D4.8 INTEGRATIVE MODELLING (RESEARCH AND EDUCATION)

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Executive summary

Deliverable D4.8, Integrative Modelling (Research and Education), presents the first application of the Simulation Framework used to support the integrative modelling for the whole DiDIY Project to some topics related to WP4.

After a recapitulation of the current state of the Simulation Framework, this deliverable provides a summary of the relevant results and issues from WP4, followed by a plan for how these might be investigated using the Framework. This investigation will focus on the issues of sharing of knowledge and/or tools and the possible change in the flow of learning from the traditional teacher-student direction to a more student-centred, peer-to-peer learning flow.

Revision history			
Version	**Date**	**Created / modified by**	**Comments**
0.0	09/12/16	MMU	First, incomplete draft.
0.1	13/12/16	MMU	Extensions and fixes.
0.2	15/12/16	MMU	Extension and fixes.
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0.4	17/12/16	MMU	Extensions and fixes.
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0.6	18/12/16	LIUC	Corrections and comments.
0.7	19/12/16	MMU	Extensions and fixes.
0.8	23/12/16	MMU / LIUC	Extensions and fixes.
1.0	26/12/16	LIUC	Approved version, submitted to the EC Participant Portal.

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1. Recapitulation of the Simulation Framework

The Simulation Framework – also called “A Model of Making”– has been introduced in detail in Deliverable D3.2 and an Annex to Deliverable D2.4, the Knowledge Framework. To make things easier for the reader of this Deliverable, this section gives a short overview of the current state of the Simulation Framework, including any extensions realised so far. For more technical details please refer to the above-mentioned Deliverables or check out the first version of the model, which is available online at openabm.org (Edmonds 2016).

The Framework was designed as a basis upon which several specific models can be constructed, allowing the exploration of a variety of “what if” or even counterfactual possibilities and thus giving a concrete, dynamic and complex instantiation of the issues and situations discussed within the DiDIY Project. In other words, it allows the development of a set of archetypal simulation models that act as thought experiments and analogies, allowing the possible impacts of DiDIY to be explored. These can be used to support analyses and outputs of this Project, but can also be used as an interactive output in themselves, allowing a wider public to play with, and hence appreciate, the issues developed therein.

The Simulation Framework comprises an agent-based model of an abstract “string maker world” with all the processes in place that may be necessary for future developments (making, using, buying and selling things), albeit in a basic or rudimentary form. This model distinguishes individual “makers” (agents), things and plans. Things are represented as strings, e.g., “ACCB”, made from a finite number of elements. Certain strings can be extracted from the environment (resources). All other strings have to be made from these. Some strings can have inherent value (targets). These can be “used” to get that value. Agents remember how they made things in terms of the actions necessary to get any particular outcome (plans). Plans can be arbitrarily complex. Since each action has a small cost associated with it, more complex plans tend to have lower value, unless they result in a more valuable thing. While agents will sometimes experiment to see what they can make, they prefer to re-use plans with higher value.

As should be clear from the above description, the Simulation Framework explicitly represents complex objects (things) and plans as separate entities in the model – embedding the “Atoms – Bits” distinction highlighted within the DiDIY Project. This allows plans, which are made of bits, to be shared between agents – either on a commercial or a free basis.

In the current version of the model, plan sharing is free. Since sharing of knowledge and instructions – be it online or in person in a makerspace – is a core characteristic of DiDIY activities and the self-image of makers, this seemed to be the obvious choice. To make sharing possible for the agents, the model contains a joint plan library, representing online contexts such as Instructables or Thingiverse. Agents may upload their plans to this joint library for other agents to use. An agent can also decide to download a plan from the joint library. At the moment, due to insufficient amount of empirical data about how and when makers actually decide to share one of their creations or make use of someone else’s instructions, this is both done with a certain probability. Whenever an agent executes a downloaded plan successfully, s/he may decide to give it an up-vote. These up-votes may in turn influence the agents’ decision about which plans to choose from the joint plan library.

In terms of implementing the Simulation Framework, we have chosen the simulation language NetLogo (Wilensky 1999), since it is the most accessible agent-based modelling language available.

This is a completely free and open-source language that has acquired many DIY simulation modellers, organised around several large open-access model libraries for the sharing and documentation of code under suitable CC licenses. This choice increases the chance that others will be able to inspect, understand, experiment with, develop and use the simulations produced. NetLogo also allows the more technical programming of extensions to this language using Java (also open-source). One such extension, a new NetLogo datatype called "factbase" to facilitate the modelling framework, has already been developed for DiDIY and made freely available to the public, including its source (Meyer 2016).

2. Summary of the results of WP4

This section gives a short summary of the results of the data collection study undertaken in WP4, concentrating on issues relevant for the future development of the Simulation Framework. An in-depth presentation and analysis of the collected data can be found in D4.4.

The study started from the premise that DiDIY is related to a new generation of students already immersed in new technologies ("digital native"), as well as to the adoption of new pedagogical tools and approaches for the benefit of general/adult learners in acquiring new skills, abilities, and ways of thinking. Thanks to the Internet, we also see learners much more involved in exchanging information and knowledge over the web than ever before. Students could be learning much more in these informal environments, making education become less institutionalized and more personalized. Thus it could be the case that students are moving from "consumers" to "producers" of knowledge. This would make educational institutions competing with a more fluid concept of learning that takes place mainly outside the classroom and in recreational spaces.

The aim of this research was to understand the current European situation regarding the adoption of the Digital Do It Yourself attitude in education, and to identify successful practices that may provide useful examples and may serve as a foundation to develop recommendations and guidelines. In order to elicit pertinent information, semi-structured interviews with European experts in the DiDIY domain and stakeholders in the education sector as well as a more general survey using questionnaires were conducted. Both sets of respondents were asked about the role of sharing, the way sharing and communication are reshaping the flow of learning, the role of teachers and trainers, and if/how DiDIY is transforming this role.

2.1 Questionnaires

One hundred and twenty one (121) questionnaires were completed and collected. The sample is composed of 40 female, 72 male, and 9 people who preferred not to answer. The average age is 23.2 ± 7.4 years. In particular, there were 45 people under 20, 62 people in the age range 20-40, and 4 people in the age range 40-60. Ten people did not answer this question.

In all questionnaires a question was included to enquire about the professional background of the respondent: 8 people declared to have an artistic background; 21 people a humanistic background; 44 people a scientific-technological background; 39 people a technical-professional background; and 9 people did not answer.

2.1.1 Attitude towards DiDIY

The questionnaires comprised several sets of questions intended to investigate the current attitude of the respondent towards the DiDIY movement. Amongst others, respondents were probed with regard to their feelings about making something "with your own hands", their appraisal of DiDIY, and their knowledge and use of new DiDIY tools. Figures 1 to 3 show the results of the analysis of answers to these topics.

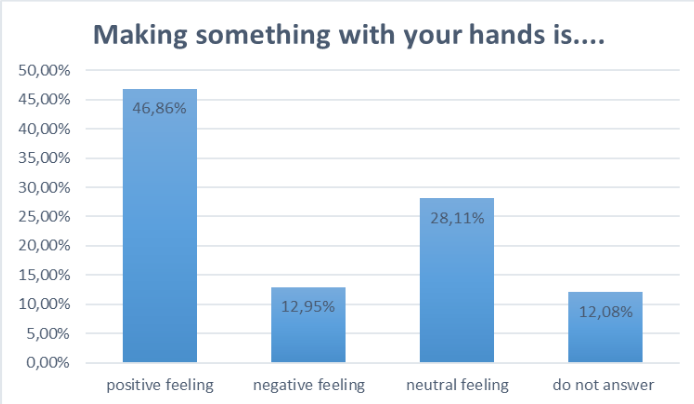

Figure 1 Percentage of positive and negative feelings on "making something with your hands" question.

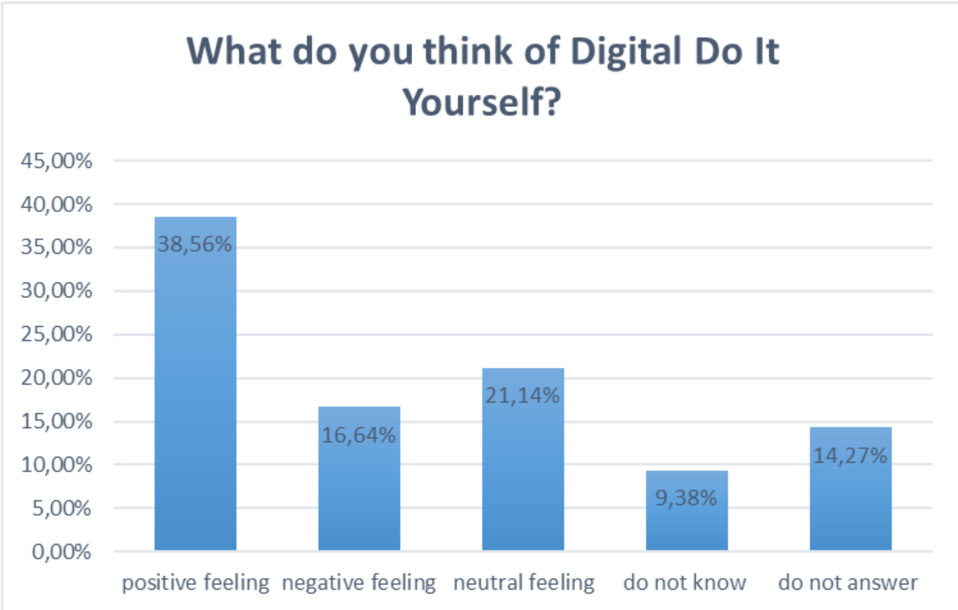

Figure 2 Percentage of positive and negative feelings on "what do you think of DiDIY" question.

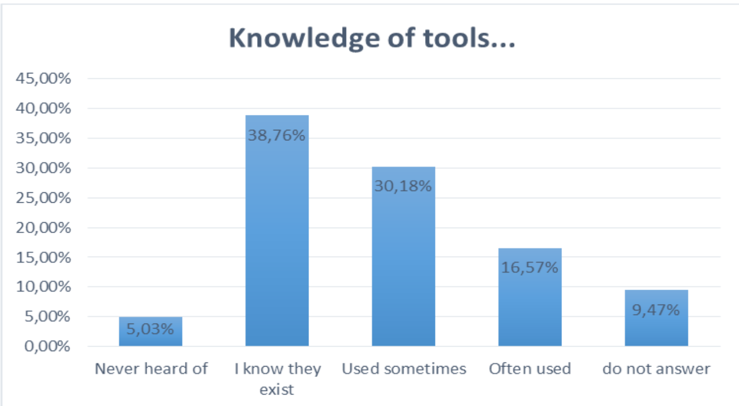

Figure 3 Knowledge of DiDIY tools

2.1.2 Creativity, communication flow, role of teachers, sharing

This set of questions was administered to a subgroup of 55 people. The questions were grouped according to four topics: creativity, flow of communication, role of teachers and trainers, and sharing. The results of the last three topics are reported in the following figures.

Figure 4 Results of the questions related to flows of communication

Figure 5 Results of the questions related to the role of teachers and trainers

Figure 6 Results of the questions related to the importance of sharing

2.2 Interviews

An extensive mailing list of 264 European stakeholders was developed during the first 18 months of the Project, ranging from European Ministries of School and Education to fab labs, maker spaces and the RoboCup Junior initiative. From all people contacted to take part in an interview, 27 replied and agreed, with 22 interviews actually taking place. These interviewees represent fifteen EU countries, so a wide variety of experiences could be included in the study nonetheless.

2.2.1 Role of sharing

Sharing plays an important role in FabLabs, CoderDojo, Eurobot, MakerSpaces, and schools. In these environments, instruments, tools, and competences are constantly being shared. These initiatives operate so as to create interesting things, to engage people in something they like to do. This is a great opportunity for children to learn new technical and social skills, as well as to learn from each other. An open vision leads to new ideas and products: however, this sharing is not market-driven, but rather comes from the desire to see things made. The problem solving techniques and the working group amplify the role of sharing as a tool to learn together. Creativity is less related to group activity or to the leader, but the environment itself allows people to be creative, because there are no constraints. DiDIY-related learning processes tend to reshape also the roles of individuals, given that working in a group lead to an enhanced communication, compared to the standard student-teacher relationship. Indeed, teaching a friend can improve the understanding of what you are teaching, and learning from a friend can improve self-confidence.

However, there were some perplexities related to the idea that pupils might now be more content-producers than before. The head of the Institute for Learning Innovation of Friedrich-Alexander-Universität Erlangen-Nürnberg (Germany) reported that this aspect has in fact not changed and that pupils do it at the same rate, but maybe in other forms, although certainly sharing has become easier nowadays. The novelty does not reside in producing, rather in sharing: creativity overall might be decreased, while the ability to reuse work done by others, hence reducing one’s workload, might have increased. It must be noted that the students’ motivation in producing new knowledge could be very limited overall (why should they, if not required?) because, as with the general population, very few people are interested in providing services to others for free, and students might have others priorities, rather than producing content.

2.2.2 Learning flow

As a project, we were also interested in understanding how communication and sharing are reshaping the learning flows between students and teachers, and how the learning process takes place during “learning-by-doing” activities.

We received different feedback from the stakeholders operating in the education area. The most common opinion was that learning is changing, being nowadays more focused on the differentiation and personalization of the learning environments. Students want to decide what and how to study, while adult learners need to develop new competences to be part of the professional evolution in the technological world. Students need to be prepared for the 21st century world, and this means that they need to go beyond the traditional curriculum. It is possible for pupils to create and share content they are interested in online and teachers need to make an effort to introduce this new knowledge into schools, where it is recognized as a very important skill for the future. In general, these activities are not integrated in the class curricula but are optional/extra activities outside school hours.

The founder of FabLab Frosinone (Italy) reported their experience of using dedicated open platforms to share research processes and competences. In their opinion students currently have a low level of independence, which is why the fab lab is trying to create open and reusable knowledge. Most of their activities are “hands-on” meetings or project-based workshops where, after a very brief introduction, they start working on a joint project as a group. Motivation to learning is the key: this new learning flow is not a “teaching flow” anymore but a “reasoning flow” (“I don’t know the answers to everything, let’s find out together”).

The critical issues were identified in how to sufficiently structure such learning. Strong pupils might be able to successfully perform according to this new paradigm, as they might have enough discipline to develop their own learning strategy and path, but others might need more help.

Another critical issue is a too optimistic view of making as a trendy movement: making is important but thinking is important too. Thinking critically about making is essential and an ethical point of view on distributed manufacturing, recycling, etc. must be kept.

2.2.3 Role of teachers

If and how DiDIY can be exploited to ease the transition from a teacher- and curriculum-centred school to a student- and experimentation-centred education is still an open issue. We therefore need to explore how the role of teachers might change as a result.

The most common view about this change in the educational environment is that this process requires teachers to be creative, to find their own resources, which can be difficult and demotivating for some. New contents are available almost everywhere (online courses and resources, shared events and conferences) but changing the teachers’ attitude towards technologies could be a hard task. Some of them might not able to use these new technologies, or at least at very different levels (they might know how to use a computer, but in traditional, passive way). The interviewees shared the opinion that this kind of innovation is still an exception, not the norm.

Several constraints emerged from the interviews regarding the role of teachers. One issue is that teachers are afraid of failing in front of their students; they fear that the students become more knowledgeable than they. CoderDojo Wilmslow believes that we should try and adopt the notion that it is not fair for teachers to think they must have all the answers to every student’s questions.

Rather, they should feel free to not know everything. This is where the project-based approach to didactics should come into play (“Let’s find the answer together”).

The stakeholders interviewed proposed some solutions to these constraints: training teachers (since you cannot expect teachers to do that themselves), showing how to use these new technologies in real contexts and showing successful experiences. The training is focused on teachers only, to help them overcome their “fears” and to feel more confident about using new technologies.

2.2.4 Response of schools as an institution to the use of DiDIY

As of today, general ICT technologies – let alone DiDIY-related technologies – have not yet been fully adopted in elementary or high schools of the European countries we surveyed, but all interviewees pointed out the need to change this. Schools are slow in taking up new things because they must deal with more preliminary, basic problems (connection, old computers). Teachers work mainly individually, and they need to be able to apply IT on concrete contexts and the funding availabilities to renew the school system seems to be very low.

The coordinator of the ICT and digital media policies at the Flemish Ministry of Education identified four main requirements for DiDIY to be integrated in schools: a flexible physical infrastructure, the availability of teachers who can work with these technologies, access to contents, and the ability to fit these new contents into the core curriculum. All of them are important preconditions to the adoption of digital technologies by schools: if only one is lacking, the whole process stops.

However, in all the European countries we surveyed fab labs and maker spaces organize free courses and workshops for elementary and high school students. The most common courses are related to coding, 3D printing, Scratch, robotics, and Arduino. In general, they found some difficulties to be part of the high school system because of the fixed courses. The shared opinion is that DiDIY should be included in school curricula via an institutional approach, i.e. top-down. In the current structure of the curriculum there is not enough time for (Di)DIY courses, and the activities offered by fab labs, maker spaces or similar initiatives are considered extra-curricula activities.

3. Future development of the Framework with regard to WP4

This section lays out our plans to investigate with the means of an integrative agent-based model some of the issues raised in WP4 about the impact of DiDIY on research and education.

If we were to try to model a more or less close approximation of bringing DiDIY into an actual school environment, a lot of detailed empirical data about the motivations, behaviours and decision-making processes of the actors involved (teachers and students at the very least) would be necessary. Collecting such data on the required level of detail has not been within the scope of the work undertaken in WP4. The available data from this work package covers instead interviews with important representatives of the DiDIY domain, extracting their expert opinions on the impact of DiDIY on education, and online questionnaires sampling the opinions of students and teachers, among others. Some of the central findings of the analysis of these interviews and questionnaires as reported in Deliverable 4.4 and summarised in the previous section are related to the importance of sharing (ideas, knowledge, tools) and the possible change in the flow of learning (more peer-to-peer or group-based instead of the traditional teacher to students flow).

Instead of implementing a particular case study, we will therefore adopt a more general approach in our model-driven investigation of the impact of DiDIY on research and education, concentrating on the issues of sharing and learning flow.

3.1 Sharing of knowledge and tools

Firstly, the concept of sharing knowledge can already be expressed in the current version of the Simulation Framework as it incorporates the possibility for agents to share plans (i.e. instructions to make things) via a joint plan library (i.e. an online DiDIY database). Agents are able to select one of the plans they developed and “upload” it to this library. They are also able to browse the library and select a plan they find interesting to “download”. If the agent deems such a downloaded plan to be successful, it may “up-vote” it on the joint library, thus influencing the future decisions of other agents when they browse the library in search of a good plan to add to their repertoire.

We will extend this to include sharing of tools. In the current version of the model, tools are only rudimentarily developed. They are a special type of thing in that they contain the special character “>”. This indicates that the item can be used to “transform” the string on the left of the “>” into the one on the right in another string (e.g., AB>BA used once on the object ABB would result in BAB). They are treated as things in that they can be made, taken apart or passed on to other agents. The reasoning behind this was that this allows agents to not only make things but also develop new tools. For the context of applying the Simulation Framework to DiDIY in the education domain, the aspect of tool development is not a priority. We will instead make the plausible assumption that a number of tools already exist in the world of the agents and that they do not change throughout the simulation.

Another point is the way tools are realised. At the moment, each tool is very specific as it can only operate on exactly one particular string, e.g. the tool “AB>BA” can only transform the string “AB” into the string “BA”. For the purpose of the model to be developed, a more generic version of tools seems appropriate. One option would be to try to stay as close as possible to the DiDIY domain and mimic the tools available there, e.g. have a “scan” tool that takes a string and turns it into a digital representation, which in turn can be fed into a “print” tool that produces a new string from this digital representation. As in the real world, these digital representations would be distinct from plans, which are sets of instructions of how to make a thing (or indeed its digital representation). Both things and their digital counterparts could be manipulated via dedicated actions or tools. This would explicitly represent the conversion of "atoms" to "bits" and vice versa, which has been highlighted within the DiDIY Project, in the model. Another option is to rather keep tools in line with the world of strings and take inspiration from the operations available in most programming languages to manipulate strings. This could include tools like "insert" (inserting a string into another string at a specified position), "substring" (copying part of a string) or "remove" (extracting part of a string).

3.2 Learning flow

As the analysis of the data collected in WP4 has shown, there is a common expectation that DiDIY may change the flow of learning in education and research. DiDIY activities are often group-based, with participants working together to find a joint solution instead of an expert (teacher) telling them what to do.

To be able to represent different forms of learning flow, we will introduce the following into the existing Simulation Framework:

1. *Skills*: Skills will be associated with the actions and tools available to the agents. In addition to the application of tools, the Framework contains a number of actions that agents may perform to manipulate things without the explicit use of tools, e.g. "join" and "split". At the moment, skills are not part of the Framework, so any actions – with or without tools – can be undertaken by any agents with a 100% success rate. This is certainly unrealistic.

   Skills will be represented as a number between 0 (no skill) and 1 (perfect). Each agent will keep track of its skill level for each action that requires it.

2. *Learning of skills*: Agents will need to obtain the skill to execute a particular action. Some actions might be easily accessible for all agents but, as the analysis of the survey data shows, learning to operate tools needs to be included in the model. Only about 17% of people questioned stated that they often use DiDIY tools, whereas the majority had no experience (see figure 3).

   The process of learning a skill will need at least one interaction with a skilled agent to get started and a number of subsequent executions ("practice") to perfect. Agents might differ in their speed of learning, i.e. the number of practice actions required to achieve a perfect skill level. Some tools might also necessitate a longer time to master than others.

3. *Social networks*: In order to be able to compare different setups to the flow of learning we will introduce social networks to the model. Agents will be connected via network links to other agents they can learn from. By choosing different network topologies, we will be able to model for example either the traditional school setup, where students learn centrally from a skilled teacher, or a group-based learning environment, in which learning happens on a self-organised basis in peer-to-peer interactions.

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