiDIY in education is mainly related to constructionism, which uses Piaget's theories of *constructivist* learning as a foundation (learners actively construct knowledge from their experiences in the world) but builds on that foundation by recognizing that new knowledge is constructed more effectively when the learner is engaged in making things that are personally meaningful (Resnick 1994). In Papert's constructionism the construction of knowledge happens remarkably well when students build, make, and publicly share objects (Blikstein 2013).

Constructionism is based on four pillars that represent four important dimensions that must be carefully investigated in order to better understand and improve the role of DiDIY in education.

The four pillars of constructionism are (Bers, Ponte, Juelich, Viera, Schenker 2002):

- learning by designing meaningful projects and sharing them in a community;
- manipulative objects for supporting the development of concrete ways of thinking and learning about abstract phenomena. (object to learn with);
- powerful ideas from different realms of knowledge;
- self-reflective practice; documentation is a wonderful vehicle for making self-reflection concrete and being able to share its products with others.

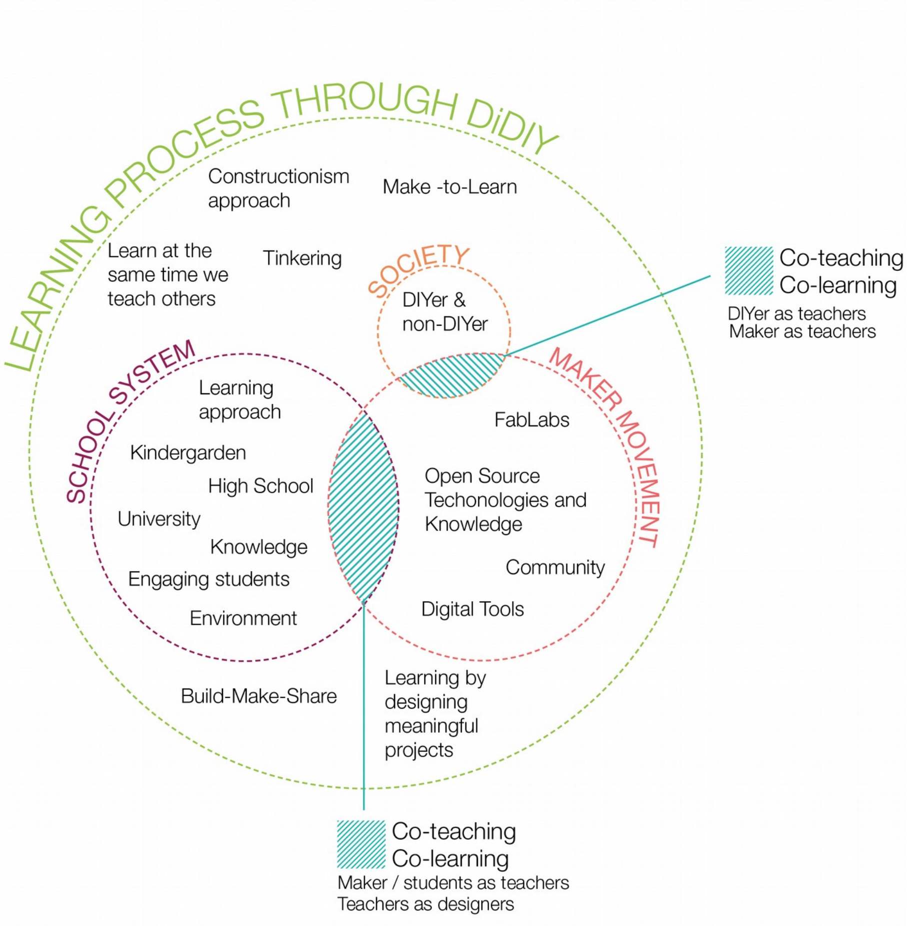
By using this approach, students are engaged in learning by applying concepts, skills, and strategies to solve real-world problems that are relevant and personally meaningful. In the process, learners engage in problem-solving, decision-making, and collaboration (Bers, Ponte, Juelich, Viera, Schenker 2002).

Although implemented primarily in community development and informal education contexts, the recent installation of FabLabs in a growing number of schools has extended the constructionist approach into formal education institutions, thereby enabling a pioneering community of children and young adults to build new literacies that help them shape their digital and physical worlds. The effective integration of DiDIY in schools has so far allowed students to follow their natural curiosity about how things work and their natural interest for making things they want or need, scaffolding them on a journey through Science, Technology, Engineering, and Math (STEM).

In FabLabs a number of critical skills necessary to succeed in the 21st century are acquired including: systems thinking, critical thinking, problem solving, analysis skills that inform an evidence-based iterative design process, communication and collaboration skills, integration of social and ethical considerations into design thinking (Janisse 2011, pp.1-2). Besides, in 1999, the United States National Research Council issued a report stating that technology was changing too fast for the "skill-based" approach to be effective and instead called for a "fluency" approach. They suggested technological education to include the development of adaptive, foundational skills in technology and computation, in particular "capabilities to empower people to manipulate the medium to their advantage and to handle unintended and unexpected problems when they arise" (National Research Council 1999).

The presence of FabLabs in schools and the exploitation of technologies such as 3D printers and related graphic software as well as electronic DIY boards such as Arduino and Raspberry Pi, allows to move towards this direction.

In this framework the Make-to-Learn effort leverages DIY culture, digital practices, and educational research to advocate for placing making, creating, and designing at the core of educational practice. The broader vision of Make-to-Learn is an educational ecosystem that incorporates these practices as a means to engage and inspire all young people towards lifelong collaborative learning, experimentation, and invention.



Finally, creativity, one of the most valued 21st century skills, is greatly about the ability to make things, whether physical or virtual, and is one of the targets of DiDIY in schools. Engendering creativity will require blurring the boundaries between disciplines and between formal and informal learning environments. To fully exploit the potentials of the use of DiDIY enabling technologies in schools, they are matched with student-to-student teaching, project-based learning, and self-centred learning environments and technology can be included into every subject and at all grade levels, which allows unprecedented levels and types of collaboration and learner to learner connectivity.

As noted by E. Yi-Luen Do, and M. Gross in their *Creativity and Cognition* paper describing environments for creativity, when students define their own problem statement, figuring out what they want or need, they are greatly motivated to engage in just-in-time learning to achieve their project goals (Do and Gross 2007, p.29). Students draw on their personal experience and needs as a primary source for creative exploration in the design environment.

On the basis of this quick overview of the foundations for the use of DiDIY for educational purposes, below are some of the its current uses.

7.1 3D printing

In general, there seem to be 2 different approaches for the use of 3D printing in education:

- 3D printer as a tool to produce things that are shown to students;
- 3D printers that are used to make students learn how to use 3D printers.

Below are some of the possible uses of 3D printing for some of the most challenging subjects at school. Interestingly, most of these uses do not entail DiDIY, as they could be done directly by teachers or exploiting ready-made 3D designs (although in many cases students are part of the creative process, and in most cases the older the students, the more DiDIY the process entails).

7.1.1 3D printing applied to school subjects

3D printing in Math. Most commonly 3D printing has been used to help students envision graphs and mathematical models. Most importantly though, 3D printing brings a "cool" factor into a subject which could normally be quite boring (cfr. the Simon Foundation video [http://www.simonsfoundation.org/multimedia/3-d-printing-of-mathematical-models] on this).

3D printing in Geography/Geology. 3D printing is an excellent way for students to better understand geological formations on a scale that is not presentable through 2-dimensional images. There are many interesting 3D printed geological forms that come to the aid of those studying geography and geology [http://andrewshears.com/2015/02/18/3d-printing-topographic-map-from-dem].

3D printing in History. History is a subject that has a lot to gain through 3D printing technology. Museums all over the globe are exploiting the potential that 3D scanning and printing can have on not only making replicas of ancient artefacts, but also backing them up and providing a more hands-on feel of them.

3D printing in Art. 3D Printing provides a brand new method of creating art. With 3D printing available in art classes around the world, our future artists will be the ones to really help the technology reach its potential in all of the different fields of art out there.

7.1.2 3D printing as a cross-cutting school subject

3D printers are gaining popularity internationally across STEM education. In many countries like the UK, Italy, France, Germany, the technology has been firstly made available to Design and Technology classrooms, where the use of 3D printers was immediately perceived as useful to curricular activities. There is considerable potential, however, for them to be used within a range of STEM subjects, particularly for cross-curricular work. The 3D printer is ideally suited to project work, where learning arises naturally as part of an investigation or construction project. Technical teachers were more familiar with this type of teaching, where pupils spend time on individual project work. In technical schools it is common for pupils to be given a design brief and be expected to make personal choices about the design, which they then test out for themselves.

This contrasts with common teaching practice in science and mathematics. Here the focus is frequently on teaching concepts discretely and in depth. Where physics and maths teachers engaged with use of the printers successfully, they did so to promote thinking, reasoning and understanding of their subject, although in schools such as the Italian *Liceo*, the lead engagement of 3D printing in the schools frequently came from the technical staff, who organised the printing for mathematics and science teachers. This allowed teachers from other STEM areas to see how their subject could make use of the printer.

7.1.3 3D printing in higher education and research

For many universities, 3D printers have become an indispensable asset for promoting learning and education. This is particularly true for students that go to universities or higher education schools that deal with creative subjects such as architecture, design, fine arts. During presentations most students have models as well as renderings to show the design process, it shows the students and professors what works structurally and what just looks good, and 3D printers are considered a regular tool in student's everyday lives. Most students come from an educational background where they learnt how to use CAD, and this makes them fully DiDIYers.

A similar case can be found at engineering universities and schools, where pupils create their 3D model of specific parts and print them to so if and how it works. At the Massachusetts Institute of Technology, for instance, students are using 3D printers in cutting edge ways that go beyond simple models. The mechanical engineering student describes 3D printers as a valuable research tool because they can help accelerate projects that would normally take time using conventional modelling methods. The technology also helps democratize processes that may be too technical for the average person when done the traditional way [http://www.engadget.com/2012/10/19/reshaping-universities-through-3d-printing].

For other subjects 3D printing is mainly used to visualize (atoms for chemistry, pathogens for biology, blood vessels or cancer cells for medicine, etc) what is too small or hard to understand. In these areas, though, at least for the time being (this could well be the only generation of students that is not proficient with 3D designing, while the next generation in most cases will), it is hard to define the use made by students as fully fledged DiDIY, as they just replicate designs made by others.

In other very innovative cases of the use of 3D printing for research purposes, again it is hard to describe them as DiDIY due to the fact that the 3D printer is used as a professional tool by professionals, such as a joint research by Harvard-MIT Health Sciences and Technologies, where 3D printing used to produce proteins and human body tissues [https://hst.mit.edu/news-and-events/events/memp-thesis-defense-mark-scott].

7.2 DIY electronics such as Arduino, Raspberry Pi, etc

Raspberry Pi and Arduino were both originally designed to be teaching tools, which is why they have become so popular, both devices being very easy to learn to use. “Programme or be programmed” is the recent rhetoric arguing for the education system to shift the curriculum balance away from generalised use and consumption of IT applications to the design and construction of IT systems, specifically to computer programming (Grover, Pea 2013). The development of several highly affordable single-board computers, such as the mentioned Raspberry Pi and Arduino, running standard operating systems and language compilers, often open source and open hardware, and capable of interfacing easily with motors and sensors, suddenly makes this eminently practical and allows schools and universities, at practically every level, to engage in authentic software tasks and projects.

In many cases, the use of DIY electronics in school is also related to the so-called “flipped classroom” a popular term and a pedagogical strategy that replaces the standard lecture-in-class format with opportunities for students to review, discuss, and investigate course content with the teacher or lecturer in class. The underlying premise is that students review lecture materials outside the classroom and then come to class prepared to participate in learning activities guided by the lecturer or teacher. Whatever the specific context, “flipping the classroom” relies heavily on technology, both popular technology and learning technology (Shrestha, Moore, Nocera 2011). The flipped classroom concept attracted considerable professional attention around 2012. Now research continues and may continue to inform subsequent developments. It represents an easy and coherent concept around which to attempt to optimise the value of personal contact between learners and teachers.

7.2.1 DIY electronics in higher education and research

The role of DIY electronics at this level is confined mainly to technical universities, and is often linked to an approach of the universities towards “open hardware, open software” [http://en.wikipedia.org/wiki/Open-source_hardware]. Within these schools, industrial projects are currently using Arduino as a prototyping platform for modular robots and many prototypes are powered by Arduino including robotic fishes, drones, quadcopters, etc. Thanks to the introduction of Arduino as learning tool, students are involved with realistic problem settings and scenarios that reflect real application prospectives. Besides, in the framework of the “open hardware, open software” movement, students are also engaged in the construction (thanks to 3D printing combined with DIY electronics) of hardware to be used in labs.

8. Interpreting DiDIY: from the perspective of creativity research and a cultural interest in making

Digital DIY is built on the foundations of the DIY ethos, and, of course, suggests particular, digitally-enhanced versions of DIY practices. Therefore this Annex considers both DIY in general, and digital DIY in particular, from the perspective of a sociological or cultural approach to making and creativity in society.

8.1 The DIY spirit

In *Making is Connecting*, Gauntlett (2011) notes that today's digital DIY practices can be seen to have roots in the ideas and writings of John Ruskin and William Morris, the English thinkers who were writing 120-160 years ago, and whose philosophy inspired the Arts and Crafts movement. These writers argued that we should foster and encourage everyday creativity, and give people tools which would enable them to share, communicate, and connect. They recognised the importance of things made by everyday, non-professional people – and the power of making, in itself – rather than a world in which people are merely consumers of stuff made by experts, professionals or factories elsewhere (Ruskin 1997; Morris 2004).

Do It Yourself ideals were more explicitly developed in the 1960s, by Alan Watts in relation to everyday life, and by John Holt in relation to education (Holt 1990, 1991). A powerful manifesto for the DIY approach was published in 1973 by Ivan Illich, *Tools for Conviviality*. For Illich – as noted in Gauntlett (2011) – the things and objects we have in our lives are significant, but there are important questions about where they came from, the role that they play, and what meanings they embody. He writes:

"People need not only to obtain things, they need above all the freedom to make things among which they can live, to give shape to them according to their own tastes, and to put them to use in caring for and about others. Prisoners in rich countries [may] have access to more things and services than members of their families, but they have no say in how things are to be made and cannot decide what to do with them. Their punishment consists in being deprived of what I shall call "conviviality." They are degraded to the status of mere consumers." (Illich 1973, p.11).

Illich's notion of 'conviviality' is therefore about having the power to shape one's own world. Illich makes it clear that individuals must retain this power – society must not seek to drain it from them. In Illich's eyes, the power to 'do it yourself' is absolutely crucial for humanity, and for the well-being of society, an irreducible core of what is necessary. As he explains,

"I consider conviviality to be individual freedom realized in personal interdependence and, as such, an intrinsic ethical value. I believe that, in any society, as conviviality is reduced below a certain level, no amount of industrial productivity can effectively satisfy the needs it creates among society's members." (Illich 1973, p.11).

Conviviality therefore also represents the joyfulness which is so easily lost when we try to organise human interests into systems and institutions. 'Do it yourself' is therefore a right of every person, and perhaps the only way to avoid the alienation of modern societies.

8.2 Digital DIY

Some DIY evangelists of the 1960s, such as Stewart Brand, later became early adopters of the Internet for convivial purposes (Turner 2006). The opportunity offered by the Internet – to connect disparate people, and give them a more-or-less free platform for the sharing of ideas – was not lost on these thinkers.

Today that notion of the Internet as a platform for creative people to connect, share and exchange, is highly familiar and is embodied in the marketing messages of vast well-known platforms such as YouTube, Kickstarter and Twitter. The significance of this mass embrace of DIY media is not just a matter of the individual pleasures associated with making and sharing, but the significance of this shift across the whole system (Gauntlett 2011). When people expect to be making culture themselves – when they assume that they will be in a "writing" or "making" mode just as much as a "reading" or "consuming" mode, it potentially makes a huge difference, not just in communication and entertainment, but in education and politics and social organisation. As Kevin Wehr notes, about DIY phenomena in general:

"At its best, DIY means that people are connecting the micro and macro levels of their lives using what C. Wright Mills called the sociological imagination (Mills 1959). DIYers are using their sociological imagination to find a solution to alienation, mystification, and loss of control." (Wehr 2012, p.57).

In the article *The internet is ancient, small steps are important, and four other theses about making things in a digital world* (included in Gauntlett 2015), David Gauntlett has set out six reasons why the digital in digital DIY is striking.

- The Internet is ancient (in other words: the Internet has affordances which connect with ancient, great aspects of humanity) (The internet forms the basis for a new set of technologies, which enable people to converse, exchange, share and trade in ways which are closer to ancient and traditional ways of interacting than the monolithic technologies of the previous century, such as television and supermarkets).
- A world with lots of interesting, creative things is always better than a world which offers a small number of popular, smartly-finished things (The really key thing about the "long tail" (Anderson 2006) is that it describes an ocean of independent amateur activity that is as big as, or bigger than, the produce of the mainstream and professional brands – and richer as well as wider, with a thousand independent ideas for every one professional message. This is a much more interesting landscape).
- People doing things because they want to is always better than people watching things because they are there (Some critics write about the exploitation of digital labour, but this is usually a category error, as it concerns work which is done not for economic reasons, but for pleasure. The desire of people making things in digital DIY is much better understood as part of a human need to shape our environment to our own needs and preferences (Illich 1973), as part of a resistance to being positioned as a consumer (Gauntlett 2011), and as a central plank of human happiness – as economist Richard Layard says, summarising piles of data on human activities and satisfactions: "Prod any happy person and you will find a project" (Layard 2006, p.73)).
- The distribution and funding possibilities of the Internet are better than the traditional models (The Internet obviously enables straightforward, potentially global distribution of

creative work, and although there is still the problem of directing attention to this material, the online world offers many ways of drawing attention to creative work, and building networks around it, or having communities talk about it. It also offers disruptive ways of funding larger-scale creative projects – notably the crowdfunding platforms such as Kickstarter and Indiegogo, which offer a striking new convergence of digital communities and physical products and experiences).

- Small steps into a changed world are better than no steps (This point emphasises the value of making things, no matter how small, for an audience, no matter how small, for the creators themselves. This leads to a recognition that "I can do this", that one can make ones own things, and that they might be appreciated by others. It is a step away from the experience of total consumerism, into a state of greater creative engagement with the world).
- The digital Internet is good, but hands-on physical things are good too (There is strong continuity between today's creative practices and those of earlier times, and between what people do in the digital realm and what they do in the physical world. People have a desire to connect the 'virtual' with the 'real', as seen in the way that the internet has driven the rise hands-on craft and maker communities; in the way that online DIY communities frequently support each other in physical life as well as virtually (Kuznetsov and Paulos 2010); in new forms of play (Gauntlett et al 2011) and learning (Gauntlett et al 2012), and in everyday life as new creative tools become available that support people to shift from the role of "consumer" to that of "designer" (Gauntlett and Thomsen 2013) – facilitated by what Gerhard Fischer describes as "a shift from consumer cultures, specialized in producing finished artefacts to be consumed passively, to cultures of participation, in which all people are provided with the means to participate and to contribute actively in personally meaningful problems" (2013, p.76)).

8.3 On Atoms-Bits Convergence

From the perspective of research of creativity as a cultural phenomenon, the convergence of digital information-sharing and communication (bits) and physical practices of making and creativity (atoms) is very exciting. However, from that perspective it is not decisively important whether it is a machine connected to a computer which does the making, or a human being interacting with (other human beings via) a computer who does the making.

The emphasis on machine-manufacture, from this perspective, is relatively spurious and oddly techno-centric. Nevertheless, we are deeply engaged with Atoms-Bits Convergence (ABC) in Digital DIY (DiDIY).

9. Interpreting DiDIY: from perspective of laws, rights and responsibilities

Some highlights on the laws, rights and responsibilities perspective to DiDIY are as follows.

- "Do it yourself" is the common term, but in reality most DIY activities can and should be seen in a larger community context: while one person can work alone to make something, that person typically builds on ideas and projects developed by groups of people. Therefore some people use also the terms "do it together" or "do it with others".
- Central in DIY communities is the aspect of sharing knowledge, so we can appreciate peers producing shared knowledge, which is what we call commons-based peer production (CBPP) [http://wiki.freeknowledge.eu/index.php/CBPP]. Commons because the knowledge is shared, it is a knowledge commons. Sometimes this shared knowledge is just about how to make something and in other cases complete design files and manufacturing instructions are shared in a commons-based form (as Free Knowledge).
- From DIY to digital DIY we introduce "digital" in the equation. Digital refers to information being coded and let us note here the particularly paradigmatic aspect of the practical zero marginal reproduction costs of digitally-coded information.
- While digital DIY can still have a broad scope, we focus on those technologies and activities where "bits become atoms" or "atoms become bits", i.e. we talk of Atoms-Bits Convergence (ABC). Looking at the conversion of bits to atoms we have digital fabrication technologies and digital actuators. In the other direction we have 3D scanners and sensor networks that "capture" aspects of the physical world and convert that into digital information (in bits).
- Costs can go down a lot, when sharing knowledge is used (and above all allowed!) to move from mass production of throwaway (cf. planned obsolescence [http://en.wikipedia.org/wiki/Planned_obsolescence]), non-repairable stuff to production at home/locally or on a different, but still "industrial/for-profit-only" scale) to production of repairable/interoperable stuff. An old style assembly line can in many cases optimise costs much more (even if you count in all the externalities) than a bunch of DIY machinery, if the goal remains to produce the same number of objects, of the same (throwaway) type, every year. But if the goal becomes production of stuff that lasts for life, that is if people stop making dishwashers and what not, with deliberately incompatible spare parts and parts that are designed to break then the cost of washing dishes with such lasting machines will become much less than those of the mass produced ones. This is about sustainability of product, household and planet.

In part we are looking at hardware projects and how people are changing their relationship to them. On one hand we can appreciate how sharing knowledge of the tools brings the overall costs down. This can be called an exodus towards the commons: proprietary knowledge and tools are "commonised" and can be accessed through the Internet without (marginal) costs, as soon (and as long) as the commons is maintained by its community. This is what we have seen with the Encyclopedia Britannica closing the press. And in so many software market segments, where mature Free Software alternatives have been made available, the market size has shrank to a tiny portion of its potential size. That is the Wealth of Networks (as is the title of Yochai Benkler's famous book on Commons-based Peer Production).

On the other hand we can appreciate how not only the knowledge is constructed as a commons, today also many design files of very sophisticated machines are becoming commons knowledge. When one of the 3D printing patents expired in 2005, Adrian Bowyer and others started to develop the RepRap, the first 3D printer that had all its design files published under a free license. Now we see a thriving RepRap community where many individuals, universities and companies have added their improvements, in such way that a considerable part of the world population can have access to this technology. In the development of electronics there is arguably even more social innovation going on. Flagship Arduino is now receiving a growing number of competing electronics projects, that also publish their hardware design files, software, manuals etc under free licenses, to enable peers to replicate, modify and improve. These are just a few well known projects, as complete pick-and-place machines that semi-automatically produce electronic circuits are being developed, robot arms, prosthesis arms, hands and legs are developed.

The bottom line is what Jeremy Rifkin argues in his recent book "The Zero Marginal Cost Society", how the communications, logistics and energy Internet of Things are boosting human productivity and reducing marginal costs of producing additional units of goods and services. As, a result, corporate profits are drying up, intellectual property rights are weakening (think patents and copyright), and the conventional notion of scarcity is giving way to the possibility of abundance. Rifkin sees a hybrid economy rising where a growing group of people peer produce a growing number of products and services collaboratively, outside the market and inside new commons-based models.

We are seeing a renewed "war on filesharing", not of software, music or movies, but this time in 3D design files (e.g., see [https://www.techdirt.com/articles/20150415/06143030661/california-bill-would-require-libraries-post-scary-warning-signs-not-to-do-infringy-stuff-with-3d-printers.shtml]). Are patents the right tool and if so, can they be enforceable, especially in the case of private non-commercial use? On the other hand, how can peers interested in building the design commons effectively share their designs, as the Free Software developer communities have done so well in the last 30 years. What policy changes do we need to allow for example small scale produced vehicles on the road?

These are significant issues to be explored.

10. Interpreting DiDIY: from the perspective of design

One of the consequences of the industrial development over the last century has been an increased distance from actual production processes and a general deterioration of people's making skills. However, to make is an option. In an era of post-industrial design we witness a renewed interest in making that extends far beyond privileged engineering labs and century long building of craftsmanship. Critical design dialogues and innovative recreations of the social and material conditions of our life worlds take place everywhere we look. From DIY clothing customization and garage build electric bikes, over communities of hacker spaces and FabLabs, to public participation in science and policy development, we see a widespread acknowledgement of the potential of making as a general human capacity. The proliferation of making, in this broad sense, poses new challenges to professional designers (Codesign Research Center at the Royal Danish Academy of Fine Arts).

The self-design and production of the DIY practice reshape the definition of professional design. The Industrial Designer Society of America (IDSA [http://www.idsa.org]) discussed the implications of DIY for designers at the 2010 conference named "DIY Design: threat or opportunity?" [http://www.idsa.org/idsa-2010-conference-diy-design] At the conference it has been acknowledged that although DIY is not a totally new phenomenon, "The implications of this shift for the design professions are potentially massive. The DIY resurgence is making consumers question the need for mass production, and by extension, the need for designers".

Actually, design theorists have been investigating the potentiality of users' involvement in the creative process for decades; with examples of projects taking place nearly regularly over the XIX century, whenever major political, societal or environmental crises occurred. In those case, such designers as William Morris, Enzo Mari, Gillo Dorfless reflected on the role of design and the possibility of involving final users in the creative process.

Brown (2008) reports "studies advocated the need for dilettante practices and user participation in design as strategies for self-representation and self-help. While these studies focused on marginal groups and post-hoc consumer interventions in a world designed by professionals, they argued for a new kind of partnership between professionals and 'users' such that designing might be conceived as providing a democratizing influence on housing provision". Brown continues highlighting the polemical discussion by Philip Pacey on the absence of non-professional design in design history, thus advocating a discussion of the relationship between professional and non-professional design. Brown explores DIY and concludes that "there remains a substantial lacuna in the debate concerning the role of professionals in communities of amateur design practice and how the role of professionals might be reconceived as a co-creative practice, supporting and expanding the horizons of the amateur designer" (Brown 2008).

10.1 Design interest in digital DIY

Design is called to identify a role to play and some designers have been investigating potential areas of intervention in contemporary DIY practice. Notably, in 2010 the designer Yves Béhar curated the exhibition "TechnoCRAFT: Hackers, Modders, Fabbers, Tweakers and Design in the Age of

Individuality", exhibited at Yerba Buena Center For the Arts [http://www.ybca.org] in San Francisco (USA). Béhar explored ways of interaction between the designer, or in other words "the different ways that consumers are personalizing design in efforts to assert creativity and individuality in an age of mass-production […] TechnoCRAFT explores how an emotional connection to objects has been resurrected in individuals and how the two realms—design and mass production—have combined to once again allow for 'Design in the Age of Individuality'" (TechnoCRAFT press release).

As Furio in an interview for the Metropolis magazine states "actually there's a new type of craft, a new type of involvement of the human and the hand in the mass-production process". For the Project we will consider "all these new ways in which people are bringing the notion of craft into design, the notion of self-made, self-crafted, self-developed products and software." These different ways are grouped by the designer into six main categories, i.e.:

- *crowdsourcing*, addressing the collective talent of the community to develop new design solutions (e.g. Threadless);
- *platforms*, consisting of designers creating open, software-based platforms, that provide the tools for individuals to create and/or customize their own unique products (e.g. Nike ID);
- *blueprints*, and in general instructions provided by the designer to let final users to create the project by themselves (e.g. Autoprogettazione by Enzo Mari);
- *hacks*, and in general modification to achieve new functionality;
- *incompletes*, leaving the user to finalise the product according to personal skills and interests (e.g. Marijn van der Poll's Do hit chair by Droog);
- *modules*, intelligently designed components that come together to create customized creations (e.g., Ronan and Erwan Bouroullec's Clouds with Kvadrat).

The six categories above identify possible strategies for design to interact with the DIYers in a direct or mediated way. Designers' outcomes are not finished products traditionally intended and typical of the mass consumption society but solutions that enable the user and allow for adaptation, also called "enabling solution" by Manzini (2006).

It can be inferred that "the dominant paradigm of user-as-consumer gives way to alternative framings of the user as creative appropriator, hacker, tinkerer, artist, and even co-designer or co-engineer" (Tanenbaum et al 2013).

Future research will explore features that design professional could use to trigger novel collaboration with final users, starting from the ones proposed by Béhar and expanding them considering the different steps of the product lifecycle in which the user can be involved, from the idea generation till the extension of the end of life. Notable areas of investigation include processes of learning, acquisition of skills, and improvement of self-confidence.

10.2 Digital DIY and materials

The spreading of contemporary DIY has been supported by the evolution of technologies and materials. Karana et al. (2014) interpret the renaissance of craftsmanship (Sennett 2008; Bean, Rosner 2012; Bardzell, Rosner, Bardzell 2012; Bettiol, Micelli 2013) as a meaningful phenomenon symbolising our time, society and daily life based on a strong integration between design, handmade and technologies processes.

This renaissance of craftsmanship is related to the new dialogues across borders opened up by the collaborations between designers and craftspeople that often bridge language boundaries with the simplicity of visuals, colours and materials (Edelkoort 2012). As Antonelli stated (2012), “the evolution in the role of technology has brought a cathartic return to the roots of making”.

Made these premises, we will investigate the emerging phenomena of DIY materials, defined like “every innovative material resulting from a (individual or collective) self-production experience and characterised by two aspects: i) the design of a new material or the modification of an existing one; ii) the material is self-produced by the designer, through techniques and processes of his/her own invention, then personally controllable” (Bianchini 2014).

We will investigate how the concept of DIY materials affects the way according to which materials are conventionally interpreted and used, expanding the boundaries of material science as a discipline. Furthermore, correlation could be made between DIY materials and the most relevant studies about materials in the field of Human Computer Interaction, in particular with the case of computational composites (Vallgårda, Redström 2007), smart material interfaces, transitive materials (Coelho 2007), open materials (Mota 2011) and material alchemy (Lee 2014). In this field the DIY approach, supported by digital technologies, is very promising for creating new solutions in materials and interactions.

11. Interpreting DiDIY: from the perspective of ethics

DiDIY will have significant ethically relevant *impact* (that will occur) and it poses significant *threats* (that might occur). Impacts and threats *directly* affect the well-being of humans and society, but DiDIY also *indirectly* has an impact on (and perhaps constitutes a threat to) the ethical norms that currently exist in European societies. So overall, we are looking at a matrix with two rows and two columns: impacts and threats, each of which are direct and indirect. This matrix re-occurs in all the main areas we have identified as major focus (organisation and work, education and research, society at large, legal systems), which is why ethics is structured in the Project as a Transversal Task, rather than as a separate Work Package.

	Impacts	Threats
Direct		
Indirect		

The study of these impacts and threats is new. It can rely on the studies that exist on the larger framework in which we operate, the changes to the 'information society', the impact of digital technology had and has information-based industries (print, music, etc.), and social science work on the DIY movement – but the impact that DiDIY will have and the threats it might have, and the fears it generates, are currently not understood. We think this is a fairly large research gap where this Project will have to lay the groundwork. Ignoring these impacts and threats would lead to very significant societal disruption and human suffering.

As far as *direct impacts* are concerned, the ability to reproduce *physical objects* precisely, atoms just like bits (Negroponte 1995), generates a number of societal challenges and ethical problems. Many of these problems are known from the ability to reproduce *information* precisely (music/sound, text, images, video): it becomes far more difficult to control distribution and use. The traditional intellectual property rights (esp. copyright) or rights to privacy and informational self-determination might still hold, but in practice they are massively undermined to an extent where they have ceased to exist in some areas. The ability to digitally reproduce objects will face all these problems e.g. objects subject to intellectual property rights (patents, design rights, etc), works of art, unique artefacts, etc. 3D bio-printing of organs raises whole new issues of 'consumer' safety and property rights (Ranaldi 2014). The direct impacts are that as a result of these developments some traditional industries and jobs will be undermined or disappear. The 3D printer itself may not bought, but printed by a 'parent' printer (RepRap Project). Electronic devices are not replaced or taken to the repair shop, but fixed in a "repair café". The weather can now be predicted by amateur groups (http://wunderground.com). Some of these industries are starting to react: the leading CAD software company Autodesk has acquired the DIY site http://instructables.com in 2011. The extreme case of digital reproduction would be the ability to reproduce anything at all on the nanoscale and below, with atomic precision, which would mean "radical abundance" (Drexler 2013) but also radical dissolution.

The major *direct threat* is that it will be much harder to control distribution and use of objects that are now legally restrained, e.g. weapons, poisons, hazardous materials, currency, synthetic biology (e.g., viruses). These threats are very real and have already started to become actual impacts, e.g. with 3D printed weapons and counterfeit money. They will acquire massive relevance with synthetic biology: if Greg Venter's and George Church's synthetic biology kit becomes reality, I can design a new flu virus strain on a computer, make it at home (DIY) and perhaps kill millions of people.

The ethical challenges generated by digital technologies are the subject of significant research but we need to expand this research to the area of DiDIY where challenges will be more severe: the technology has all the issues of traditional digital technology, plus a whole new set of very real societal threats. We propose to investigate in particular the changes it brings to organisation and work, education and research and the impact it has on society at large and legal systems. In each of these areas, we will detail the ethical challenges this techno-social change generates.

As far as the second row in the matrix of *indirect impacts* and threats are concerned, we see a technological and social development that will challenge traditional controls by questioning their ethical value. At the same time, just like in traditional DIY, the participants challenge the traditional institutions and norms that establish control and replace them with reliance on individual initiative and Commons based peer production (Wikipedia, Drupal, Arduino). Societies continuously negotiate what is ethical, what is "the right thing to do", for individuals, groups and institutions; these negotiations are dependent on changes in the societies, and influence such changes, in turn. One important driver of such changes are the technologies available because new technologies not only influence societies massively (changing socio-economic basics, jobs, social strata, gender roles, mobility, etc.) but also generate new challenges when old agreements fail because assumptions made are undermined by a technology. This has happened to who is the "mother" (with extrauterine fertilisation and loan-mothers), when to wage "war" (with nuclear bombs), who "listens" (with ubiquitous surveillance), etc.

The growing techno-social development of DiDIY will have a significant indirect impact on extant ethical norms. Again, the analogy to digital reproduction of information is useful: While traditional norms like copyright and privacy rights still hold, they are not only practically undermined, but also on the retreat in society. For many of the younger generation (the 'digital natives') the motto is just that "Information should be free" and the old norms are on the way out. Mark Zuckerberg (CEO, Facebook) said in 2010 that if he were to create Facebook then, all information would be public by default, which the NYT summarised as "The age of privacy is over" (10.1.2010). Some of this impact is a *indirect threat* to values that some of us might want to uphold, for example the value of respecting a creator and intellectual property rights.

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