D2.4 KNOWLEDGE FRAMEWORK, REVISED VERSION

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Executive summary

Deliverable D2.4, Knowledge Framework, revised version, presents the second version of a Knowledge Framework on the phenomenon that we are proposing to call “Digital Do It Yourself” (DiDIY), and is aimed at “providing a common conceptual and lexical ground to the activities performed in [the Project] by integrating the different competencies of the interdisciplinary Project team, in particular by harmonizing languages, approaches and research methodologies”, by “interpreting the DiDIY phenomenon” (from the Grant Agreement).

As such, D2.4 completes the second stage of the activities related to WP2, Creating and maintaining a shared knowledge framework on DiDIY, and takes into account and synthesizes the contributions from the activities and the outcomes of all other WPs so far.

The Knowledge Framework (KF) emphasises that DiDIY is a primarily human-centric phenomenon, rapidly evolving thanks to the widespread social availability of affordable technological tools and the growing number of DiDIYers operating in communities. The impressive quantitative growth of individuals connected through these communities further lowers the technological and psychological barriers to new entries and thus makes DiDIY increasingly attractive.

The KF is structured according to: (a) the fundamental dimensions in which human beings can be involved in DiDIY (DiDIY as cognitive process, individual practice, and group processes and the wider societal context) and (b) the components of such involvement (DiDIY as an activity and a mindset, and DiDIYers as doers, adapters, makers, and creators). This general interpretation, presented in *Section 1* together with the basic methodological hypotheses, grounds a rich conceptual structure. *Section 2* introduces the conditions considered as necessarily characterising DiDIY; then in *Section 3* several general interpretations of what DiDIY may be are presented; finally, *Section 4* assumes the focus of the four “core” Work Packages of the Project (DiDIY in organisation and work, in education and research, in creative society, and in laws, rights and responsibilities) and proposes some related interpretations.

In order to make it more explicitly and effectively understandable, this complex structure is systematically introduced through the metaphor of a building, whose structural elements (storeys, pillars, and walls) represent the several mutually interacting dimensions of the phenomenon.

In synthesis, the KF includes *contents* on DiDIY organised in a *conceptual structure*, presented by means of a *metaphor*, as follows:

Structure	**Metaphor**	**Contents**
the necessary conditions specifying what DiDIY is (Section 2)	Pillars: the yes/no condition of existence of the phenomenon: Pillars are central to the building, that cannot stand without them	DiDIY as: – a specific kind of DIY – a specific kind of activity enabled by digital tools
the interpretations of what DiDIY may be, common to	Load-bearing Walls: the more/less interpretations common to two or	DiDIY and the role of:

multiple aspects of the phenomenon and admitting a range of options (from narrow to broad interpretations) (Section 3)	more WPs: the Load-bearing Walls carry the weight of the building and are common to all Storeys	– individuals – communities – technology – design – ethics
the aspects of the way DiDIY can affect the society and the related interpretations, admitting a range of options (from narrow to broad interpretations) (Section 4)	Storeys e Internal Walls: what is specific to each WP / TT and the related interpretations: each WP corresponds to a Storey, that includes some Internal Walls	DiDIY in: – organisation and work – education and research – creative society – laws, rights and responsibilities

This version of the KF is complemented with two Annexes: *Annex 1* presents and comments some data gathered from DIY/DiDIY online communities; *Annex 2* introduces a first sketch of an ontology and a related computational model simulating the dynamics of a DIY/DiDIY community.

The building of DiDIY is under rapid and largely undirected construction. By identifying and studying those which appear today the main structural elements of DiDIY we hope to provide some guidelines useful to drive it according to a socially rational plan, as an element of the city that may become our society of knowledge.

Note on contributors

This deliverable is the result of a collaborative work, and all partners have contributed to its development.

Revision history			
Version	**Date**	**Created / modified by**	**Comments**
0.0	15/09/15	LIUC	First, incomplete draft, with some preliminary updates and extensions to the first version.
0.1	15/02/16	LIUC and all partners	Extensions. First formal distribution to TB as an online document.
0.2	29/02/16	LIUC and all partners	Extensions and fixes.
0.3	14/03/16	LIUC and all partners	Extensions and fixes.
0.4	28/03/16	LIUC and all partners	Extensions and fixes.
0.5	30/03/16	LIUC and all partners	Extensions and fixes.
1.0	31/06/15	LIUC	Approved version, submitted to the EC Participant Portal.

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1. Introduction

This Knowledge Framework (KF), on the phenomenon that we have proposed to call “Digital Do It Yourself” (DiDIY), is aimed at “providing a common conceptual and lexical ground to the activities performed in [the Project] by integrating the different competencies of the interdisciplinary Project team, in particular by harmonizing languages, approaches and research methodologies”, by “interpreting the DiDIY phenomenon”. “Multiple information and data gathering methods will be exploited to this goal. With the collaboration of all partners, a set of hypotheses and research questions on DiDIY will be formulated, to inspire and contribute driving the activities of [the Project]” and ultimately to characterise what DiDIY is, so as to provide a conceptually and methodologically grounded support to policy makers, teachers, entrepreneurs and managers, etc interested in DiDIY and its possible roles in improving schools, companies, organisations, and society.

Under the assumption that DiDIY “is an ongoing social phenomenon requiring the adoption of a diachronic perspective”, and therefore its “iterative observation in the course of Project development”, after a first version, that was delivered at Month 6 (June 2015, as deliverable D2.3), the present revised version (Month 15, March 2016, D2.4) is released, that will be followed by final version (Month 30, June 2017, D2.5), “in order to make [the KF] a shareable knowledge base” (all previous quotations are taken from the text of the Grant Agreement).

The KF builds upon the outcomes presented in the deliverables D2.1, “Options for the knowledge framework”, and D2.2, “Foundational interpretation of DiDIY”, and takes into account and synthesizes the contributions from the activities and the outcomes of all other WPs so far.

1.1 Terms and acronyms

DIY	Do It Yourself
DiDIY	Digital Do It Yourself
ABC	Atoms-Bits Convergence
IoT	Internet of Things
KF	Knowledge Framework

1.2 DiDIY as a human-centric phenomenon

Consider the following exemplary situations.

- I 3D scan an existing broken part, correct its failure in a 3D design software system, 3D print it, and make it “smart” through sensors and actuators connected to an Arduino board.
- I regularly visit Instructables (http://www.instructables.com) because I like to learn about new “making” projects but also because I like to answer questions posed by others and to support other makers. I share my own projects, I adapt projects created by others, and I inspire people with my techniques and ideas, at Ravelry (http://www.ravelry.com).

- I have an idea for a new product based on a technology that I can not develop on my own. I enter in the community of "experts", ask for help and I work to implement the software component. In the process myself and other contributors have shared iteratively the design files and software code under free licenses through an online platform so the result is available for all for replication and further development.
- Using designs downloaded from the Web, I build hardware tools that, connected to a personal computer, can be driven by it to cut, drill, etc wood, metal, plastic and set up with them a community lab where everybody can book those tools for as many hours as needed, to build or repair furniture, car parts, toys, appliances, etc.
- I am a teacher and, together with some colleagues, I make a web platform where we collect some tools for a new educational approach. It is a dynamic platform where other teachers, and people, can download materials and upload new tools and experiences.
- A group of educators using Raspberry Pi discuss in an online forum the pros/cons of using it in K12 classes, and they come up quickly to a complete requirement analysis. Based on this analysis, a new version of RP is developed.
- I am a member of a local makerspace and really enjoy socialising and learning new skills through creative making. I find that this community making resource helps me to get together with my community.

Despite their differences, these situations share the feature that many people today can afford to use (and then sometimes to buy, always to learn how to use) digital tools to do something themselves, sometimes alone and more often in social, traditional or online, contexts. While the Do It Yourself (DIY) phenomenon is surely not new (the origin of DIY could be traced back to the beginning of the organisation of work), the widespread availability, versatility, and flexibility of digital tools are generating something new, with the potentiality of a game changer (Annex 1 presents some data showing the growing social diffusion of DIY and its technologically-enabled versions). We have proposed to call this phenomenon Digital Do It Yourself (DiDIY).

1.2.1 The dimensions of involvement of human beings in DiDIY

By focusing on the human-centric nature of the phenomenon, multiple facets of the human beings involved in DiDIY have to be taken into account. DiDIY operates on, and in the interactions between, a number of levels of human activity. From the inner, less visible, cognitive and tacit processes that concern individuals to the outer, more evident and articulated interactions with other people and between groups of people. DiDIY outcomes are the result of the interplay of these dimensions (see Figure 1):

- *cognitive process*: DiDIY is a process intended to generate an outcome through multiple steps from idea generation to product realization; this involves such cognitive competences as creativity, critical thinking and problem solving;
- *individual practice*: DiDIY is a practice, requiring forms of bodily activity, things and tools, states of emotion and motivational knowledge; this involves intrapersonal competences such as intrinsic motivation, self-development and self-management;
- *social phenomenon*: DiDIY is a phenomenon resulting from the interaction between people at different levels of skills and commitment, sharing resources and collaborating on projects,

and encouraging a sense of creative agency and participation in the world; this involves interpersonal competences such as communicating and collaborating, emotional literacy, peer support, adaptability and flexibility, community engagement, and system thinking.

In parallel to these dimensions, the 'yourself' in DiDIY is originally an individual, but the widespread availability of networked digital information processors and the interest to share knowledge have created new options of DiDIY, in which the yourself can be a group, a class, a community of practice, a company, an industrial cluster, the society as such. The collaboration is set up not only in face-to-face situations but also through:

- *transmission networks* (from the Internet to the Internet of Things), that enable
- *communication and design networks* (sharing digitally coded information on texts, music, images and videos, geo-localization of objects, shapes of objects, ...), that enable
- *collaboration networks* (thus intended as social, technologically-enabled systems).

Such networks are thus the effective enablers that make DiDIY not only a cognitive process or an individual practice but also an important social phenomenon.

1.2.2 The components of involvement of human beings in DiDIY

Given the human-centric nature of the phenomenon, individual motivations and abilities strongly influence the way each DiDIY practitioner operates in different contexts: less motivated or skilled practitioners may feel satisfied by simply replicating or customising a ready-made product, while more motivated and skilled ones may strive to create something new.

Hence DiDIY is neither a purely technological phenomenon nor a purely psychological or sociological one, even though it includes both technological, psychological, and sociological components. A fundamental tension is present in (DIY and) DiDIY, as something that someone:

- *does*: an activity to create, modify or maintain objects or services; in this sense, (DIY and) DiDIY can be studied, understood, and promoted in terms of tools, products, structure of collaborations, etc; this is the object-related component of the phenomenon;
- *has*: a mindset, and then a producing and consuming culture; in this sense, (DIY and) DiDIY can be studied, understood, and promoted in terms of motivations, competences, social contexts, etc.; this is the subject-related side of the phenomenon.

Both components focus on DiDIY as a human-centric phenomenon where:

- the component of DiDIY *as an activity* is the condition that allows us to consider as a DiDIY practitioner also an individual who engages in DiDIY for necessity rather than for personal interests, i.e., a reluctant DiDIYer; this guarantees that the phenomenon can be analysed in terms of social, economic, and technological conditions, dynamics, and consequences;
- the component of DiDIY *as a mindset* is the condition that allows us to consider as a DiDIY practitioner also an individual who is drawn to DiDIY in virtue of their interests, but whose personal circumstances do not contingently allow them to engage in that kind of activity, i.e., an inactive DiDIYer; this guarantees that the phenomenon can be analysed in terms of motivations, competences, and skills.

The co-presence of *object-related* and *subject-related* components is a basic reason for the complexity of the phenomenon, particularly in the longitudinal perspective of a person. Indeed DiDIY usually:

- *originates as an activity* – for example, someone has to fix something and they decide to do it themselves, even though they never did anything like that before, because they suppose that what has to be done is not that lengthy and hard — and later on this
- *turns into a mindset* – they discover that doing this themselves has been effective, rewarding, etc, and then begin doing other things themselves, thus further developing their skills and attitudes.

Sometimes the same happens in education: students start from an assigned activity, which for them at the beginning is just a task to be completed, and progressively some of them develop a mindset transferring the concept to other learning activities.

In a more refined interpretation of this dynamic, once a person overcomes the state of passive user/consumer in a given context, they may progressively upgrade their degree of involvement in DiDIY (adapted from Sanders 2006) so to become:

- *doer*, who operates to accomplish something through productive activity with minimal amount of interest and skills (doers are then reluctant DiDIYers);
- *adapter*, who operates to make something one's own by changing it in some way, with the interest to personalise the object so that it better fits their personality or contextual constraints;
- *maker*, who aims at creating something that did not exist before, with a genuine interest in the practice as well as the experience;
- *creator*, who operates to express themselves or to innovate, fuelled by passion and guided by a high level of experience, and relying on the use of raw materials and the absence of predetermined patterns.

Table 1 – Levels of creativity as means to interpret the engagement of DiDIYers in the practice (adapted from Sanders 2006).

Level of creativity	**Motivations**	**Requirements**
Doer	To get something done / to be productive	Minimal interest Minimal domain experience
Adapter	To make something on my own	Some interest Some domain expertise
Maker	To make something with my own hands	Genuine interest Domain experience
Creator	To express my creativity	Passion Domain expertise

Although with different levels of interest and commitment to the practice, people in this relatively wide range of involvement degree will contribute to the establishment and development of DiDIY

in time and space. Therefore, even apparently less significant activities carried on by doers foster the spreading of the DiDIY phenomenon.

This mutual relation of the two components – sometimes DiDIY-as-activity develops DiDIY-as-mindset, and sometimes DiDIY-as-mindset develops DiDIY-as-activity – can then activate a positive (self-reinforcing) feedback process, thus progressively transforming DiDIY into a socio-technical phenomenon.

1.3 Methodological assumptions

DiDIY is proving to be a complex, multifarious, dynamic, and still evolving phenomenon, and at least at the moment a definitive criterion can hardly be given to establish what DiDIY is and what it is not, and more concretely, in front of a given candidate situation, whether it is a case of DiDIY or not. Nevertheless, the concept is not empty, nor just subjective or contextual. This KF provides a well-grounded and at the same time flexible foundation to the several perspectives developed by the four Project "core" WPs – (i) DiDIY reshaping organisation and work, and (ii) education and research; (iii) DiDIY impacting on creative society, and (iv) on laws, rights and responsibilities – and aims at making them convergent toward a consistent and encompassing interpretation of the phenomenon.

This endeavour is also supported by (i) the analysis of some data, gathered from DIY/DiDIY online communities that witness the complexity of the phenomenon, and (ii) a first sketch of an ontology and a related computational model that simulates the dynamics of a DIY/DiDIY community. Both real and simulated data are exploited to validate the interpretive hypotheses formulated in the research and to provide insights toward new hypotheses.

In this perspective the KF is the shared context for the Project to develop:

- a *descriptive* model, in which DiDIY is presented according to its main structural features: the descriptive model is developed along the Project life cycle by all "core" WPs and is progressively synthesised in the subsequent versions of the KF;
- an *explanatory* model, in which, building on the descriptive model, DiDIY is interpreted according to some hypotheses on its determinants: the explanatory model is developed with the contribution of all "core" WPs and will be structured in the integrative model(s) produced in WP7, and possibly also synthesised in the final version of the KF;
- a *prescriptive* model, in which, building on the descriptive and the explanatory models, DiDIY is proposed as a tool to promote given social objectives and some guidelines for policy makers are suggested accordingly: the prescriptive model is the final outcome of the whole Project and will be presented in particular in the deliverable D7.4, DiDIY-related policy recommendations.

Acknowledging the observed spatial (synchronic, cross-sectional) and temporal (diachronic, longitudinal) complexity of the phenomenon under consideration (DiDIY is not identical in different geographic areas and social contexts and is changing over time), in structuring the KF *openness is preferred to specificity*. The KF is indeed expected to be:

- *encompassing*, so as to allow the consideration, comparison and – where considered appropriate – integration of multiple interpretations;

- *adaptive*, so as to allow the modification of its structural elements and of its contents in case new perspectives emerge or the phenomenon itself changes.

As a consequence, DiDIY is not formally defined in the KF, and therefore no clear-cut criteria are proposed here to decide whether something is a case of DiDIY or not. Nevertheless, the KF provides an interpretation of what DiDIY *is* in terms of (at least loosely intended) necessary conditions for DiDIY, which of course are not claimed to be also sufficient. Instead of sufficient conditions, the KF proposes then several interpretations of what DiDIY *may be*, each of them presented as a potentially continuum of options:

- *from a narrower view*, assumed as identifying non controversial, canonical cases of DiDIY,
- *to a broader view*, enabling us to include in the analysis also borderline cases that might be accepted as DiDIY only by someone in some contexts.

The conceptual structure upon which the KF is built aims thus at providing a characterisation of the DiDIY phenomenon, that allows us to study it and to better understand it, rather than providing its mere definition. To this end, a structure is defined to set boundaries and to highlight declinations. This structure enables the integration and interpretation of data and information deriving from DiDIY experiences (practices, activities, projects, experiments, etc) and research (methods, approaches, case studies, etc) collected over the Project development, and will drive the development of a roadmap and guidelines intended to support phenomena resulting at the core of our model and to drive the peripheral ones – yet innovative – towards the core.

1.4 A metaphoric interpretation: DiDIY as a building

The previously mentioned observed complexity of DiDIY implies that an interpretative framework on DiDIY which can be sufficiently analytical must be multidimensional, and therefore complex in turn. In order to make this KF more effectively understandable, we present here DiDIY by means of a metaphor, as a multiple Storey (i.e., aspects of interpretation) building whose structural elements are:

- *Pillars*, i.e., the necessary conditions specifying what DiDIY is and without which the whole building would collapse and disappear;
- *Load-bearing Walls*, i.e., the interpretations of what DiDIY may be, common to multiple aspects of the phenomenon and admitting a range of options: the building has Load-bearing Walls that carry the weight of the building and are common to all Storeys;
- *Storeys* and *Internal Walls*, i.e., the aspects of the way DiDIY can affect the society and the related interpretations, admitting a range of options: each WP of the Project corresponds to a Storey, that includes some Internal Walls, i.e., specific interpretations of what DiDIY may be.

Table 2 – Synthesis of the metaphoric elements used to present the KF structure and their interpretation.

Element of the metaphor	**Interpretation in the phenomenon**
Building	The phenomenon of Digital Do It Yourself
Pillar	A yes/no condition of existence of the phenomenon
Load-bearing Wall	A more/less interpretation of the phenomenon, common to two or more WPs
Storey	An aspect of the way DiDIY can affect the society
Internal Wall	A more/less interpretation of the phenomenon, specific to a WP

Such a building is under rapid and largely undirected construction. By identifying and studying those which appear today its main structural elements we hope to provide some guidelines useful to design it according to a socially rational plan, as an element of the city that may become our society of knowledge.

1.4.1 Pillars

Each Pillar provides a fundamental shared interpretation of what DiDIY is – a condition claimed to necessarily characterise DiDIY. The Pillars are intended to be the fundamental features of DiDIY, and as such they are common to all WP-related perspectives and independent of any WP-related specificity. The two Pillars that have been identified are presented and commented in the KF.

1.4.2 Load-bearing and Internal Walls

Each Load-bearing or Internal Wall provides an interpretation of what DiDIY may be, thus enriching the information on DiDIY according to specific features. Each Wall admits a multiplicity of options, thus explicitly acknowledging that DiDIY is currently a fuzzy (more-or-less) rather than a crisp (yes-or-no) phenomenon. To make this clearer, all Walls are introduced with the same formal structure:

> "in a narrower view DiDIY..., while in a broader view…"

where there is a tension between the narrower and the broader view, based on the provisional hypothesis that the narrower view *is non-controversially acknowledged as DiDIY* (and maybe even "stereotypically DiDIY"), whereas the broader view *might be accepted as DiDIY* only by someone in some contexts (possibly, also depending on market conditions, legislation, etc).

From the narrower to the broader view there is then a potentially continuum of options, that attempt:

- to contribute to a *shared core interpretation* of DiDIY ("when we talk and research about DiDIY we plausibly intend at least..."), in reference to the narrower view for each Wall and thus by complementing the specifications provided by the Pillars, and

- to obtain a *flexible concept system*, that admits and allows us to study multiple positions ("when we talk and research about DiDIY we might also intend..."), in reference to the broader view for each Wall.

In this context the distinction between Load-bearing and Internal Walls relates to the their generality in the structure and therefore to their degree of influence in the phenomenon:

- each Load-bearing Wall represents an interpretation *that is common to multiple aspects* identified as relevant of the phenomenon;
- each Internal Wall represents instead an interpretation that is *specific to one of such aspects*.

1.4.3 Storeys

Each Storey of the building represents an aspect of the way DiDIY can affect the society, as interpreted in the perspective provided by one of the "core" WPs of our Project, i.e.,

- *organisation and work*, as reshaped by DiDIY;
- *education and research*, as reshaped by DiDIY;
- *creative society*, as impacted by DiDIY;
- *laws, rights and responsibilities*, as impacted by DiDIY.

1.5 In synthesis

As also highlighted by the metaphor of DiDIY of a building under construction, with its several structural elements, we are proposing here a sophisticated, analytical structure, aimed at providing a formal context in which multiple perspectives on the phenomenon can be hosted. DiDIY emerges as a socio-technical phenomenon, whose features can have significant mutual correlations worth specific explorations and analyses.

While introduced in this second version of the KF, this structure will be progressively refined and filled toward the third, final version of the KF.

2. Pillars

P1. DiDIY as a specific kind of DIY

DIY is a phenomenon that started well before DiDIY, so that the hypothesis that DiDIY is a specific kind of DIY (i.e., every case of DiDIY is also a case of DIY, but there are cases of DIY that are not cases of DiDIY) implies that:

- everything that generally characterizes DIY also applies to DiDIY, so that the existing studies on DIY are useful also to understand DiDIY, but at the same time;
- not everything that specifically characterizes DiDIY also applies to DIY, so that new studies on DiDIY are useful to better understand it.

In synthesis, DIY is 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, that can be understood (Watson, Shove 2008) through the interpretation of the practice in terms of:

- *materials*, i.e., tangible resources required to accomplish the process;
- *competences*, i.e., capabilities and skills required or involved in the accomplishment of the process, typically to use the materials components mentioned above;
- *meanings*, i.e., individual and possibly collective motivations for accomplishing DIY.

Addressing how these elements and their complex mutual relationships apply to DiDIY is fundamental to achieve a specific characterisation of it.

The whole Section 4, On DIY, of the deliverable D2.2, Foundational interpretation of DiDIY, is devoted to introducing and exploring DIY as the context of DiDIY.

P2. DiDIY as a specific kind of activity enabled by digital tools

Digital tools spread in our society well before their actual use in DiDIY, so that the hypothesis that DiDIY is a specific kind of activity enabled by digital tools (i.e., every case of DiDIY is also a case of use of digital tools, but there are cases of use of digital tools that are not cases of DiDIY) implies that:

- everything that generally characterizes the use of digital tools also applies to DiDIY, so that the existing studies on this use are useful also to understand DiDIY, but at the same time;
- not everything that specifically characterizes DiDIY also applies to the use of digital tools, so that new studies on DiDIY are useful to better understand it.

In synthesis, digital tools provide us with flexible and efficient options to operate on information, and can be understood in terms of:

- *software*, for operating in virtual worlds and then opening new opportunities for creative people;
- *internet*, for efficiently transmitting information and then opening new opportunities for open communication and collaboration;
- *physical computing*, for interacting with physical objects through information and then opening new opportunities for the scenario that we have called “Atoms-Bits Convergence”, the new ABC.

The whole Section 3, On digital, of the deliverable D2.2, Foundational interpretation of DiDIY, is devoted to introducing and exploring the use of digital tools as the context of DiDIY.

3. Load-bearing Walls

3.1 DiDIY and the role of individuals

LW1. DiDIY and individual motivations

In a narrower view DiDIY involves individuals who operate on the basis of an ethical principle, while in a broader view it includes all people who choose to engage in the practice of DiDIY independently of their individual motivations.

The possible motivations that move an individual toward DiDIY are many and different, and may be related to ethical principles (e.g., concern for the environment), but also to a desire to save money, develop new skills, acquire social reputation, generate profits, etc.

Some research questions

- What are the specific motivations driving DiDIYers (whether casual or regular practitioners), and which ones should be viewed as the most important forces behind the spread of DiDIY, both today and for the foreseeable future?
- Is there any significant correlation between the specific motivations driving DiDIYers and the way they operate (e.g., their collaboration attitude, the tools they use, etc)?

LW2. DiDIY and the relations between producers and consumers

In a narrower view DiDIY involves individuals who are both producers and users/consumers of the produced items, while in a broader view it relates also to cases in which these two roles remain separate, such as hobbyists occasionally selling 3D printed items to others.

As both an activity and a mindset, DiDIY further blurs the distinction between producers and consumers that is already a characteristic of DIY, leading to the concept of a “prosumer” (Toffler 1980): a person who combines the roles of producer and consumer with regard to one and the same product.

Some research questions

- What are the main conditions that enable prosumers to create value for the context (group, company, society) in which they operate?
- What is the likely impact of DiDIY on the class of producers (e.g., retailers) and on modes of consumption? To what extent will prosumers and hobbyist producers take over the roles played by commercial producers, and how will the latter have to evolve to adapt to this new state of affairs?

LW3. DiDIY and critical thinking

In a narrower view DiDIY is a means for fostering critical thinking, while in a broader view it is done by individuals who may not necessarily use such competence on a deep level.

Critical thinking allows people to make effective analyses, inferences, evaluations, reasoned decisions and to take purposeful action. This skill is important namely for students to deeply understand academic content and for workers to think about how to continuously improve products, processes or services.

Some research questions

- Which are the dynamics triggering critical thinking in DiDIY?
- How critical thinking can be fostered in DiDIY and transferred from here to other domains and practices?

DiDIY and the role of communities

LW4. DiDIY and collaboration

In a narrower view DiDIY is about activities carried out collaboration (the plural form of "you", also known as "Do It With Others", DIWO, or "Do It Together", DIT) and transdisciplinarity, while in a broader view it is about activities carried out by one person (the "yourself").

By taking a helicopter view, one can find almost always some form of collaboration, as even the individual maker builds on previous knowledge produced by others. The individual can be seen as standing on the shoulders of giants: building on collective works produced and shared within (online) communities, typically by many others.

Some research questions

- Is the ability to manage collaboration a strategic dimension of DiDIY? And in particular how do DiDIY collective actions influence the sense of ownership, personal involvement, motivation and satisfaction?
- How do co-design tools influence the way people construct new meanings on DiDIY?
- Might co-design be both a valuable research approach used to investigate DiDIY and a valuable method to be used by non-designers in DiDIY activities independently? And would implementing co-design in collective DiDIY activities increment creativity and therefore innovation?

LW5. DiDIY and open communities and releases

In a narrower view DiDIY is about openly sharing knowledge in communities and openly released outcomes, while in a broader view it is also of individuals operating alone and about outcomes that are maintained proprietary.

The legal rights under which the digital files are shared determine the affordances that users in these communities have, and thus their possibilities to use, reuse, share, adapt and become economically sustainable. Liberal licensing schemes like free and open licensing are typical in online design

sharing platforms, as they convey the maximum freedom or rights to their peers (for an overview of online design sharing platforms in the context of DiDIY, see http://wiki.freeknowledge.eu/index.php/Design_Sharing_Platforms).

Some research questions

- What are the main (cultural, psychological, etc) factors hindering from openly sharing DiDIY-related knowledge in communities, and how can the attitude to open sharing be promoted?
- What motivations do participants have to openly share knowledge in communities and what incentives could be helpful to facilitate the change from knowledge hoarding towards openly sharing?

LW6. DiDIY and free or open access policies

In a narrower view DiDIY is associated with opening the source of personal projects with a specific and specified use and redistribution license and enabling collaboration through communities offering distributed revision control, while in a broader view it is associated with the informal sharing of a project, or just its outcomes, to an online community or social network, leaving the access policy just undefined.

The effectiveness of DiDIY through transmission → communication → collaboration networks has been emphasized and accelerated by the availability of free or open access policies:

– at the transmission level, the protocols of the TCP/IP stack, that constitute the technical foundation of the Internet, are freely licensed and open by design;

– at the communication and design level, both digital, machine-ready designs and the documentation needed to learn how to produce, modify, and use them can be freely shared, sometimes in open formats, that can be processed with free of charge, low-cost software of third parties, accessible to everybody with a computer, not just with expensive applications by the inventor and sole “controller” of the file format;

– at the collaboration level, projects can be developed, shared and reused quickly, without paying royalties and/or going through complicated, expensive legal/bureaucratic procedures, or generally asking for permission, and at global scale in the logic of open collaboration and innovation (open source communities, IPR management via Creative Commons licensing, etc).

Some research questions

- What are the main opportunities and the main threats in DiDIY when performed according to free or open access policies?

DiDIY and the role of technology

LW7. DiDIY and outcomes

In a narrower view DiDIY is aimed at producing physical artefacts, while in a broader view it is also aimed at creating intangibles and performing services.

This has fundamentally to do with the role of the digital in DIY, as the means to integrate physical and informational components ("atoms" and "bits") of entities, a situation that we have proposed to call "Atoms-Bits Convergence" (ABC). While there is not a principled necessity that ABC is the only significant component of DiDIY, ABC has several important consequences, in particular by making it possible:

– to transfer, store, and process manufacturing instructions without any practical degradation in the final product, thus in many cases guaranteeing the complete replicability of the results even if multiple individuals are involved in the process of design and manufacturing, as in the case of objects produced by 3D printers from 3D CAD data files;

– to create distributed processing and control systems, in which the components can automatically acquire information from their physical environment and exploit it to contextually operate in order to modify the environment, as in the case of 'smart objects', possibly as parts of Internet of Things systems;

– to produce objects even if the producers are unable to operate functionally equivalent non-digital tools, due to distance (the tools are somewhere else), lack of manual skills (the designer can make a 3D drawing on a computer but might be unable to use a chisel, maybe because of a physical disability), etc.

Some research questions

- What are the roles of digital tools in DiDIY, and how can they be exploited to make DiDIY more effective or efficient?

LW8. DiDIY and state-of-the-art technologies

In a narrower view DiDIY is associated with state-of-the-art technological tools, while in a broader view it is performed also with traditional, well-established tools.

This aims at exploring whether there is some significant reasons for assuming that DiDIY is related to innovative tools or they are only attractors. An example somewhere in the middle is that of BetterPress Lab, a group of Italian female makers based in Rome www.betterpresslab.com. They use traditional typography, employing old movable type to create old looking or vintage posters. In many cases they use a 3D scanners and printers to re-create movable types of some letters that had been lost or broken over the years.

Some research questions

- What are the tools currently and mostly used by DiDIYers? Which ones do they consider innovative or state-of-the-art technologies?
- What is the actual role that DiDIYers attribute to state-of-the-art technological tools? Is the being state-of-the-art a significant reason for making DiDIY attractive or is it just an extrinsic element?
- How do the current technologies change the way DiDIY is carried out with respect to the past (e.g., required skills, possibility for collaboration and sharing)?

LW9. DiDIY and cheap resources

In a narrower view DiDIY involves the use of affordable tools and materials in principle available to every individual "maker", while in a broader view it can also involve more hi-tech and expensive methods of making things, also in collaboration with commercial services.

The software and hardware tools exploited in DiDIY are often very cheap, and often also free and open-source (as illustrated for instance by modelling software like Blender, or hardware like the RepRap 3D printer), thus in principle widely affordable. On the other hand, thanks to online 3D printing services like Sculpteo, people are now gaining access to hi-tech manufacturing methods like "CLIP" (Continuous Liquid Interface Production) 3D printing with which to turn their digital designs into reality.

Some research questions

- To what extent can DiDIY help democratize access, thanks to significantly lowered costs, to products and modes of manufacturing that would otherwise have been reserved to the wealthy?

DiDIY and the role of design

LW10. DiDIY and co-design process

In a narrower view DiDIY involves individuals who are co-creators of what they produce, from idea generation to final outcome implementation, while in a broader view it includes also those who are simply users of the outcomes of creative process, made by professional possibly with other co-creators.

What essentially characterizes co-design is the involvement of non-designers in collaborative activities: collaboration is then a key element of the process and knowledge is produced and shared as a collective action. Making is at the heart of co-design as it is of other design disciplines: "one key ingredient of the designerly ways of doing research is that they involve creative acts of making. These acts of making are not just a performative act of reproduction, but a creative act which involves construction and transformation of meaning" (Sanders, Stappers 2014). As Sanders and Stappers state, "methods and tools for making give people – designers and non-designers – the ability to make 'things' that describe future objects, concerns or opportunities".

Hence, two dimensions embedded in co-design enable DiDIY: (i) the social and rational idea of democracy setting the conditions for proper and legitimate people participation, and (ii) the importance of eliciting participants' tacit knowledge (not just their formal and explicit competencies, but those practical and diverse skills that are fundamental to collective making). In this view collaboration through co-design might be seen as a collaborative process to implement the practices of DiDIY.

In a narrow view, laypeople can be involved in the creative process as co-creators of what they need, using their creativity and being involved in the whole creative process, from idea generation to final outcome implementation. However, not everyone is interested or available for such a full commitment. Hence, on a broader view DiDIYers can be participant or simply users of the outcomes of creative process, made by professional possibly with other co-creators.

Some research questions

- How can DiDIYers be involved and encouraged to participate in co-design processes? Which are the motivations or dynamics that can work as levers for such engagement?
- How can design contribute to the work and creativity of DiDIYers? Can professional designers develop tools enabling DiDIYers in the optimization of their practice?

DiDIY and the role of ethics

LW11. DiDIY and ethical values practised

In a narrower view DiDIY simply refers to a new approach to making things, while in a broader view it also involves a set of ethical values and convictions that tend to prevail among practitioners of DiDIY and to govern their activities.

When observing the core values behind the characteristics of DiDIY we can extract the following: (i) the value of sharing and helping others (solidarity), (ii) the reputation economy (trust, transparency, demonstration of skills), (iii) equal rights of access and participation (equity), and (iv) participants do not need to obtain permission (free-as-in-freedom, autonomy). These values may not be necessarily shared by all, but they can be seen as present in most if not all of the DiDIY communities.

Some research questions

- Which are the core ethical values behind typical DiDIY practices? How are these values conflicting or in sync with mainstream values? How do they relate to legal systems?

LW12. DiDIY and Intellectual Property Rights

In a narrower view DiDIY is about sharing designs, instructions and documentation under non-exclusive conditions, while in a broader view it can also include exclusively controlled forms of knowledge.

DiDIY may be specifically about sharing designs, instructions and documentation under non-exclusive conditions, even though the current Intellectual Property Rights (IPR) legislation tends to restrict this kind of sharing by default (e.g., copyright is granted as all rights reserved by default). In this sense, the IPR system is the first one being challenged by DiDIY practices. And not necessarily by infringing exclusive rights in patents or copyright, but by questioning the foundation of IPR itself. IPR is based on the hypothesis that creators and inventors need to have exclusive control over their works. The open sharing under free licenses of software, hardware design, documentation and instructions has shown that exclusive control over a developer's work is not a necessary condition for such works to be created (and in abundance). In a broader view, however, DiDIY can also include exclusively controlled forms of knowledge, including the use of patented tools and designs or documentation that can be used for only certain practices of DiDIY.

Some research questions

- If digital innovation is shown to work without exclusive IP rights, including in the context of DiDIY (e.g., open source modelling software or 3D printers like the RepRap printer), should non-exclusive sharing practices be strengthened in our legal systems?
- What main legal obstacles currently exist towards the practice of DiDIY and what changes could be proposed?

LW13. DiDIY and sustainability

In a narrower view DiDIY simply describes a new set of methods for designing and manufacturing things in a "DIY" spirit, while in a broader view it also introduces the goal of promoting the long-term sustainability of our practices.

DiDIY has complex relations with sustainability (see, e.g., the considerations of Rifkin (2013 and 2014)): it is typically based on small-scale technologies, with limited efficiency and low repeatability, and occasionally relies on materials that are not optimal from an environmental point of view (e.g., non-recyclable plastics). But on the other hand, it may help save items otherwise discarded (thereby countering planned obsolescence), reduce waste and the purchase of new items, and develop new skills.

Some research questions

- How can DiDIY help contribute to more sustainable practices when it comes to design, production and consumption? In this context, what is the role of DiDIY manufacturing as contrasted with other forms of DiDIY, e.g. related to the Internet of Things?

LW14. DiDIY and social risk

In a narrower view DiDIY offers a new way for people to make the things they need for everyday life and to exercise their creativity, while in a broader view it can also include the creation of dangerous materials such as weapons and viruses that would present real risks for society.

DiDIY has short, medium and long term risks for society. The experience that the flow of digital information is difficult or even impossible to control suggests that the control of physical systems generated through digitally driven DIY will be equally difficult. Control of intellectual property rights (design, copyright, trademark, patents, etc) and dangerous materials (weapons, some of which might be undetectable by current security systems; and chemicals, drugs, microbes, viruses, nanoscale materials, etc) will thus be a challenge or - in the former case at least - perhaps needs to be given up.

Some research questions

- Assuming it is desirable to exercise some control over the circulation of DiDIY weapons, should this be done by regulating the possession of digital blueprints for their manufacture? Or should we rather focus on alternative solutions, such as controlling some of their components, such as gun powder? Would self-registration (as is being introduced in the area of DiDIY Drones) be a reasonably effective measure?
- Can the spread of "distributed manufacturing" as a correlate of DiDIY contribute to negative social developments like technological unemployment (by rendering some links in the

supply chain superfluous), and should we take regulatory steps to counter this - and if so, which ones? Or will the net social impact of DiDIY be overall positive?

LW15. DIDIY, ethical responsibility, and duties of care

In a narrower view DiDIY only requires us to ask how society should regulate the practices of the "maker" community (what should it permit/forbid), while in a broader view it also forces the makers themselves to think about the duties of care that they have towards the consumers of their products.

It is generally taken for granted that commercial manufacturers have certain duties of care towards those who consume their products, duties that can for example provide the basis for a negligence lawsuit in cases where a defective product results in injury to the consumer. However, there is less consensus regarding the extent to which hobbyists who engage in DIY practices are ethically responsible for the harm that the products they create might cause, and have an obligation to do their best to prevent harm to those who might use these products. The advent of DiDIY highlights the need for more careful reflection on such issues.

Some research questions

- Does DiDIY change the nature of the duties and responsibilities that makers have when creating new products, and if so, how exactly? Do we need new mechanisms (e.g., regulatory) to ensure that these duties are fulfilled, or can relatively simple technological solutions (e.g., software that scans and automatically corrects the flaws in a digital design) offer sufficient guarantees in this context?

4. Storeys and Internal Walls

DiDIY in organisation and work

IW1. DiDIY and organisation

In a narrower view DiDIY is related to individuals, while in a broader view the 'self' in 'yourself' is also an organisational entity of any size, with strong organisational ties (e.g. a firm, a formal network of enterprises) or weaker organisational ties (e.g., a community of practitioners, a cluster).

Makers' communities (as a type of communities of DiDIYers) are typically organised around voluntary contribution to a commons-based digital resource or set of resources, that can be distributed and reused by anyone free of charge, and generally under free or open licenses (this is called Commons-based Peer Production (CBPP), a term first introduced by Harvard Law School professor Yochai Benkler (Benkler 2002) and greatly expanded in 2006, in his book Wealth of Networks).

Some research questions

- How will the work of a workman in a manufacturing firm be reshaped due to the influence of DiDIY? How will it change in relation with the evolution of other organisational roles in their firm?
- How will the work of a knowledge worker be reshaped due to the influence of DiDIY? How will it change in relation with the evolution of other organisational roles in their firm?
- How will the work of the Chief Information Officer (CIO) be reshaped due to the influence of DiDIY? How will it change in relation, in particular, with the related evolution of other CxO roles? And more generally: which organisational roles are most likely to disappear, and which will be most likely created, due to the influence of DiDIY?
- Do DiDIYers cluster? What are the factors enabling single DiDIYers get together and create teams to design and develop innovative digital products (e.g., robots)?
- How do collaborative innovation networks among DiDIYers foster cluster initiatives? How can DiDIY-related entrepreneurial ecosystems transform in cluster initiatives?
- What are the factors enabling small or medium-sized enterprises to evolve from single-player subcontractors into components of a DiDIY-like cluster, competing with large companies?

IW2. DiDIY and work

In a narrower view DiDIY is related to activities carried out by individuals, while in a broader view we can assume that the 'self' in 'yourself' is also an organisational entity of any size, thus DiDIY is

related to activities in organizations with strong ties (e.g. a firm, a formal network of enterprises) or weaker ties (e.g., a community of practitioners, a cluster).

Some research questions:

- How will the activities performed in an R&D department be influenced by the advent of DiDIYers among the R&D employees and among the firm customers?
- What are the properties of a co-working space that lead to superior performances of accelerated start-ups due to the interaction among DiDIYers and eventually the development of a community of DiDIYers?
- How will the activities of a retailer be influenced by the advent of DiDIYers among its customers?
- How will the activities in the supply chain within the manufacturing industry be influenced by the diffusion of DiDIY practices among the firms in the supply chain and among final customers?
- How Digital DIY can contribute (by shrinking, growing jobs or changing job profiles) to the evolution of the workforce?

IW3. DiDIY and business models

In a narrower view DiDIY is about activities satisfying personal needs, while in a broader view it may also include activities with a business aim, both in a profit or a no-profit context.

While DiDIY typically focuses on creating solutions to solve one's personal or collective problem, it does not exclude the making of products and then selling them. When a business builds certain tools appropriate for their business activity by themselves, this activity can be considered DiDIY. The existence of a business aim, or an economical impact, does not exclude it from DIY.

Typically the sharing of knowledge of DiDIY takes place in online communities where people participate with a large variety of motivations. Peers produce collectively digital resources that some use to solve their personal needs, while others offer professional services "on top" of the digital common. We can take as relevant examples:

– the Free Software community, where a large part of developers make a living with services related to their contributions to the common resource;

– the Open Hardware communities, where artists, researchers, entrepreneurs, activists, hackers and makers of all sorts come together and contribute to shared projects as they see fit.

If this model might be generalized, we could argue that DiDIY thrives particularly well when people have full rights to engage in any kind of activity related to the digital resources shared.

Some business models that can be observed include:

– sell products as kits: users buy a kit and self-assemble it instead of making all individual components themselves - the original developers tend to make a margin on the sales;

– sell finished products: even though you can make it yourself, some people prefer to buy a finished product - the original developers tend to make a margin on the sales;

– platform model: people can replicate freely the hardware and/or software but connect to an online platform (e.g., gitHub, particle.io);

– services: provide value added services while keeping the designs under free/open licenses.

Some research questions

- In what conditions past experiences and cases of DiDIY attempted or proved to generate a business impact?
- Can DiDIY be a resilient business opportunity? What are the barriers to overcome?
- What is the role of knowledge sharing among peers in the building of a successful business model?
- What business models do people and organisations pursue to dedicate their time and resources to DiDIY?

IW4. DiDIY and professionalism

In a narrower view DiDIY is related to activities performed by non-professionals, while in a broader view it is also for professionals who maintain their DiDIY mindset.

Artisans, and the typically micro or small sized organizations they set up, are often solely focused on the product sold to a local market, and operate with a do-it-yourself attitude privileging creativity and proactivity. Digital innovation appear to bring new opportunities for this category of individuals, who appear to own the characteristics of the digital artisans envisioned by Barbrook almost two decades ago (Barbrook 1997).

Some research questions

- What are the differences, if any, in DiDIY if carried out by an amateur or a professional?
- Under what conditions is a professional activity appropriately considered DiDIY if performed with the mindset of the DiDIYer?
- Which are the constraints and opportunities that DiDIYers, as digital artisans, need to face?

DiDIY in education and research

IW5. DiDIY and education

In a narrower view DiDIY is related to a new generation of students already immersed in new technologies as “producers” of knowledge, while in a broader view it refers to the adoption of new pedagogical approaches for the benefit of general/adult learners in acquiring new skills, abilities, and ways of thinking.

As the segment of society which usually adapts first to the “new” is the young, we see youth much more they are involved in exchanging information and knowledge over the web than ever before. Consequently, students are learning much more in these informal environments, making education become less institutionalized and more personalized. Students are thus moving from “consumers” to “producers” of knowledge.

Educational institutions are now competing with a more fluid concept of learning, that takes place mainly outside the class and in recreational spaces. Extra-curricular activities such as RoboCup Jr (http://rcj.robocup.org) and First Lego League (www.firstlegoleague.org) involve schools’ teams in

project-oriented education initiatives, providing scaffolded learning environment where students can develop sophisticated solutions to a given challenge.

DiDIY in education is currently being used in many different ways, from holistic experiences to more specialized ones. In the educational setting, where the pedagogical goals are predominant, DiDIY enables students to create and at the same time demonstrate what they have learnt to do, providing direct evidence of the outcomes of the learning process. The opportunity to talk about that object, to communicate about it, to tell a story about it is a way to learn, while at the same time we teach others. The creation of physical outputs reinforce the students' interests in engaging in such activities.

Some research questions

- Thanks to the widespread and affordable access to the Internet and the growth of the free software and open source and open hardware movements, pupils work on common projects and share working spaces with their colleagues-friends. Does this lead to new ideas or to conformism? Besides they also share the same working spaces with teachers, thus making it harder to predetermine the flow of communication. How is communication and sharing reshaping student-teacher and learning/teaching flows?
- How sharing and learning happens is influenced by cultural models. A possible critique to DiDIY is about the individualism of the model, perhaps implicitly based on western cultural assumptions. Does DiDIY emphasize individualism, and how can the roles of individuals be shaped in DiDIY-related learning processes?
- How can DiDIY be exploited to ease/emphasize the transition from a teacher/curriculum-centered school to a student/experimentation-centered education ("flipped learning")? Is DiDIY also transforming the role of teachers accordingly? How? What new competences are expected from them? (these questions need to take into account that DiDIY educational activities are also related to environments different from schools – such as labs, museums, robotics academies, etc – and educators that are not teachers). Is this transition always a desirable outcome?
- It has been argued that schools as institutions could have greatly benefited from the computer age, but was somehow reluctant to do so (S. Papert). Will DiDIY have better chances to allow for major changes within the educational system, also taking into account the concurrent existence of multiple forms of DiDIY aimed at substituting schools, such as MOOCs?
- How is gender of individuals related to the attitude toward DiDIY? (also considering that DiDIY is used in many countries as a special tool to attract more students and make them study more STEM (Science, Technology, Engineering, Mathematics) subjects, and considering that STEM courses have a very low percentage of female attendance, one possible areas of interest could be that of evaluating if and how DiDIY may attract more women to STEM classes)
- At present DiDIY in education is mainly used in close relationship with STEM subjects (and if other subjects are involved, they have an ancillary role). Is there a main role for DiDIY in other subjects, such as humanities, arts, etc, so to move from STEM to STEAM (Science, Technology, Engineering, Arts, Mathematics)?

IW6. DiDIY and research

In a narrower view DiDIY is related to individuals who, outside traditional research environments, engage in research activities by virtue of the widespread availability of affordable new technologies and open access knowledge, while in a broader view it refers to the reshaping of the concept of scientific research itself as free from traditional institutional constraints.

DiDIY research laboratories are emerging as an alternative to academia research. The DiDIY revolution has increasingly made available (and affordable) tools and knowledge to a wider audience, enabling citizens to participate to research activities that would otherwise been out of their reach. Research outside universities is typically carried out in two different settings:

– industry-based laboratories: the size of these facilities might differ significantly, from big enterprises to small start-ups. Research is typically well focused on a particular issue. Gaining an economic revenue is a key aspect of this activity;

– open labs: typically organized by associations of citizens. Open-source principles and knowledge sharing are usually encouraged. Self-reward and the sense of belonging to a community are the key reasons for people to participate.

Without the need of formal qualification or strict procedures, this closer contact between citizen and research might create fertile ground to innovation. By changing the idea of who can do science and what science is, this new research setting have the potential to improve the long lasting difficult relationship between scientists and society.

Some research questions

- The many uses of DiDIY in education and research have one element in common: creativity has a crucial role, and is often relieved from the burden of the actual “making” of the outputs (“If you can imagine it, you can create it”). Thus, students and researchers really have the opportunity to work on their ideas, shaping them mostly in a non-physical environment, and even the last part of the process may not require them to have particular dexterity. How do teachers, students, and researchers use this unique feature of DiDIY?
- How is the age of individuals related to their possible attitude toward DiDIY? Is the fact that at the moment DiDIY is exploited in learning and research mainly by young people contingent to the current “DiDIY culture”? May DiDIY effectively exploited as a driver in learning also of adults, and in the case how?
- How can DiDIY help special groups of individuals (e.g., disabled, second generation immigrants, specially gifted) getting more (or less) involved in research activities?
- If, and how, is DiDIY affecting the research careers of young researchers?

DiDIY in creative society

IW7. DiDIY and creativity

In a narrower view DiDIY fosters creativity as people make things using state-of-the-art digitally-controlled technologies, while in a broader view it is also about the ways in which creativity can be

fostered much more widely, as people connect using digital tools and systems (such as the internet) to develop various digital or non-digital kinds of creative practice.

Within this research, the term “creativity” is intended to encompass a range of creative interactions. It includes the creativity of individuals who are making objects using DiDIY technologies; the creativity that results from the social interaction of individuals coming together and exchanging ideas and working on DiDIY projects; and creativity in the wider community, for example, the creative impact on society that results from how DiDIY projects are manifested in the wider world.

The level of ‘creative engagement’ itself may be subjective to the participants. It may encompass a wide range of activity from simple engagement in a making activity to complex original design and construction of original objects or projects. Similarly, creative groups, and creative society impacts, are likely to operate at a range of scales.

As a mindset DiDIY may also be seen as a creative continuum, in particular small creative projects and activities may lead to a self-reinforcing DiDIY mindset and lead to more complex creative activities. There are creative implications for this progressive engagement, for example, the exchange of creative ideas and inspiration via online communities enables widespread dissemination of designs. Collaborative engagement opens the way to potentially enabling creative solutions to local, social and environmental problems.

Free and open access is concerned with the protocols allowing or restricting the use and modification of designs and as such has implications for both the creators of designs and those wishing to use them, moderating the shared use of creative capital. DiDIY enables the shared production of creative content and therefore greater opportunities for co-design and the creation of collaborative value chains. It may also lead to the need for a new class of creative professionals mediating DiDIY.

Research, in context, will be carried out to establish how creativity is sparked, fostered and sustained within DiDIY activities and how this impacts on wider creative society. The extent of creativity needs to be studied in the context of the specific creative engagement and its perception by the participants involved.

DiDIY is an emergent phenomenon and our research is aimed at exploring DiDIY in relation to creativity, through case studies of emergent and current practice and hands-on workshops.

Some research questions

- What is the impact of DiDIY on the creative agency of individuals? Can DiDIY influence, alter or empower the dynamics of an individual maker’s relationship to digital technologies?
- Does DiDIY foster a spirit of self-motivated creativity and entrepreneurialism that could lead to significant social change?
- Do ABC technologies such as 3D printing offer a significant alternative to previous ways of making things, and what difference do they make to social attitudes to material production and consumption?
- What is the impact of DiDIY on creative society?
- Can DiDIY enable communities, online or offline, to meet the challenge of social, environmental and economic issues? What is the potential for DiDIY to provide the creative resources for communities to tackle problems locally?

- What are the relationships between digital cultures, offline making, and digital making?
- Does the DiDIY ethos inspire people to bring about changes in their local culture?

DiDIY in laws, rights and responsibilities

IW8. DiDIY and its socio-legal challenges as a different production system

In a narrower view DiDIY is an activity for hobbyists or amateurs making unique or customised things themselves within the existing system dominated by mass production, while in a broader view DiDIY is part of a larger shift towards collaborative commons and open source sharing of knowledge that is facilitated by new business models focused on specialised, value added services.

The laws, rights and responsibilities that dictate economic and social behaviour have been shaped primarily during the early industrial revolutions, when large, centralised infrastructures for mass production needed exclusive control over intellectual property. This narrower view holds that DiDIY practices have little impact on the production system and the laws that were designed for it, maybe because its rise can be stopped or reoriented by regulation or because it is thought that the economic impact of DiDIY is limited.

In a broader view, however, DiDIY may be considered as part of a larger shift towards collaborative commons and open source sharing of knowledge that is facilitated by new business models focused on specialised, value added services. In this sense it can be appreciated that the phenomenon of DiDIY implies a change in both the number of people engaged in the production process of physical objects (“production by the masses”) as well as in the scale of this production (scale of one or few units).

The emerging phenomenon of DiDIY and the rise of openly shared hardware designs (so called “Open Source Hardware”) questions this model of exclusive control over intellectual works. Moreover the engagement of non-professional designers and makers in the production of physical objects raises questions of responsibility and liability, when third parties get injured by these objects.

The possibility of DiDIY becoming a mindset is interesting in relation to its potential social and ethical implications. If widespread enough, it could mark a shift in social practices and expectations that made it more difficult to implement certain types of regulation. As an analogy, one can think of the way in which a number of people have been conditioned to expect music to be available online for free: this new mindset seems to have made online music providers more cautious about trying to abolish free streaming services (funded by ads) in favour of a subscription-only system or other paid services. Another dimension in which DiDIY becoming a mindset is interesting is the “repair” culture, (e.g., http://www.didiy.eu/resources/rusz-refurbishment-repair-services).

Some research questions

- What laws may hinder the adoption of DiDIY and what challenges pose DiDIY practices to current legislation?
- What exemptions in IPR legislation exist to allow and encourage the use of DiDIY practices for (self) repair? Which legal measures can be taken to strengthen these rights vs. the

exclusive protections held my IPR owners? What can be done to protect commercial repair services based on small scale DiDIY activities, even of exclusively protected parts?

- How do DiDIY practices affect the control of dangerous weapons and pathogens?
- How can the practice of DiDIY in the field of Unmanned Aerial Vehicles (UAVs) - commonly known as “drones” - be regulated?

(A longer list of issues and challenges under research in this area can be found at the page http://www.didiy.eu/didiy-rights-and-obligations-legal)

IW9. DiDIY and the relation with Free Knowledge & Open Source Hardware

In a narrower view DiDIY knowledge is shared freely within communities, while in a broader view DiDIY projects may come also with non-free conditions.

One of the foundational principles of DiDIY is the sharing of knowledge. Where DIY is something that one theoretically can do completely alone and keep private, in the case of DiDIY there is practically always a form of knowledge sharing (imagine that someone buys a household 3D printer or an electronics product that helps them set up a little sensor network for themselves: even if they are proprietary systems, in some way some shared knowledge is involved).

In the narrower view knowledge is shared freely within DiDIY communities. Most typically this occurs through online knowledge sharing platforms that are open for participation and share knowledge about techniques, solutions and projects providing certain rights to other users. Very typical are projects classified as Free Knowledge, Free Software, Open Source Software, Open Source Hardware and Free Cultural Works. These are different terms for expressions of knowledge (“works”) that are shared with the following four freedoms:

a) the freedom to use for any purpose;

b) the freedom to study and adapt to one's needs;

c) the freedom to copy and share with one's neighbour, and

d) the freedom to distribute modified versions.

In a broader view, DiDIY knowledge sharing at least requires access to the ideas and the possibility to adapt these to one’s needs. DiDIY projects may come with non-free conditions. One restriction that may apply is the non-commercial one (e.g., under the CC BY-NC license), which limits the use or sharing of the works for non-commercial contexts. DIY typically is done for solving a person’s or group’s problems and not directly commercial exchange (though selling of the results may occur). Another restriction that sometimes is used is a non-derivative restriction (e.g., CC BY-ND), which restricts users from distributing modified versions. Now when one or more of such restrictions apply, these works can not be considered “free” (as in freedom) nor “open” (as in “open source”) and (thus) they would not be part of the collection of free knowledge. That said, the use of free licenses – that guarantees the mentioned four freedoms – is often a considerable advantage for communities to become sustainable and very common under practitioners of DiDIY. This relates also to the sustainability and business models.

Some research questions

- What legal limitations and solutions exist for protecting the sharing of Open Source Hardware?

IW10. DiDIY and the openness of the Internet of Things

In a narrower view DiDIY communication and knowledge sharing through the Internet occurs mostly using open standards, thus allowing vendor-independent tools to be interoperable, while in a broader view proprietary protocols are used.

The entire stack of TCP/IP protocols, on which the Internet is based, is free and open, and so are most application protocols on top of TCP/IP, such as HTTP that is the core component of the web. However many proprietary protocols are also being used, in particular in the emerging Internet of Things (IoT) domain. Will the application protocols of IoT be eventually free and open?

The best assumption / forecast / hope we can say on this, at this point in time, is that IoT is likely to have an evolution similar to the original one: a first stage of lots of competing non-interoperating protocols (regardless of their IPR status, i.e., whether they are patented / copyrighted or not), followed by extinction of most of them, and survival of one or a very few ones, maybe just for protectionism reasons (think power plugs in different countries) but with almost full interoperability.

Open standards have a strong advantage to maximise the possibility for collaboration between competitors and implementation in a rapidly changing IT environment. Because of the social importance of the network effect, legislators may want to design policies to avoid vendor lockin and assure specifications are defined as open standards.

Some research questions

- Given the importance of open standards for vendor-independent interoperability, what legislative efforts and policy recommendations should be made in this field?
- What effect is the emergence of IoT, i.e., sensor and actuator networks, having on the privacy and anonymity of its users?

IW11. DiDIY, quality control, and product liability

In a narrower view DiDIY is about hobbyists creating new things using digital technologies, while in a broader view it can also involve business entities (e.g., 3D printing services) - provided that such entities are not in control of the entire process of creation of the relevant artefacts.

New rules regarding quality control and product liability might need to be introduced to protect users and consumers of DiDIY products for two main reasons: 1) non-professional makers, unlike businesses, are typically not covered by existing liability laws, warranty and insurance and 2) small-scale production lacks the scale to afford professional testing and product certification.

Some research questions

- How does the phenomenon of DiDIY affect the notion of duty of care and product liability? Who bears the consequences of the damages caused?
- Is current European legislation on product liability and consumer protection adequate to deal with the challenges raised by DiDIY? If not, what legislative changes are required to meet those challenges?
- How can small scale production be facilitated in testing and product certification?

- What cultural shift in awareness is needed to encourage the duty of care in the process of design, production, exchange and usage around DiDIY practices?

Annex 1 - Some data about DIY/DiDIY online communities

The data presented in this Annex were previously unpublished, and what follows should be intended as just a preliminary analysis of them. In the remaining part of the Project activities they will be further refined and better analysed.

A1. Introduction

DIY has changed and become increasingly complex in last few years. This is due to a wide spectrum of reasons that have led to describe it as a socio-technical phenomenon. Several isolated factors could be addressed, related to technology, economy, society, psychology, ... that, realistically, have broadened the range of individuals that decide to become DIYers, lowered the difficulty barrier to undertake DIY activities and, more in general, reshaped how people make things in the 21st century, but no single element seems to provide a really general explanation of what is happening around DIY.

Even before the Internet, groups of people united by a shared passion already existed. There were, and there are, clubs based on sports, hobbies and any kind of activities. The same thing happened for DIY, which originated local associations often based on specific branches of activities, like electronics, gardening, home improvement activities, cooking, and so on. But we cannot effectively understand today's DIY looking at local communities only, many of them focused on specific matters and all limited to specific geographical areas.

With the Internet, people were finally allowed to share their interests while overcoming the geographical and communicational boundaries of the local, known, and confined networks of DIY enthusiasts. The Internet enables people to step over the old limitations and build international groups based on their passions. And it enables us to have "ready to use" information about DIY, in the context of communities that are virtual places where millions of individuals, pooled by their common DIY interest, share ideas openly, find inspirations, give and receive feedbacks, promote collaboration and help individuals and communities themselves grow. Knowledge becomes more and more open. Thanks to Web 2.0, everyone is now an expert amateur (Tanenbaum et al. 2013, p. 2604), able to publish contents and ideas, while, before it, just a few were enabled to do that.

Online communities have then incredibly broadened the boundaries of DIY, considering both the produced artefacts and the people involved. Step-by-step tutorials, high resolutions images and videos attached, critiques and feedbacks are a very strong contribution to the knowledge sharing and enhancing process. Even beginners can now understand every single detail of a project work and its complexities, becoming more capable and autonomous as makers.

This broadening effect is leading to hundreds of thousands of users joining online communities. Each user, after signing up, provides some sort of personal information and, if they want to, can start publishing, i.e., sharing, their ideas and works as "projects". Hence, these two entities (users and their artefacts) are a huge, global, and mostly untapped source of data to explore DIY and DiDIY.

Literature has already investigated online communities by analysing data scraped from (Di)DIY websites. There have been studies on the choice of licenses for 3D printing models (Moilanen et al. 2014), an in-depth web traffic analysis comparing, Shapeways and Thingiverse, two major platforms for sharing 3D models (Phillips 2014), and also studies of 3D printing online platforms from a legal perspective with an empirical analysis of user behaviour (Mendis, Secchi 2015).

These studies, however, are very limited in scope. They are often limited to a very specific type of community (e.g., 3D printing communities) or isolated features (e.g., choice of license) leading to interesting results but of limited relevance for the DiDIY phenomenon as a whole.

To discern relevant structures and emergent patterns from what could be nothing more than contingent behaviours of the observed online community, it is possible to consider multiple points of view (PoVs) for reducing possible bias, and to analyse in parallel both a community of DiDIYers and one of DIYers, so to observe the phenomenon both from within and from outside, of course under the assumption that DiDIY is a specific case of DIY.

In order to carry out this multiple PoV analysis, two of the currently most significant communities have been identified, as for users enrolled and projects published:

- Instructables (www.instructables.com), which showcases artefacts from every possible DIY domain: we used it as a reference for the DIY phenomenon as a whole, hence for the "from outside" analysis. It counts today about 215,000 users and 200,000 projects (Instructables' users and projects as of February 15th, 2016);

- Thingiverse (www.thingiverse.com), which, instead, collects only 3D-printing-related projects and, thus, is perfect for a DiDIY-specific, "from inside", analysis. Even with a narrower scope, it is bigger, with more than 400,000 projects and about 630,000 users (Thingiverse's users and projects as of November 2015).

Here below are illustrated the first, interesting results: the registration rate (Figure A1.1), i.e., the number of new users who signed up every month, and the publication rate (Figure A1.2), i.e., the rate at which new projects were published every month. In order to make a proper comparison, both Instructables and Thingiverse data is shown starting from October 2008, when the latter was opened (Instructables exists since March 2005).

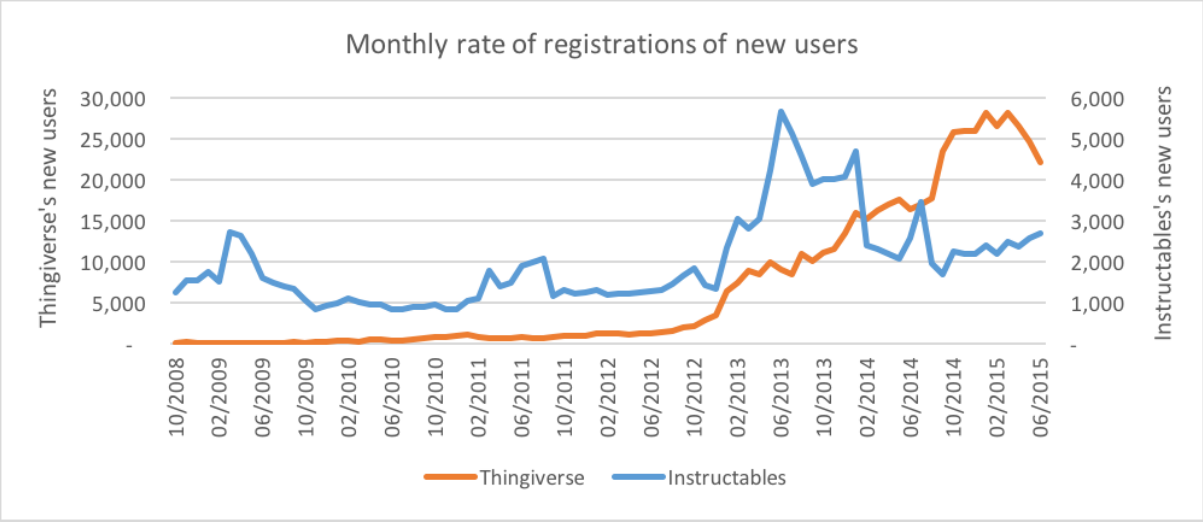

Figure A1.1 - Monthly registration rate of new users in the two analysed online communities.

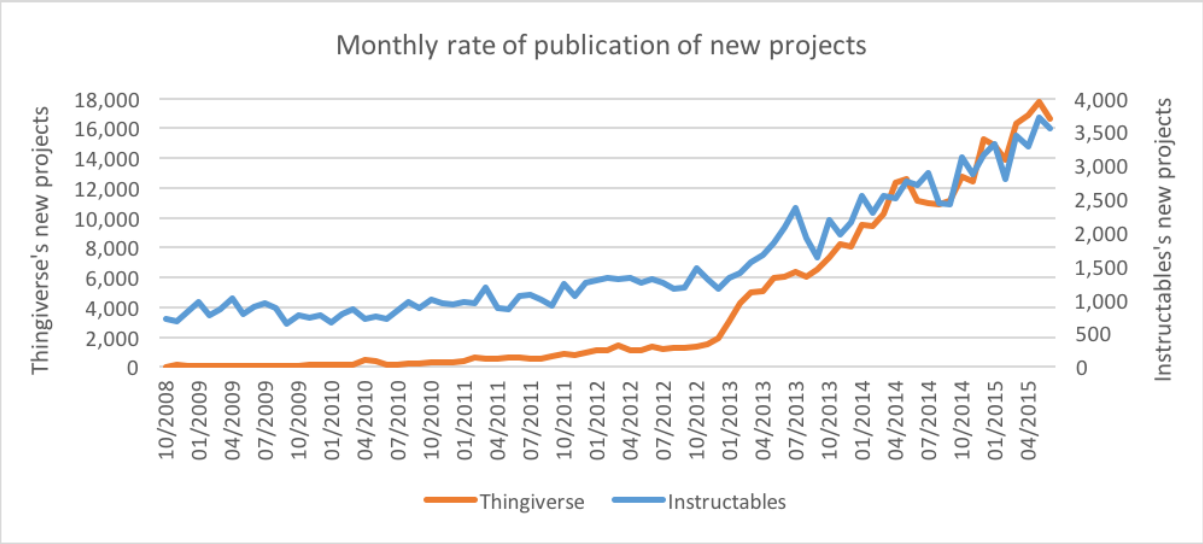

Figure A1.2 - Monthly publication rate of new projects in the two analysed online communities.

The first chart shows some significant differences between the two time series. The vertical axes have very different ranges, due to the different growth rate of the two websites' users bases. Thingiverse's growth multiplied by more than 20 times in the last 3 years and started to decline only in the last few months, keeping, however, a notable rhythm of 22,000 new users per month. Instructables, on the other hand, had a "boom" in 2013 and 2014, getting to a maximum of more than 5,500 new users in a month, after which it slowed back to 2,000-3,000 users/month. The only common structure of the two series seems to be the abrupt growth at the beginning of 2013. Their correlation, 0.49, reflects this limited correspondence, still a remarkable value for a social phenomenon.

The second chart conveys quite a different message. Again, Thingiverse shows growth rate remarkably higher than Instructables's, with a maximum value of about 17,700 of the former versus the about 3,700 of the latter, but incredibly similar trends appear here, especially after the

mentioned boom in 2013. The two patterns seem to be drawn together, and indeed their correlation beats an astonishing value of 0.98.

While more data should be taken into account to propose some specific and reliable interpretations, this first parallel observation, from outside and from inside, supports at least two of the basic hypotheses on which the DiDIY project was designed and is developing: first, *DiDIY shares some common patterns with DIY*; second, *both DIY and DiDIY are spreading to new audiences and domains and this is happening, increasingly, in the form of DiDIY*.

With this sort of observation it appears necessary that further analysis is needed. Although Thingiverse, focused on 3D printing, is very in-topic regarding DiDIY, undergoing more thorough examination on this very specific community would certainly leave out critical details on wider and more general aspects of digital DIY, thus retracing the narrow perspective given by previous studies found in literature.

For this reason, and to give a more representing outlook of the DiDIY community, focusing on Instructables and capturing several forms of digital and non-digital DIY appears to be the best suited perspective at this point of the Project.

A1. Data analysis on Instructables

Probing the Instructables community with a data mining exercise, two different but highly interrelated datasets (i.e., collections of data) can be built:

- *Users*: people that signed up to participate in the community by uploading new projects and/or interact with other users and their projects. Even though some users never published a single project, they are not to be confused for generic website visitors since they actively signed up and somehow interacted with the community;
- *Projects*: the artefacts or, more in general, the step-by-step how-tos of the artefacts published by the users of the community.

The Instructables website counts millions of visitors, and it is possible to separate the read-only members (or lurkers, https://en.wikipedia.org/wiki/Lurker) from the active participants of the community. Whereas simply browsing the website wouldn't possibly count as an interaction, there are some possible actions that would and that, indeed, only a registered user is allowed to do:

- publish or edit a project;
- comment on your own or somebody else's project;
- comment on your own or somebody else's profile;
- favourite a project;
- follow a user.

Following this reasoning can be identified, as represented in Figure A1.3, the users that completed at least one single interaction with the rest of the community.

What follows is a graphical representation of user registrations.

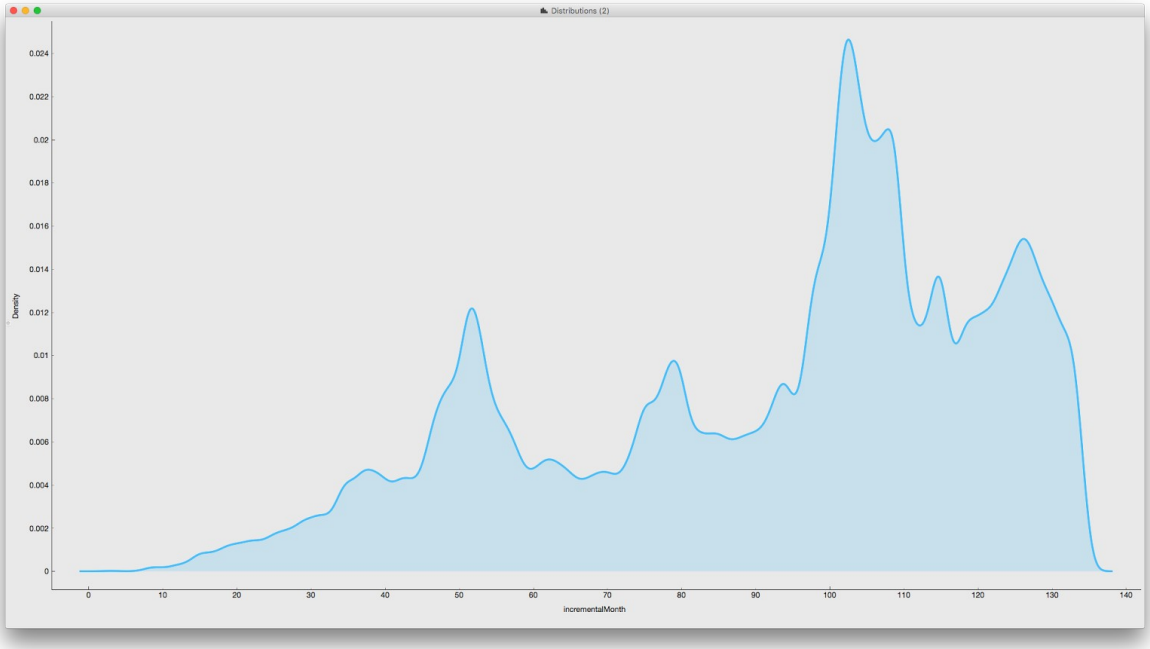

Figure A1.3 - Monthly Instructables user registrations,
where the monthly numbering considers January 2005 as no.1 and December 2015 as no.120.

Some preliminary statements (1):

- Instructables counts about 215,000 registered users.
- User registrations show a general increase over time.
- 2009 and 2013 show a notable peak in user registration, outlining them from the trend.

Separating the users who published a project (in blue) from the ones who did not (in red), as shown in Figure A1.4, there is a clear correlation between the increase of active user with the increase of publishing users.

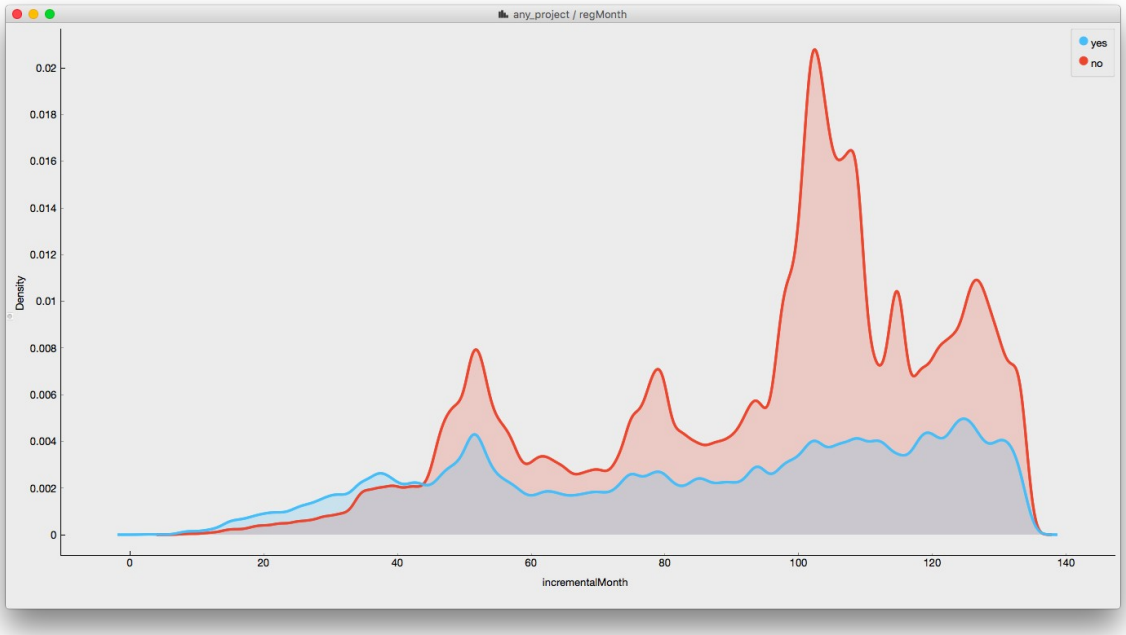

Figure A1.4. Monthly Instructables user registrations,
where the monthly numbering considers January 2005 as no.1 and December 2015 as no.120.

Some preliminary statements (2):

- About 32.5% of users shared a project with the rest of the community.
- Peak user registration results in an increase of active users that don't necessarily decide to publish a project.
- Even though not all users share a DiDIY activity, they share, by interacting together, the same DiDIY mindset.

Several considerations can be made by looking at individual user features such as gender (Figure A1.5),

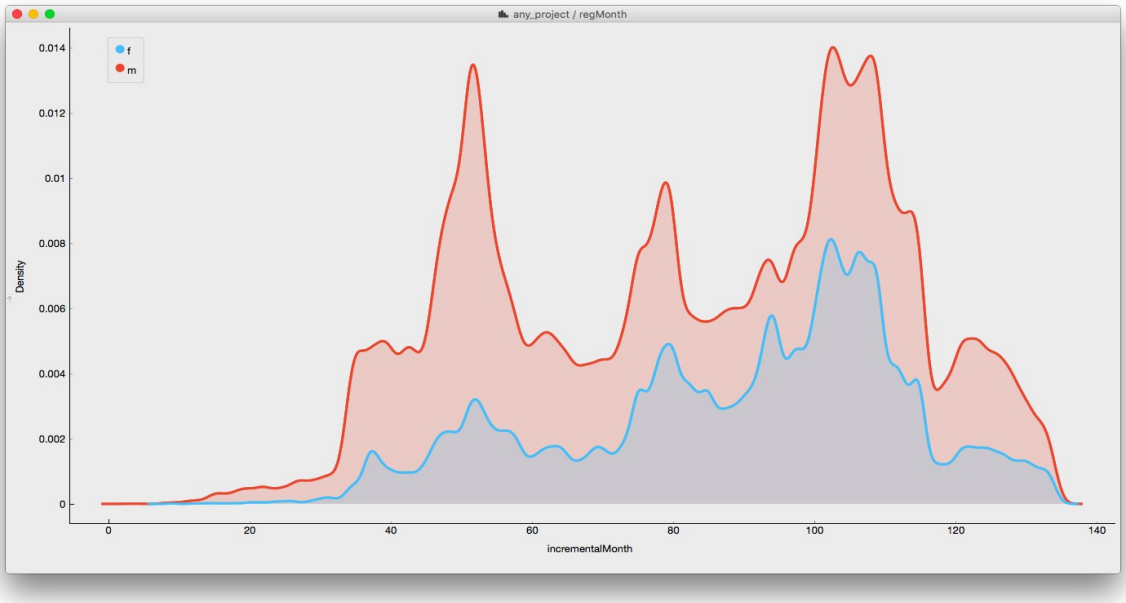

Figure A1.5 - Distribution of user registrations over time grouped by gender.

where it shows how the female presence is improving in a community that remains predominantly male, or age (Figure A1.6),

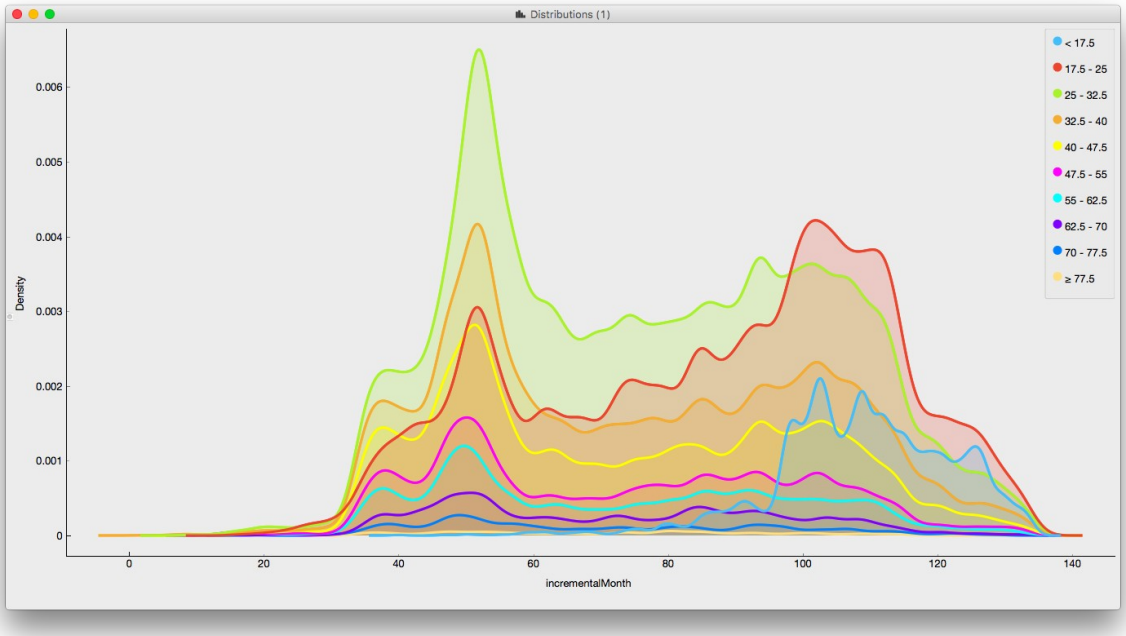

Figure A1.6 - Distribution of user registrations over time divided into age groups.

that shows how the community was initially grown by young adults (25-40 years old), then taken over by a younger population (18-25 years old), or even both features put together (Figure A1.7),

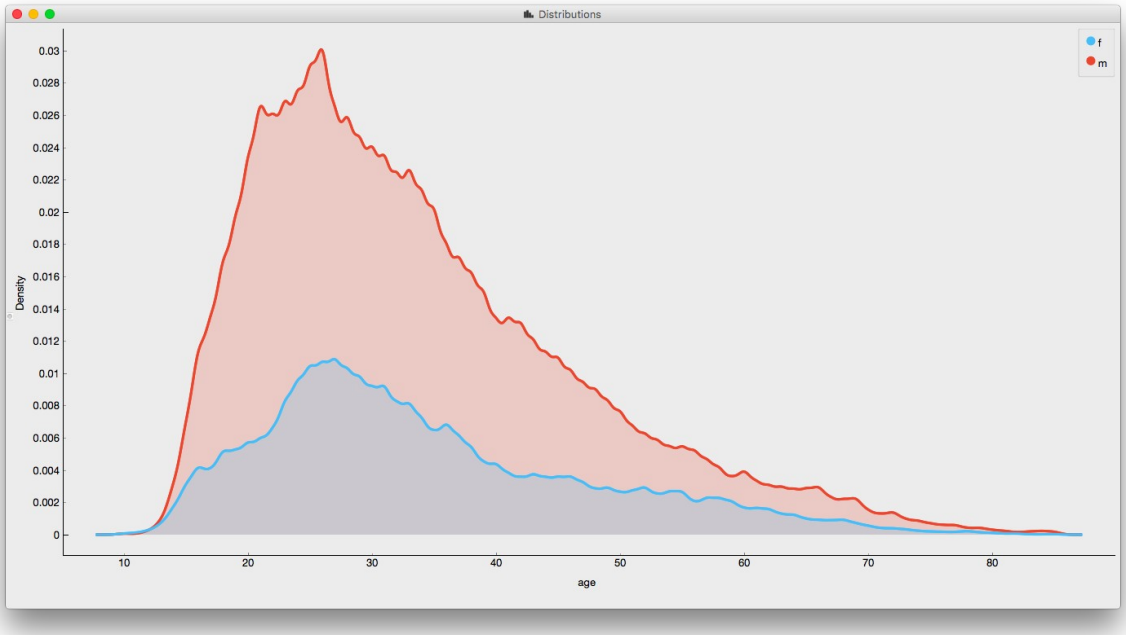

Figure A1.7 - Distribution of user's age grouped by gender.

allowing the observer to glance how, on average, the smaller female population tends to be more evenly distributed among both younger and older age groups.

Even before delving in any feature-specific analysis of the Instructables community, there is still much more to be investigated on the community activity as a whole that further confirms Instructables as an excellent probe of DiDIY phenomenon online and offline.

Some preliminary questions

- Due to the open commitment of signing up and joining the Instructables community, can users be considered DiDIYers?
- Is it possible to identify typical Producer and Consumer behaviours within the user base?
- Given that all active users are part of the DiDIY phenomenon, is it possible to identify multiple kinds of DiDIYers according to the kind of actions and interactions they tend to undertake?
- What are the reasons that fuelled massive user signups in the first half of 2009 and throughout 2013?
- What is the emergent DiDIYer profile from the Instructables demographics?
- How did Instructables evolve in terms of DIY activity as the community demographics changed over the years?

Annex 2 - The sketch of an ontology about DIY/DiDIY

Context and motivation

This KF and the Integrative Modelling (IM), developed in WP7, stand at opposite ends of the DiDIY Project, almost like bookends. Although both are integrative and crosscutting, they have different goals. The KF is to help forge a common understanding – a kind of conceptual map of the terrain of study that will help the Project coordinate, locate its goals and scope and communicate effectively about DiDIY. The IM is to bring together resultant knowledge into dynamic instantiations of DiDIY – ultimately to capture the essential processes and exhibit its key characteristics.

The KF and IM also use very different "technologies": KF using natural language and analogy, IM using complex computer programmes. This has subtle, but deep ramifications for how they represent issues as well as how they are used – analogies and simulations are both (in the broadest sense) models of phenomena but they work in different ways.

Firstly, simulation is a formal technique that is it can be precisely specified and communicated without error. This means that it can be indefinitely passed between researchers for critique and piecewise improvement without confusion about its definition. A simulation is an artefact, similar to others made in DiDIY activities, and its plans (the code) are shared among its own communities and re-used. This is unlike discursive accounts whose interpretation, and hence meaning, will change from individual to individual, which means that as the background ideas and values change so does the meaning of its analogies.

Secondly, although they can be both used to theorise the connections between micro- and macro-phenomena they do this in different ways (Figure A2.1). Discursive accounts relate these in semantically rich but imprecise ways; they are free to bring together very different kinds of process and properties under a single label (e.g., social capital). It allows a fluidity of expression that is ideal for group discussions and motivational stories but the limitations of the human mind means that it cannot cope with situations that are too complicated to express or mentally follow (e.g., the details of hundreds of agents interacting) – it has to do this via abstraction. In contrast simulations map complicated but precise possible ways they could relate (usually there is more than one-way).

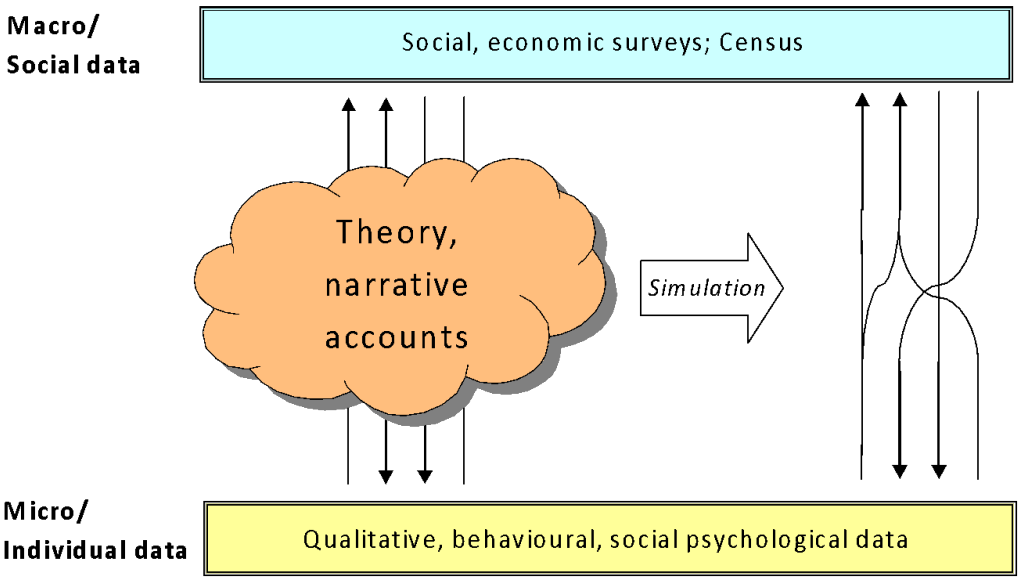

Figure A2.1 - Discursive approaches vs. Simulation.

The consequence of these differences is that representing the issues as a simulation forces a number of distinctions that can be comfortably conflated or abstracted away in natural language. Thus, even the process of building a simulation can change the way one thinks about things, for example by:

- revealing gaps in our knowledge – bits of the process we had assumed we understood when in a natural language formulation, but when considered in detail it turned out that either there were several ways in which this process could occur, or we don't know how the process occurs;
- forcing us to assign a process or a property to a part of the system – for example whether an observed pattern is due to individual or collective mechanisms;
- forcing us to decide whether a phenomenon is basic, in the sense that it will assumed and built into the structure of a simulation, or emergent in that it is a (non-trivial) result of the simulation set-up.

This difference in viewpoint – what might be called the simulation viewpoint – is not something that is immediately apparent, but is something that develops over time as one interacts with a simulation (either building and testing it or a series of discussions about a simulation). Thus, we expect that, as the DiDIY project progresses, the simulation viewpoint to impact upon the KF, influencing its shape and content at the end of the project (which is why we include it here in an Annex to the KF). At the moment we are just at the start of this process.

At the current stage, the prototype IM can relate several ways to the KF:

- it can serve as an instantiation of the KF – an in-silico example;
- an abstraction of its structure can be compared against the KF, to see any differences or omissions;
- the simulation viewpoint might suggest ways in which the KF can be further articulated.

We expect the KF and the IM to become increasingly intertwined as the Project progresses (see last section of this Annex), thus we include a bit about the IM here as a record of the situation at the start of this process.

About the prototype Integrative Model – A model of making

Purpose

The purpose of this model is to provide the simulation infrastructure needed in order to model the activity of making. That is individuals using resources they can find in their environment plus other things that other individuals might sell or give them, to design, construct and deconstruct items, some of which will be of direct use to themselves, some of which they might sell or give to others and some of which might be used as a tool to help in these activities. It explicitly represents plans and complex objects as separate entities in the model – embedding the "Atoms – Bits" distinction highlighted within the DiDIY Project. This allows plans to be shared between agents which give the steps of how to make objects of use – either on a commercial or a free basis.

The framework is intended as a basis upon which many, more specific, models could be constructed, allowing the exploration of a variety of "what if" or counterfactual possibilities and thus give a concrete but dynamic and complex instantiation of the issues and situations discussed within the DiDIY project. In a sense this model is a "bits" representation of the ideas discussed – hopefully these will converge!

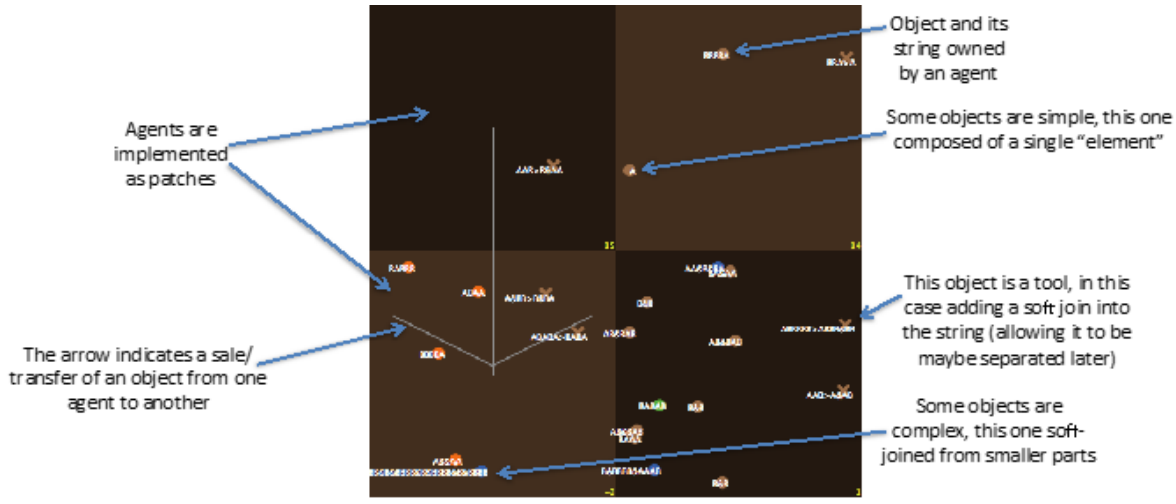

Figure A2.2 - A view of the model with agents, objects and a sale.

Entities, State Variables, Scales

There are three main kinds of entity in the model, agents, things and plans:

1. *Agents*. There are a fixed number of agents that do the making and decision making in the model. These are individually represented as "patches" in the model. They own and hold things. They can (depending on the nature of the things) act upon these things to make new things. At the moment, their position is not important and they can swap/trade things with

any other agent. They also hold in their mind a number of plans which they have either learnt themselves (through trial and error) or obtained from another agent.

2. *Things*. Things are individually represented and tracked within the model (from creation to destruction). They each have the nature of a 1D string of symbols, composed of a fixed number of "elements" (the letters "A", "B" etc. depending on the parameter which determines the number of elements) and the two symbols "&" and ">". "&" indicates a soft join that is a join that an agent can make (or break) without a specific tool. ">" indicates that the item can also be used as a tool, that is it can be used to "transform" the string on the left of the ">" into the one on the right in another string.
3. *Plans*. Agents remember sequences of actions they used to construct/deconstruct strings and the cost/benefit of the result as explicit plans. These plans are a tree structure of actions and the strings that resulted. The ability to remember these plans allows agents to repeat successful plans and also allows the possibility of plans being shared/licensed between agents.

The world of 1D strings is sufficiently complex to make the process of working out what sequences of actions would result in which valuable strings is a hard problem. Which strings are available in the environment and which strings have inherent "use" value are randomly determined at the start of the simulation. Which subset of strings are available to each agent and which subset can be redeemed by each agent can be varied, so as to be able explore the impact on the heterogeneity of resource availability and agent's needs. This hardness is what makes plans valuable and so worth sharing.

A complete description of the model, including its code can be found in Edmonds (2016).

Illustrative results

Figure A2.3 is a graph of the average number of items realised for different average lengthed targets showing the increasing difficulty of making/finding longer strings. Note the gap between Len=5 and Len=6 since the average length of resources available in all these runs was 2, meaning that finding/constructing strings of a length of 6 and above was hard for agents.

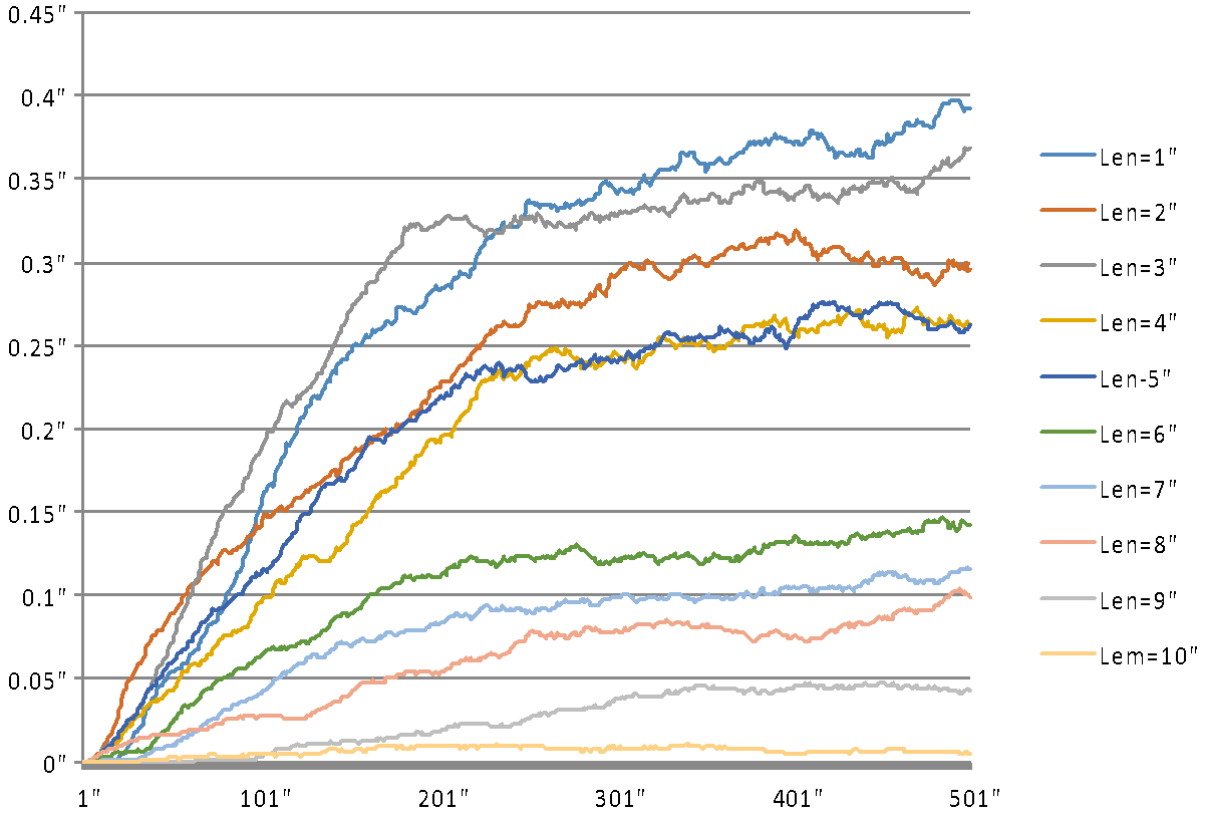

Figure A2.3 - Average number of items realised for different settings for the average length of target strings (over 10 runs per setting).

Drilling down we just look at the runs above with Len=2. Below are graphs of the average wealth of agents in these 10 runs (Figure A2.4) and their spread, measured by standard deviation (Figure A2.5). These show a general increase in wealth over time as the agents work out how to make/get valuable strings, but these differ a lot in terms of the inequality in wealth that results.

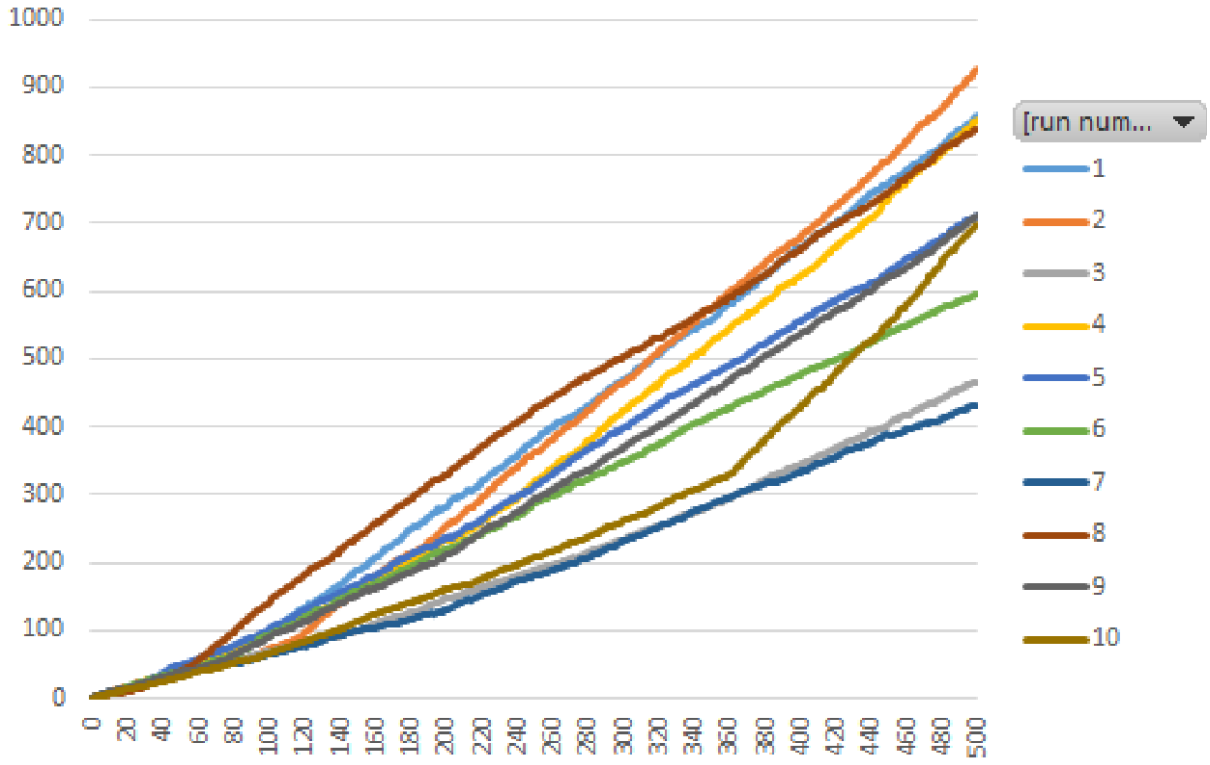

Figure A2.4 - Average wealth of agents for 10 runs (for av. Len=2 for targets).

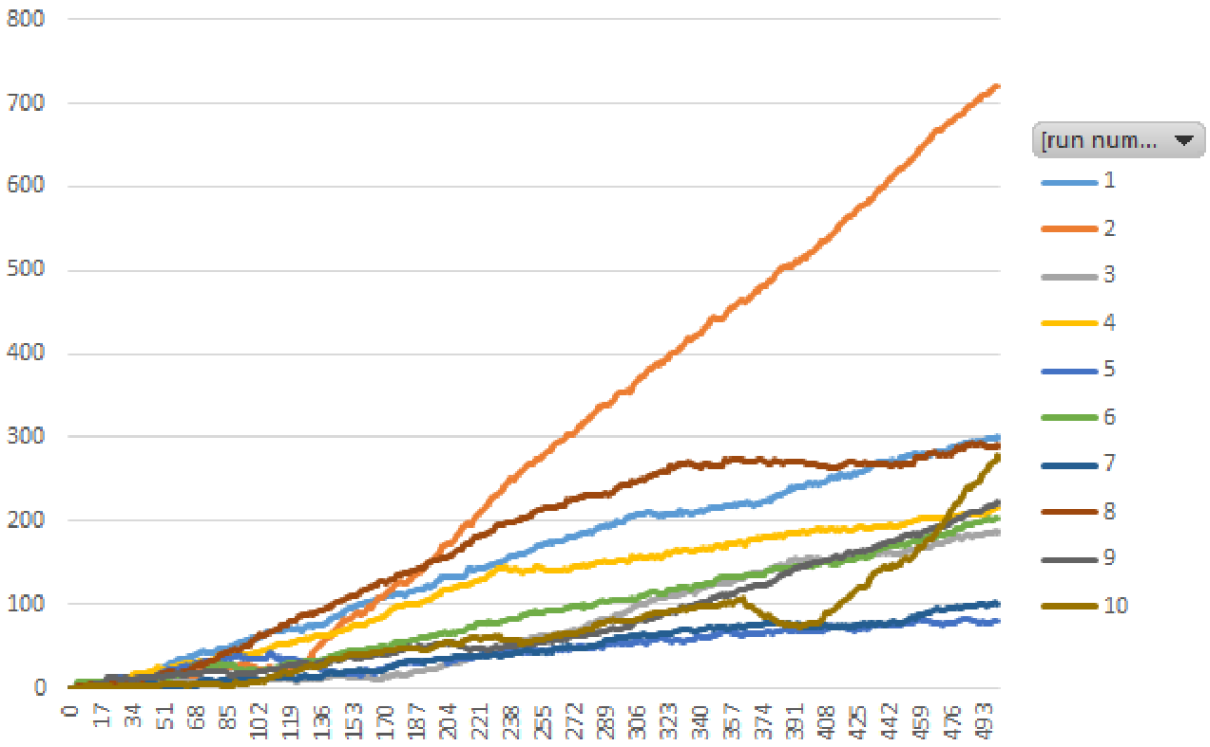

Figure A2.5 - Standard Deviation of the same runs as immediately above.

We now drill down to a single run, in terms of run 10 in the graphs immediately above. The following figures show a summary of a number of measures for this run, over time, all scaled so their maximums are 1 (so they all fit on the same graph), and some are smoothed to make the trends more visible. First, the number of things, the number of distinct things, and the number of tools (Figure A2.6).

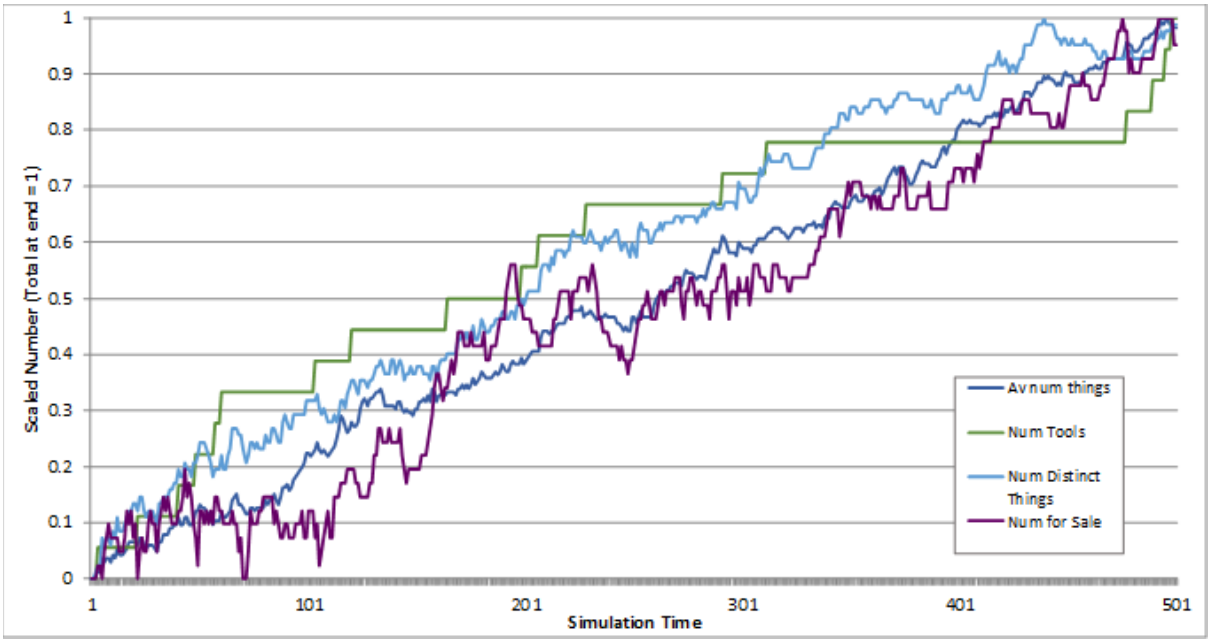

Figure A2.6 - Number of things, distinct things, tools and items for sale in a single run of the model (Run 10 in the graphs immediately above), scaled so the maximum of all measures is 1 (some of these lines are exponentially smoothed to ease viewing).

This indicates that agents are learning to make new things and gradually discover new tools. The number of things for sale also increases, albeit not smoothly. This shows the development of an informal market in items as the simulation progresses.

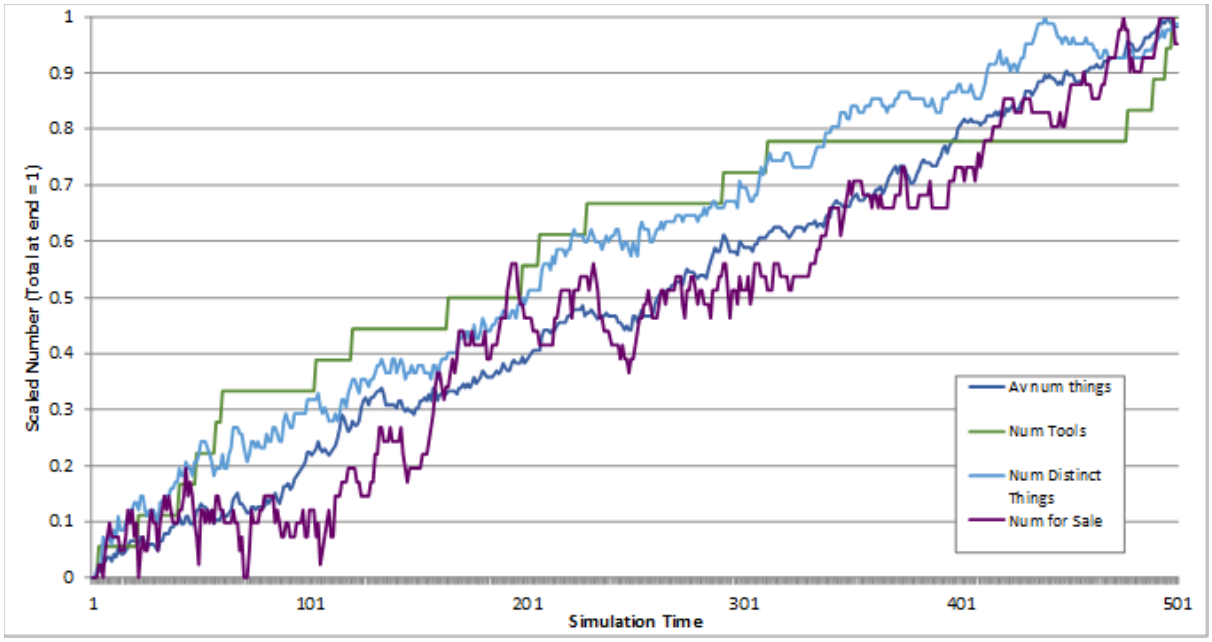

Figure A2.7 - The average length of plan and the greatest plan value in the same single run of the model (Run 10 in the graphs immediately above), scaled so the maximum of all measures is 1.

The average length of agent plans increases rapidly at the start as random exploration of plans seeks for useful strings, but after this is a gradual reduction as more efficient plans (with lower costs) are discovered (Figure A2.7). It also shows the value of the most valuable plan. Around the tick 360 an agent discovers a much more valuable plan than previously existed – a step change in its ability to create value.

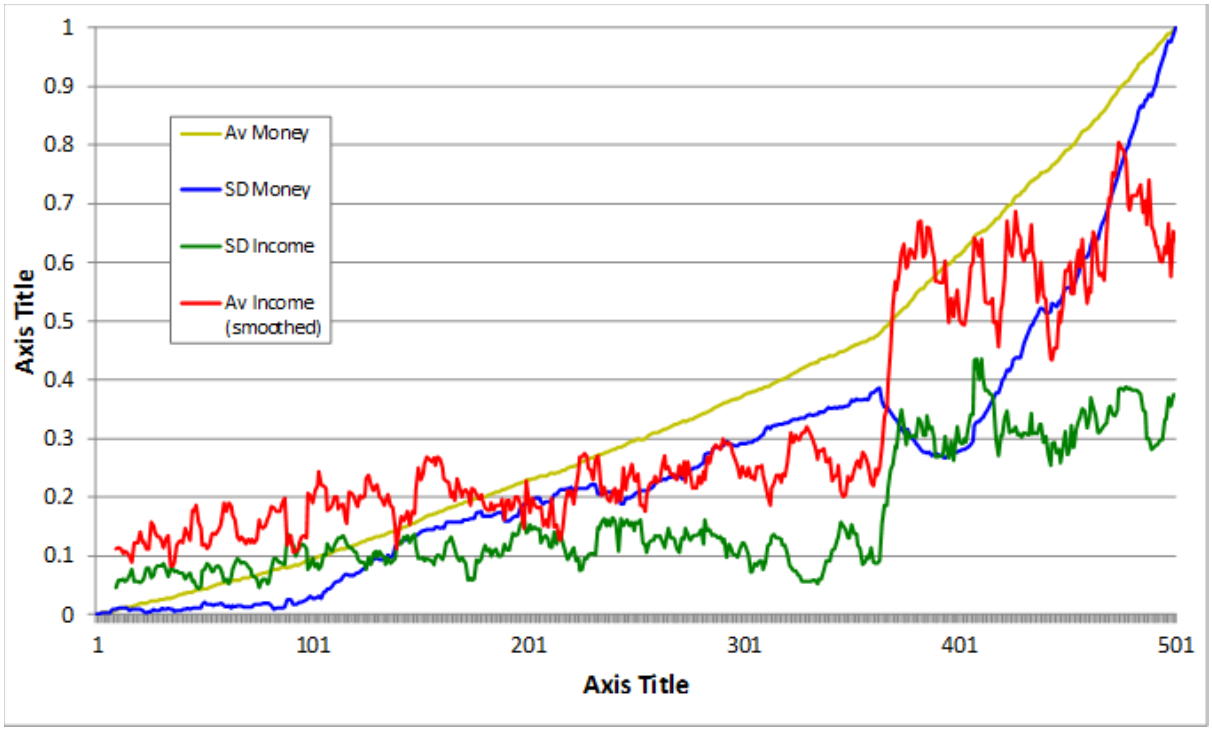

Figure A2.8 - The average money, the standard deviation of the money, the average income and the standard deviation of income of agents in the same single run of the model (Run 10 in the graphs immediately above), scaled so the maximum of all measures is 1 (income lines are exponentially smoothed to ease viewing).

This discovery around tick 360 has an impact upon incomes and accumulated value of agents (Figure A2.8). It seems to cause a sudden increase in both income and spread of income but a temporary drop in the spread of wealth before these then increases sharply – it seems that the discovery was made by a previously (relatively) unsuccessful agent that then overtook the old wealth leaders. After this event, the rate of wealth accumulation increased.

In this model, the potential for technological advancement is implicit in the affordances built into the making possibilities – this is built in to the model. The ability to try actions and learn what seems to work, according to the motivations provided to the agents is also built in. However the discovery of what works by the agents, and what they discover is largely a matter of chance. The inequality in terms of value accumulated is something that emerged in the runs that were done. Similarly the kind of market that emerges in terms of buying and selling is a macro-level outcome from the model – the micro-level actions and learning of all the agents combines to produce it. Thus the model spans and distinguishes between cognitive processes, individual practices and social phenomena.

An Ontology of the prototype Integrative Model

In simulation and computer science the formal, modelling equivalent of a Knowledge Framework is an ‘ontology’ (Livet et al 2010). This is a list of the types of entity that are represented in the model and their logical (Static) relationship.

The entities in this model are:

- **Elements** (an indivisible kind of **thing**)
- **Things** (configurations of **elements**)
- **Tools** (a kind of **thing**)
- **Environments** (made of **locations**)
- **Locations**
- **Affordances**
- **Needs**
- **Agents**
- **Motivations**
- **Evaluations** (of outcomes of **plans** according to **motivations**)
- **Actions**
- **Plans** (sequences of **actions**)
- **Skills** (ability to do **plans** so the outcomes have good **evaluations**, not implemented in prototype model)
- **Goals** (at the moment only implicit in the model)

The relationship between entities are as follows:

- **Things** are composed of indivisible components of different kinds – call the **elements**
- Joining **elements** in different configurations result in different **things**
- Some joins and splitting can be done without **tools**
- The **environment** is composed of different **locations**
- **Agents** implicitly inhabit different **locations** (in the prototype model agents are implemented as locations and cannot move)
- **Agents** keep the **things** in their own **location**
- The **environment** is composed of several **locations**, one of which the **agent** inhabits
- Each **location** has a set of **affordances**, that is **things** that can be extracted from that **location** at different costs
- **Agents** can get direct benefit from certain **things** – they can be used up to satisfy their **needs**
- **Needs** can be judged by **agents** according to their **motivations**
- **Agents** extract (from the **environment**), own, consume things (use them up for their own benefit or discard them)
- **Agents** give, buy, sell, and receive **things** with other **agents**
- **Agents** make **things** from other **things**
- **Agents** destroy **things**
- **Agents** use some **things** (**tools**) to transform other **things** (as part of their making or destroying), but **tools** cannot create new components of **things**
- Extracting, consuming, giving, buying, selling, receiving, making, and using are all **actions** that an **agent** could do.
- Not all attempts at doing **actions** by **agents** are successful.
- **Skills** are an ability to perform certain **plans** of **actions** so that the results of these **plans** are evaluated well according to their **motivations**
- **Skills** can be learnt only by doing **plans** of **actions** (though what **plans** are worth developing as a **skill** can be communicated in terms of the likely **evaluations**)
- **Agents** remember (or record) the sequence of **actions** concerning how they made/destroyed **things** as **plans** (these **plans** could include where to obtain the **things** needed for another **plan** or how to sell/dispose of the **things** that result or not)
- **Agents** can mentally join **plans** to form longer **plans** (where the **plans** are compatible)
- **Agents** also do **actions** without a **plan** – e.g. playing, trial and error, exploration (conceptually these could be meta-plans but anyway they have different properties to normal **plans**)
- **Agents** can execute **plans** that they remember
- **Agents** can give, buy, sell, receive, license **plans** with other **agents** (though the **plans** that can be communicated might be an abstracted form of the **plans** they remember)
- **Agents** have **motivations**, which they use to judge between alternate **plans** and other **actions**

- **Agents** assess past outcomes from doing **plans** according to their **motivations** (e.g., cost, novelty…)
- These **motivations** along with their **plans** and their past **evaluations** of **plans** help them decide their **goals** (e.g. do this **plan**, sell this **thing**, find a **plan** to achieve something, etc)
- **Goals** allow for a sequence of **actions** to be inferred (and hence attempted)

Note that neither the individual practices nor the group processes are built in to the model, but rather are emergent from it. This requires the actions of agents to be measured or interpreted in terms of actions within a societal context, but this is what happens in reality anyway, where we collectively both constitute and interpret actions in terms of social constructs. Note that there is no reason why, in a simulation, there can not be both "downward" as well as "upwards" causal processes, such as the creation of social norms or laws that then constrain or influence the agents (Conte et al 2001).

Relationship between the IM and KF

Although this model is only a prototype with no skills or communication yet implemented, it already illustrates a number of aspects of the KF. These include:

- An explicit atoms-bits distinction, between the things and the plans (remembered sequences of actions to make the Things). This allows plans to have value and be worth sharing between agents.
- The embedding of the agents within their environment, which is composed of: (physical environment) locations which offer the agent affordances in terms of things it can extract, and (social environment) the other agents with which it can trade things and communicate plans.
- The explication of the human elements at the individual level in terms of its needs, motivations, skills, learnt plans, goals and actions. This allows us to relate the dimension of cognitive process of the KF to the dimensions of individual practice and social phenomenon as these higher levels emerge from the actions of individuals.
- Already developed practices develop within the model, based on initial trial and error with doing actions to things, but later by building upon previous experience. What kinds of things an agent can make depends upon these developed practices, with an obvious path-dependence becoming apparent – future developed practices are both limited and enabled by past, learnt plans. Thus, the dimension of individual practice of the KF is displayed in the model but is an emergent micro-level phenomenon.
- There are rudiments of the dimension of social phenomena emerging in the model. As we see above, an unstructured market in items develops with agents learning what they can buy and sell, where they can buy and sell particular things and at what price. As we include communication structures, we would expect more social phenomena aspects to be illustrated.

Future co-development of IM and KF

By design, the IM reflects many aspects of the KF. The current structure of the KF in terms of its dimensions mirrors the micro-meso-macro levels that modeller and social scientists consider. Of course, the prototype IM, described above, does not capture all that is described in the KF. The DiDIY Project will facilitate the following processes to occur that encourages the co-development of the IM and KF:

- The development of the IM in response to the ideas of the project members, which constitute and fill the KF. This includes the inclusion of skills and multiple motivations in the IM framework.
- The development of particular scenarios to be explored (the impact of makerspaces, different IP/legal structures on sharing, and the impact of different communication structures/possibilities) will throw up new issues for inclusion in both the IM and KF. “User Groups” for each of these scenarios are being formed to direct, critique and inform the model development process. As partners engage with these modelling enterprises, it will start to inform how they think about the phenomena they are interested in and hence the structure and content of future versions of the KF.
- These variations of the IM for these scenarios will develop to illustrate the different “corners” of the building that makes up the KF dimensions, complementing the conceptual structures with explicit instantiations.

References

A more extended list of references on DiDIY can be found in the deliverable D2.2, Foundational interpretation of DiDIY.

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