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SCUOLA DI INGEGNERIA INDUSTRIALE

Corso di Laurea in Ingegneria Gestionale
per la Produzione Industriale

**Education in the DiDIY Era:
Implications and Opportunities**

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Anno Accademico 2015 – 2016

ABSTRACT

DIY has always been present in society. Creating, making things, inventing and tinkering is in fact intrinsic of human nature. Many local DIY communities have risen in the past decades, especially around common interests such as sewing or bricolage.

At the same time, the advent of the Internet brought a dramatic change in the way people communicate and opened up a new array of possibilities. For example, Do-It-Yourself (DIY) communities could now engage on a wider scale and with little to no cost, having the potential to expand both in scope and reach. Digital communication enabled a higher degree of connectivity and the social network effects that it enabled (such as the ones generated by DIY enthusiasts) have played a key role in the development of society in the past years.

Together with the Internet, movements such as Open Source and Open Hardware were born, advocating for the freedom of information; slowly, they evolved into the ideal of the democratization of knowledge, which should be freely shared online and made available to anyone.

Technology also evolved and patents such as the ones on 3D printing expired. Gradually, the 3D printer gained popularity and paved the way for the wide diffusion of affordable digital fabrication technologies; this includes 3D printers such as the Open Source Rep-Raps, programmable boards such as Arduino/Raspberry Pi, laser cutters and so on. These technologies enable the embedding of digital information into physical objects (as in smart sensors) and vice-versa, (as in 3D printing a real object from a digital file). The paradigm of creation shifts, as atoms assume a new relationship to bits.

In this dynamic context, a new interest in creativity and tinkering is rediscovered and amplified on a global scale through the Internet; movements such as the one of the Makers are on the rise. What was once known as DIY has evolved into Digital-DIY, or DiDIY: a digital revolution that closes the circle and brings the interest back to the bone, back to making things.

This dissertation is based on the themes of a research project (H2020, n.644344) funded by the European Commission and lead by Università Cattaneo LIUC, aimed at analysing DiDIY and its impact on society.

In particular, this research studies the implications and opportunities of the application of DiDIY in the field of education. In recent years DiDIY has already been adopted in education, such as in Fab-Labs or Makerspaces. However, its current applications are still limited in scope/purpose and mostly related to informal educational contexts.

The research objective was achieved through the development of experiential workshops run by the author and by conducting semi-structured interviews with both teachers and students. The main purpose of the research was exploratory and a qualitative approach was adopted.

Findings suggest that DiDIY offers great opportunities to improve education. Namely, its introduction in the existing curricula could help stimulating students or allow teachers to tackle themes that would have previously been very difficult or impossible to explore.

Furthermore, given the flexible nature of DiDIY activities, it is possible to adopt a DiDIY approach in virtually any stage of education and to tailor each activity according to the desired learning objective. Findings also show that DiDIY should not revolutionize the existing curriculum but rather be adopted as an integrating and enhancing tool to existing teaching methods.

The main challenges regarding the adoption of DiDIY revolve around its implementation: in fact, schools and universities would need to undergo relevant investment in resources and training (especially for teachers) in order to properly incorporate DiDIY activities in the curriculum.

Given the novelty of the theme, this research represents one of the first, formal approaches to the study of DiDIY and its implications in education. As such, its findings should not be regarded as final but rather be used as a reference by future studies aimed at further exploring these concepts.

Keywords: *Education, DIY, DiDIY, Do-It-Yourself, Digital Do-It-Yourself, 3D Printing, Teaching, Learning, Atoms-to-Bits, Workshop, Interview, European Commission, Horizon 2020.*

ACKNOWLEDGMENTS

First and foremost, I would like to thank my family and my loving wife for their incredible support throughout all my life: this final chapter of my studies is dedicated to you. Thanks for all that you have done for me, and for all that you will do.

Thanks to all the people that I met in this incredible journey, who made it worthwhile all along. Thanks for having shared memories, joys, fears and dreams; it has been a blessing to be able to count on you as dear friends.

I acknowledge that this research would have not been possible without the support of Università Cattaneo LIUC, the European Commission, the DiDIY Research Team and The Robert Gordon University. I would like to thank my two coordinators, Professor Luca Mari and Professor John Park, for their invaluable help and guidance.

My gratitude also goes to MAKE Aberdeen and its staff for the great help in the organization of the experiential workshops; a great thanks especially goes to Ben.

A big thanks to all who participated in the workshops and who also took time to help me with the interviews. Thanks to Anna, Annie, Anya, Dat, Elvis, Giuseppe, Massimo, Mirko, Rosemary and Sara. A huge thanks goes to Mauro for his incredible help.

As a closing note, I could not conclude this section without renewing my best wishes for Spoon and the infamous dweller of page 23, whose legacies will never be forgotten.

A thanks also to you, the reader: thanks for your attention; I hope you will enjoy reading this document.

This work is dedicated to my dear grandparents.

Costantina, Giacomino, Lena and Rolando. This one is for you.

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GLOSSARY

DIY	Do-it-Yourself
DiDIY	Digital Do-it-Yourself
ABC	Atoms-Bits Convergence
STEM	Science, Technology, Engineering and Mathematics
EC	European Commission
PLA	Polylactic acid
RGU	The Robert Gordon University

1. INTRODUCTION

The aim of this research is to briefly outline the emerging phenomenon of DiDIY and to study the implications and opportunities that DiDIY could bring forth in the field of education. DiDIY, or “*Digital Do-It-You*” can be identified as “*a new socio-technological phenomenon which stems from the widespread availability of digital devices that support the convergence of physical (atoms) and informational (bits) components – such as 3D printers and Arduino boards – as well as the growing accessibility of related knowledge and data through open online communities*” (LIUC et al. 2014, p.31).

DiDIY is a dynamic and interesting phenomenon that could lead to the emergence of new scenarios and opportunities in different aspects of society; furthermore, it holds the potential to impact not only people and organizations but also nation states and, to a wider extent, the ways these entities relate. However, due to the novelty of the phenomenon and its dynamic nature, it is not yet possible to certainly outline its evolution and as such, studies like the one presented in this dissertation will prove vital to the understanding of DiDIY and its implications.

In particular, the phenomenon should be analysed and understood taking into consideration two perspectives:

- **The increasing ease of access to technologies and knowledge that enable a direct conversion and integration of digital information into physical artefacts, and vice-versa** (Ratto and Ree 2012); this is identified as the “*Atoms-Bits Convergence*”, or “*ABC*” (LIUC et al. 2014). In this regard, DiDIY is embodied in technologies such as 3D Printers, laser cutters, Arduino/Raspberry PI boards, 3D scanners or 3D modelling software. The ease and affordability of manufacturing and prototyping effectively acts as an enabler and amplifier of

personal creativity and inventiveness, opening up new concepts such as the one of personal fabrication (Gershenfeld 2008).

- **The democratization of knowledge and the social and technological network effects that characterize it.** The development of online communities and movements such as the one of the Makers emphasizes the importance of concepts such as collaboration and cooperation (Hoftijzer 2009): ultimately, what is produced by an individual could not be the mere result of his/her only intellect but the final outcome of multiple contributions coming from an interconnected, world-wide network of developers. This paradigm, which can be seen both as an enabling cause and a direct consequence of the first perspective, contributes to fostering concepts of open innovation and democratization of not only information but also projects and ideas (Blikstein and Krannich 2013).

The result is the emergence of a new, dynamic framework that is bound to challenge existing dynamics of society, in what some already called a new Industrial Revolution (Berman 2012).

This dissertation follows the themes of a research project (grant agreement #644344) financed by the European Union under the “*Horizon 2020 Research and Innovation Programme*” aimed at studying DiDIY, its implications and the way it is reshaping modern society. The project is led by “*Università Cattaneo LIUC*”, the home university of the author, together with other European universities and bodies (acknowledged in this work as the “*DiDIY Research Team*”). One of the main areas of analysis of the DiDIY project is in fact education and this research will be specifically aimed at analysing the way DiDIY is affecting its deployment.

1.1 Background Information

A preliminary literature review suggests that scholars agree on the broad possibilities that DiDIY technologies could have in education (Eisenberg 2013) and the fact that DiDIY approaches could be successfully applied to a wide range of curricular activities and disciplines (Vossoughi and Bevan 2014). It is generally agreed that DiDIY represents a great potential, but it is still unclear how this perceived potential could be concretely realized on a wide scale and integrated into formal educational curricula; furthermore, and likely due to the novelty of the phenomenon, most of the existing literature examples only describe limited applications of DiDIY, such as pilot projects or specific workshops, seminars or classes (DiDIY 2016).

While existing studies underline the importance of factors such as creativity (Boy 2013) critical thinking (Bers et al. 2002) and fluency with technology (Blikstein 2013), it is not entirely clear what the critical determinants of success in the deployment of DiDIY for educational purposes are. Moreover, existing studies often adopt either the perspective of the teacher or the student, rarely addressing both.

The lack of content in literature is mostly due to the novelty of the theme, as the publishing date of most studies on the matter testifies; to be more specific, the very own research project that this work is part of is aimed at creating “*a conceptual framework that will enable the analysis, exploration and understanding of the impact of DIY in a human-centric digital age*” and at “*producing well-founded transferable information, models and guidelines to support both education and policy making on DiDIY as it is forming*” (LIUC et al. 2014, p.31). It is especially relevant to underline the dynamic nature of the phenomenon and the fact that while mainly driven by technological factors, a social and cultural perspective should be adopted in its analysis rather than a technological one (DiDIY 2015b).

1.2 Aims and Objectives

The main objectives of the study will be:

1. to develop a conceptual framework for the analysis of DiDIY and its impact on education;
2. to identify the critical factors underlying a successful deployment of a DiDIY approach to education;
3. to develop DiDIY experiential workshops aimed at testing the conceptual framework and at gathering data about its participants and their interaction, other than divulging the concept of DiDIY;
4. to identify a relevant sample;
5. to conduct qualitative interviews adopting a dual perspective of students and teachers;
6. to analyse the collected data and make recommendations on the subject with the aim of facilitating the successful adoption of a DiDIY approach to education.

The contribution of this study to existing literature will be:

1. the adoption of a double perspective that will consider the opinion of both teachers and students,
2. the analysis of the critical factors in the deployment of DiDIY in education and
3. a review of positive and negative implications of DiDIY in education.

1.3 Rationale

The interest of the author in engaging in this research project stems from his academic background. He studied Management Engineering in “*Università Cattaneo LIUC*” and worked as a collaborator in the digital manufacturing laboratory “*SmartUp*”, which later became the first “*Makerbot Innovation Center*” in Europe. In that context, the author learnt about 3D printing and digital manufacturing and he then developed his bachelor

thesis on the impact of rapid prototyping in industrial contexts, especially analysing a particular case in the fashion industry.

After his thesis he kept engaging in digital manufacturing activities and when the university received the research grant from the EC to study DiDIY, he decided to ask permission to analyse part of the phenomenon in his master's dissertation. Given his background as a teacher in an Italian technical school and in several introductory workshops to Arduino prototyping and 3D Printing in LIUC, he specifically decided to focus on the education area.

1.4 Chapter Overview

This section will briefly outline the content of the following chapters, in order to give the reader a clear understanding of the structure of this study.

1.4.1 Introduction

This chapter outlines the scope and aim of the dissertation, other than providing insights about its structure.

1.4.2 Literature Review

This chapter outlines the relevant background theory concepts that lie at the foundation of this study. The main themes are analysed and key findings of the literature review are presented. The conceptual framework characterizing this study is also outlined.

1.4.3 Research Methodology

This chapter gives a very brief overview of Research Methods principles and outlines the methodology decisions and tools that the author chose to adopt. In particular, the structure of the workshops and of the interviews is discussed.

1.4.4 Findings

This chapter presents the findings of the research, especially focusing on the findings of each phase: workshops, questionnaires and interviews.

1.4.5 Discussion

This chapter critically evaluates and discusses the issues and problems that the author encountered during the research. A critical perspective over the achievement of the initial research objectives is also presented, along with an insight on possible future developments of further research on the topic of DiDIY in education.

1.4.6 Conclusion and Recommendations

This chapter summarizes the conclusions that the author drew during the research, while also presenting his recommendations.

2. LITERATURE REVIEW

2.1 Initial Literature Review

Before proceeding further, it is important to take a moment to clarify the concept of DiDIY. It should be conceived not only as a particular form of DIY that exploits digital technologies, but also as something broader. As such, studying DiDIY will require to acknowledge concepts relating to DIY but also concepts that are specific to DiDIY (DiDIY 2015a).

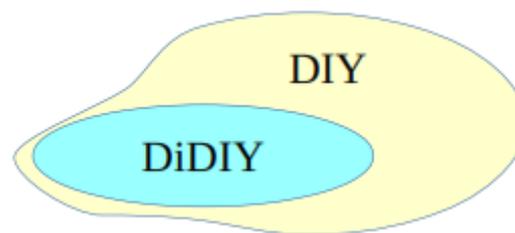


Figure 1: The relationship between DiDIY and DIY (DiDIY 2015a)

Furthermore, DiDIY can be interpreted in two ways:

- **as an activity**; in this perspective, it is possible to study it by analysing tools, materials, products, the creation of artefacts etc.
- **as a mindset**; in this perspective, it is possible to analyse it in terms of attitudes, motivation, competencies, creative process etc.

Usually, DiDIY originates as an activity and then turns into an attitude or a mindset, creating a positive feedback between the two components (DiDIY 2015a). For example, in education, when students are assigned a task to complete they can develop a mindset upon executing the task, which can then be transferred to other learning activities (DiDIY 2016). While this duality was already present in forms of DIY (Atkinson 2006), the digital component of DiDIY (embodied both in the

social/technological network effects and in the ABC) further amplified the feedback process and contributed to the social expansion of the phenomenon.

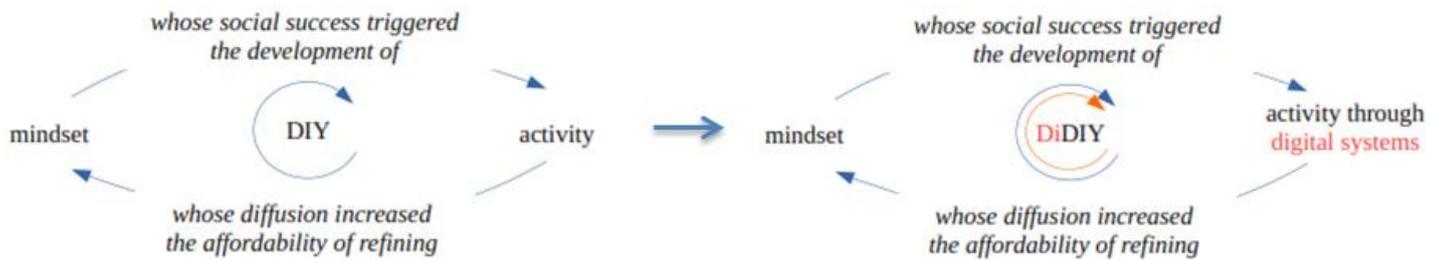


Figure 2: The positive feedback between DIY as a mindset and as an activity and the evolution to DiDIY (DiDIY 2015a, adapted by the author)

As such, it is important to consider also the psychological and sociological components of DiDIY, other than its technological one (which could be misinterpreted as the major factor of DiDIY but should be perceived as a necessary enabling factor instead).

The opportunities of employing DiDIY in education can be understood through the “*learning by doing*” paradigm proposed by John Dewey (1902); he and other academics believe that education should be experiential and involve real-world artefacts (Freudenthal 1973, Montessori 1917). Successively, the studies of Freire (1974) underlined the importance of unleashing students’ talents by using education as a form of empowerment and as a generator of self-esteem: as such, educational projects should connect with problems that are meaningful to the students, in order to make the achievement of the solution an educational, but also an empowering experience (Blikstein 2008, Cavallo 2000).

The concepts of DiDIY in education also relate to the “*constructivism*” theory (Wadsworth 1996) which implies that learners can develop and acquire knowledge through their experiences; this theory was later refined by Papert in the “*constructionism*” theory (Harel and Papert 1991), which implies that the learning process can be enhanced through the

creation of real, meaningful objects and by sharing such objects within a community: “*construction that takes place ‘in the head’ often happens especially felicitously when it is supported by construction of a more public sort ‘in the world’ [...] (where) the product can be shown, discussed, examined, probed and admired*” (Papert 1980, p.42).

Other academics have built upon the theory of constructionism and developed different perspectives on the theme, however most studies tend to agree that four main concepts lie at its foundation (Bers et al. 2002):

1	The belief that constructionism is important in education.
2	The importance of real objects and artefacts to support the development of critical thinking and knowledge.
3	The belief that powerful ideas empower the individual; more specifically, ideas can enable new, meaningful connections within different domains of knowledge and ultimately help developing new thinking patterns (Papert 2000) which can then be applied to other contexts. This principle is aligned with the theory of the “ <i>integrated curriculum</i> ” (Edwards 1993), which advocates for the adoption in education of powerful ideas and concepts which are meaningful for the students and that are applied and generated across disciplines.
4	The premium value offered by self-reflection; the learning experience can be enhanced by encouraging student to reflect upon their creative process and the multiple factors that affect their learning experience (Bers et al. 2002).

**Table 1: The main concepts of constructionism
(generated by the author, adapted from Bers et al. 2002)**

Blikstein (2013) argues that due to different factors the second half of the 20th century marked a transition from a practical towards a more theoretical, “*skill-based*” form of education. For example, already in 1999 the “*US National Research Council*” published a report calling for the need of a “*fluency*” approach, as opposed to the traditional “*skill-based*” one commonly adopted in schools; the report emphasized the need to adopt a more dynamic and technology-based approach in education that would lead to the development of technological fluency to “*empower people to manipulate the medium to their advantage and to handle unintended and unexpected problems when they arise*”

(National Research Council 1999, p.18); a successive publication in 2002 further reinforced this thesis (National Research Council 2002).

Nowadays, technological fluency is no longer seen as a requirement for only STEM subjects but as valuable across all disciplines (Blikstein 2013). The widespread availability of affordable digital fabrication tools (Gershenfeld 2008), the democratization of knowledge (Hoftijzer 2009) and the rise of open-source online communities based on concepts of open sharing and innovation (such as "The *Makers*") (Dougherty 2012) further reinforced this perspective, effectively creating a favourable context for the development of DiDIY.

The re-discovered interest for a more creative and practical approach in education can also be in part attributed to the "*realization that the traditional models of professional education may fall short in the changing economic context [...] we encourage individuals to transgress traditional disciplinary boundaries and learn to function in whatever fields of knowledge they need to accomplish their goals*" (Do and Gross 2007, p.1). Furthermore, Blikstein (2013, p.2) argues that "*digital fabrication and 'making' could be a new and major chapter in this process of bringing powerful ideas, literacies and expressive tools (to education) [...] in addition, there are calls everywhere for educational approaches that foster creativity and inventiveness*". It is as if "*the evolution in the role of technology has brought a cathartic return to the roots of making*" (Antonelli 2012, p.6).

Many studies have been carried out applying technology-based approaches (or expressions of DiDIY) to education; for example, some relied on the use of programming languages such as the LOGO language (Stevens et al. 2008), or robotics, such as LEGO Mindstorms (Behrens et al. 2010), to teach creativity and critical thinking. Further examples are given in the table below:

Projects/Topics	Brief	Source
FabLab@School Project	Aims at developing a world-wide network of educational digital fabrication labs to be used by high-school and middle-school students	(Blikstein 2013)
MC2STEM High School	Opening of digital fabrication labs to help the development of cross-disciplinary skills and reinforce the teaching of STEM subjects	(Perry and Wallace 2012)
MAKERSPACE Project	Founded by DARPA, the project aims at installing 1000 digital fabrication labs in schools across the United States	(Blikstein and Krannich 2013)
Fab Lab Robotics Outreach Programme	Aimed at teaching basic electronics and programming skills in marginalized areas of Kenya through the development of workshops	(Wanyiri and Ombatti 2013)
RoboCup Jr	A study of the Robocup Jr, an international robotics competition aimed at promoting STEM disciplines to young students	(Eguchi 2016)
Rep-Rap and Open Source 3D Printing	Deployment of workshops where teachers were encouraged to build their own 3D Printer and reflect upon the educational possibilities that Open Source 3D Printing can bring to education	(Schelly et al. 2015)
Programmable Board and Electronic Prototyping	A study in three universities based on analysing the impact of providing unlimited access to programmable digital boards to students to enhance their learning outside of class	(Radu et al. 2012)
Digital Fabrication	A practical application of digital fabrication tools in a 45-hour course developed in Denmark	(Smith, Iversen and Hjorth 2015)

Table 2: Examples of applications of DiDIY in education (generated by the author)

Gersehenfeld (2012) was among the first ones to bring the concept of personal fabrication in a classroom with the development of the “*Fab-Lab*”. The success of the initiative was so great that it is commonly regarded as one of the two major catalysts of the Maker movement (Blikstein 2013), together with the establishment of the “*MAKE Magazine*” (and later of the “*Maker Fairs*”).

It is also important to note that educational institutions “*are now competing with a more fluid concept of learning, that takes place mainly outside the class and in recreational spaces*” (DiDIY 2016, p.25). This creates a shifting paradigm in the relationship between

students, teachers and learning and creates opportunities and challenges to bridge formal and informal education (Trinder et al. 2008).

Students are in fact increasingly engaging in informal learning that happens online, in museums or laboratories (Halverson and Sheridan 2014); the community aspect is important, as is sharing and cooperating with peers. To an extent, students can become peer-to-peer teacher themselves: this transition from student to Maker symbolizes the constructionism approach in the shift from a passive consumer to an active producer of knowledge (DiDIY 2016); in this view, students become the main actors of education and teachers move towards a more supportive and facilitating role. This concept is also embedded in the “*flipped classroom*” approach (Pantò and Comas-Quinn 2013).

The complex framework that is developing can be summarized in the following figure:

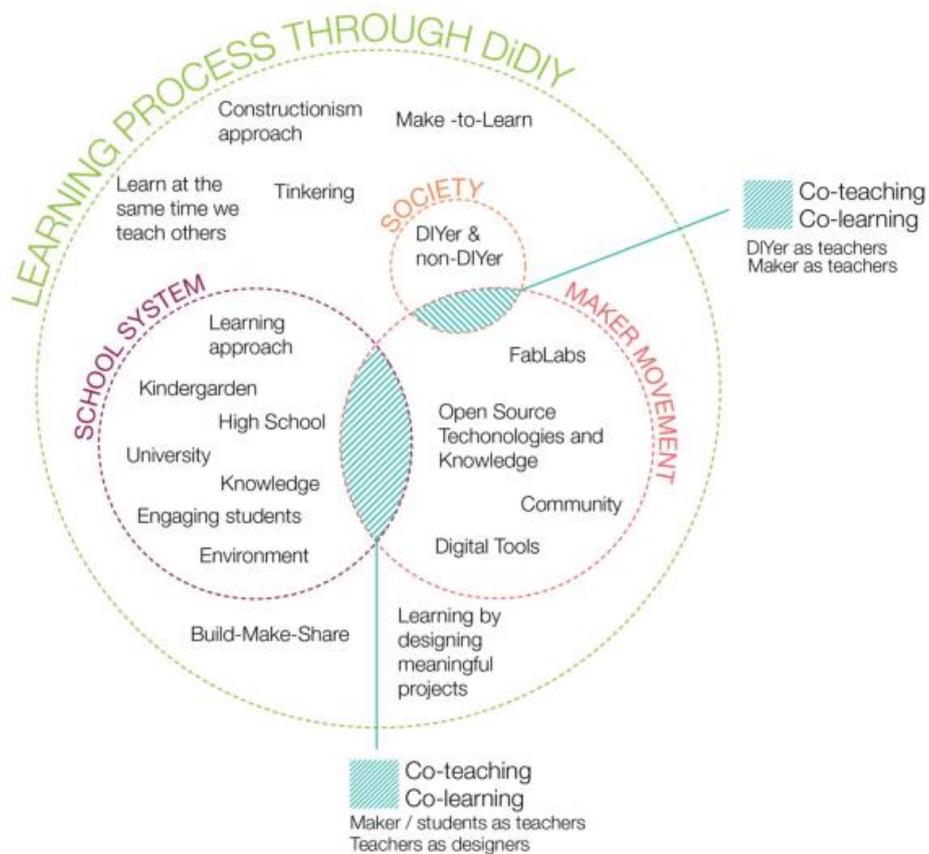


Figure 3: DiDIY in education: a conceptual framework (DiDIY 2015a)

In this perspective, it is clear that in the upcoming future technology and DiDIY will play a key role in education, especially in “*student-to-student teaching, project-based learning, and self-centered learning environments [...] (where) technology can be included into every subject and at all grade levels [...] allowing unprecedented levels and types of collaboration and learner to learner connectivity*” (DiDIY 2015a, pp.32-33).

It is important, however, to note that the most relevant aspect of the new framework is not represented by the technological perspective but rather by the construction and development of a dynamic DiDIY mindset that can then be applied in many different contexts (DiDIY 2015b).

While it is clear that DiDIY presents great opportunities and challenges for the future, its implications are still not fully understood and especially given the dynamic nature of the phenomenon, further study is required (DiDIY 2015a).

It is in fact argued that given the novelty of the theme the majority of resources about this emerging phenomenon can be accessed in newspapers, blogs, websites and magazines rather than academic publications (Fox 2014). Despite this, as it was previously discussed, some recent studies can still be identified, mostly aimed at analysing a specific aspect of DiDIY or an application of its themes to a specific context.

Among these, one appears especially aligned with the concepts of DiDIY. Fox identified a new “*wave*” of DIY, a phenomenon that he defined as “*revolutionary for prosumption, for innovation and for entrepreneurship*” (Fox 2014, p.1) and for manufacturing (Fox 2013). Fox bases his study on the view of Toffler, who describes how humans evolved through three types of society: the agricultural, the industrial and the informational one (Toffler 1980). He extends this concept by affirming that the evolution of DIY also reflected these three stages and happened in what he defines “*waves*”. First Wave DIY, or “*subsistence DIY*”, consisted in “*people growing what they eat and make what they*

need without regularly making purchases in a marketplace” (Fox 2014, p.1). Second Wave DIY, or “*Industrial DIY*”, consisted in “*people buying ‘made-to-forecast’ kits of pre-designed goods [...] sold together with standardized instructions for self-assembly*” (Fox 2014, p.1). The concept he defined as Third Wave DIY is strikingly similar to that of DiDIY: he argues that it is a new phenomenon that is leading to a shift in paradigm in the way physical goods are created (Fox 2013) and that its main drivers are “*the read/write functionality of the Internet and digitally-driven design/manufacture that enable ordinary people to invent, design, make and/or sell goods that they think of themselves*” (Fox 2014, p.2). In this perspective, his view is similar to that of Anderson (2012) which states the possibility that individual DIY-ers can now easily invent, make, use and sell their own goods.

He also argues that this phenomenon is revolutionary, since it will potentially enable anybody to engage in it, at any given location (Hatch 2013).

Furthermore, he identifies that not every output of Third Wave DIY is necessarily physical but could also be represented by “*electronic data products*” (Fox 2013 p.4) and that what constitutes a revolutionary paradigm is not the creation processes that Third Wave DIY enables, but rather their scope: “*a different conceptualization of invention, production and sale*”. (Fox 2013, p.2).

Fox also underlines how Third Wave DIY enables the interaction of different individuals in different locations and that a strong aspect of social learning is tied to the phenomenon (Fox 2014). He also developed a concept similar to that of the “ABC”, which he calls “*Virtual-Social-Physical Convergence*”. The figure below illustrates how he applied this concept in the fields of prosumption, innovation and entrepreneurship:

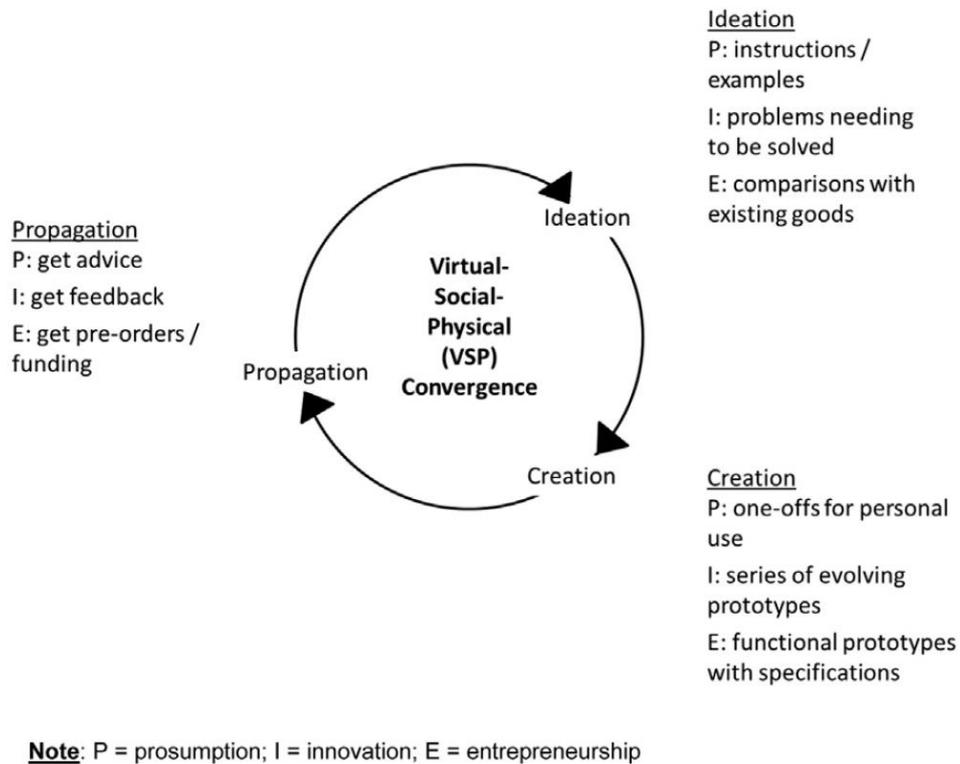


Figure 4: The VSP concept and its impact on Prosumption, Innovation and Entrepreneurship (Fox 2014)

Among other relevant studies on the matter, an example is that of Lan (2009), who argues that the increasing possibilities of transferring data through the Internet is allowing more and more individuals anywhere in the world to participate in the open, distributed and minimal development of physical goods that are characterized by a low cost of production and also a high degree of customization.

Regarding the perspective of Education, studies report that applications of DiDIY can stimulate learning and the development of social skills such as empathy (Barsade 2002) through manual manufacturing, especially when individuals can engage in group activities.

Other interesting studies that partially relate to the phenomenon of DiDIY analyse the use of digital technologies in education.

A study conducted by the US Department of Education has found that students perform better in online courses as opposed to face-to-face learning; however, the best results were obtained by adopting a mixed approach (Garrison and Kanuka 2004). Combs and Meskó (2015) especially argue that the adoption of digital technologies in education can be disruptive depending on its scope and use, rather than its mere introduction; their view follows that of Christensen (2000), who argues that the new models and possibilities enabled by a technology are to be considered disruptive, rather than the technology itself. Combs and Meskó also underline that using digital learning environments could foster the development of a more customized style of learning “*that suits individual learners*” (2005, p.3), which is also fostered by the rise of tools that allow students to produce their own content (Conole et al. 2008) and to autonomously acquire knowledge online based on their interests.

A study by Kumar (2013) identified 11 technologies that could revolutionize education in the coming future; these are: Big Data, APIs, Tin Can, Responsive e-Learning Design, Wearable Computing, Digital Textbooks, Videos, 3D Printing, Mobile Learning, Cloud Computing and HTML5. Combs and Meskó (2015) critically analysed them and concluded that whether these technologies will actually realize their innovative or disruptive potential will be based on understanding the opportunities and especially the challenges that they pose and that the leaders of academic institutions commit to their introduction in existing curricula.

Another study that theorizes that digital technologies will bring a transformation in learning is that of the founder of the “*Envisioning Technology Research Foundation*” Michell Zappa. His study “*attempts to organize a series of emerging technologies that are likely to influence education in the upcoming decades. Despite its inherently speculative nature, the driving trends behind the technologies can already be observed, meaning it is a matter of time before these scenarios start panning out in learning*”

environments around the world” (Zappa 2014). He especially envisions that peer-to-peer learning will increase and thanks to digital technologies transcend a single location and happen on a global scale. He also argues that learning will become more project/performance oriented, that classrooms will gradually be replaced by virtual environments and that education will become “*a continuous, interconnected effort, allowing students to cope with a perpetually changing world*” (Zappa 2014). A figure in Appendix, A.8. summarizes his vision.

Combs and Meskó greatly emphasizes how the current educational system is likely to change in the future, especially in universities: “*the aging model of higher education appears ripe for disruption. It is residential, expensive and degree-oriented; uses institution-specific curricula; and shows little concern for equipping students with the basic skills of employment*” (2015, p.11).

A recent relevant trend that is identified is also that the role of creativity and its implications has gained increasing attention in the education field (Mullet et al. 2016). Some see the development of creativity as a fundamental factor of education (Skiba et al. 2010) while others argue that it enhances problem solving capabilities and amplifies the process of constructing knowledge (Beghetto, Kaufman and Baxter 2011). However, it is also reported that this factor is usually not valued in traditional education environments, which through standardized assessment promote student conformity instead (Kim 2008).

Some scholars also argue that the development of critical thinking is “*among the most desirable outcomes of higher education*” (Dunne 2015). A series of studies (Association of American Colleges & Universities 2015) (Gallup-Lumina Foundation 2014) in fact suggests that employers highly value skills such as “*critical thinking, problem solving and oral/written communication*” (Sanders, Balius and Sanders 2016, p.5).

Another interesting view is that of Barnett, which adopts the term “*criticality*”, which comprises “*critical thinking, analytical reasoning, critical self-reflection and critical action*” (1997, p.6). He advocates that the main purpose of education should be to educate students and to form “*critical persons who are not subject to the world, but able to act autonomously and purposively within it*” (1997, p.7).

In this perspective education should equip students with a methodology, the ability to think critically and to solve problems adopting an analytical approach. As Quinn stated, “*students need to be liberated to think, rather than be forced to memorize*” (2012, p.6).

Another important theme that the literature suggests is that in order for teachers to be effective educators it is essential that they engage their students (Barkley 2010) and that they establish inviting learning environments (Bryson and Hand 2007). Some studies imply that deeply engaged students will be encouraged to “*question, reflect, evaluate and make connection between ideas*” (O’Flaherty and Phillips 2015, p.5). It is also reported that in order to reach a high level of student engagement, a teaching method that transcends the traditional face-to-face approach should be developed (Ferreri e O’Connor 2013). Digital technologies offer a great possibility in this regard, especially considering the fact that Millennials are often referred to as “*Digital Natives*” and that technology permeates every aspect of their life; in fact, some of them expect this to be reflected in their education as well (O’Flaherty and Phillips 2015). Some studies report that “*millennial students have been relying on technologies more than ever while at the same time demonstrating an ever-decreased tolerance for lecture-style presentation*” (Sohrabi and Iraj 2016, p.1), while others confirm that students are in fact expecting a more and more transformative kind of education (Thompson 2007), as their role shifts from that of consumers to creators and their expectations regarding their education are evolving. (Roberts 2005).

In response to these expectations, universities all over the world have already acknowledged that the use of digital technologies in education will be essential in the coming future (O'Flaherty and Phillips 2015). It is argued that a possible solution to these emerging needs of flexible learning is represented by the adoption of the Flipped Classroom approach (Bergmann and Sams 2012), which greatly encourages a more liberal and collaborative interaction between teachers and students (O'Flaherty and Phillips 2015). In short, this method foresees that activities that were once done at home are carried out in the classroom, and vice-versa. This on one hand enables students to learn at their own pace, supported by digital and virtual learning environments and content made available by their teachers; on the other hand, teachers can now focus more on the needs of single students and mentor them during their practical activities in class (Sohrabi and Iraj 2016). In this perspective the role of the teacher shifts to that of a counsellor, a guide, rather than a traditional dispenser of knowledge (Johnson et al. 2014). This methodology is deeply influenced by the theory of constructivism, in the view that "*learning is an active contextualized process of constructing the knowledge*" (from experiences), rather than acquiring it through direct teaching (Sohrabi and Iraj 2016, p.2).

Practical applications of the flipped classroom approach registered that students not only performed better by adopting this method but also were more satisfied of their education (Yarbro et al. 2014). Other studies report that adopting a flipped classroom approach could help developing information literacy and critical thinking skills (Kong 2014).

Taking into consideration all factors mentioned above, it is easy to understand how DiDIY could represent a valid tool to enhance education and give a practical answer to the evolving needs of students and especially to the ones of the new generations. Themes such as critical thinking, the use of digital technologies or student engagement are in fact strictly related to DiDIY or directly lie at the core of its philosophy, such as creativity.

In this perspective, the importance of studying and understanding its true potential becomes even more evident.

2.2 Key Findings

This section presents a summary of the key findings identified in the literature review:

- The wide availability and affordability of digital fabrication tools, the increasing democratization of knowledge, the ideals of open sharing and collaboration and the network effects enabled by the digital diffusion of information and possibilities offered by the ABC marked the rise of DiDIY as a new socio-technological phenomenon, holding the potential to revolutionize different areas of society, such as education (LIUC et al. 2014).
- DiDIY can be interpreted both as a mindset (a set of attitudes and competencies that can be developed and applied to different contexts and disciplines) and as an activity (the process of making things, tinkering, inventing); both aspects are relevant and offer possibilities to be exploited in education. There is in fact an increasing interest for a more practical type of education, especially following a creationist approach (Apple 2008).
- The process of making is meaningful for education and proves empowering for students (Blikstein 2008). More specifically, the desire and drive for making things can be interpreted as an expression of the human need to shape the environment based on one's needs (Illich 1970) or as a resistance to being a passive consumer of mass-produced artefacts (Gauntlett 2013).
- The importance of the role of creativity (Boy 2013), technological fluency and the development of problem-solving, critical thinking and team-working skills in education (Do and Gross 2007).

- It is important for students to engage in projects that are emotionally meaningful to them, as it is harder that they will feel the same motivation or sense of empowerment upon completion of a project that has been assigned to them by someone else (Blikstein 2013).
- It is possible to encourage students to define their own problem statement and engage in “*just-in-time*” learning to achieve their goals (Do and Gross 2007).
- Informal education environments such as museums, laboratories or online communities are spreading (Halverson and Sheridan 2014); as such, the boundaries between formal and informal education are shifting (Trinder et al. 2008) and new teaching paradigms are developing, such as the one of the “*flipped classroom*” (Pantò and Comas-Quinn 2013).
- The establishment of digital fabrication laboratories in schools can enable students to experience “*new ways of work and novel levels of team collaboration*” (Blikstein 2013, p.7). It is especially relevant to note that such environments would allow students to engage in long-term projects that can extend far beyond the possibilities offered by standard class-hours and learn to deal with new challenges, such as the one of failure or working in heterogeneous teams

Ultimately, it is important to note that while many applications of DiDIY are already emerging in the recent years, most are still limited in scope and their implications need to be better assessed and understood (DiDIY 2016).

2.3 Conceptual Framework

Miles and Huberman define a conceptual framework as “*a visual or written product, one that explains, either graphically or in narrative form, the main things to be studied—the key factors, concepts, or variables—and the presumed relationships among them*” (1994, p.18).

Given the themes analysed in the literature review, the author identified that the main variables and factors that should be analysed to understand the implications and opportunities that DiDIY can offer in the field of education are:

Factor	Relevant Sources	
Creativity ; to be intended as a skill.	(Illich 1970), (Gauntlett 2013), (Boy 2013)	(LIUC et al. 2014), (DiDIY 2015a), (DiDIY 2015b), and (DiDIY 2016)
Technology Fluency ; or technology literacy, to be intended as a skill.	(Combs and Meskó 2015), (Kumar 2013), (Zappa 2014), (Kong 2014)	
Problem Solving and Critical Thinking skills.	(Do and Gross 2007), (Sanders, Balius and Sanders 2016)	
Interests and Aptitudes of the student or of the teacher; to be intended as individual traits of a person and as factors that can be used to motivate and engage students.	(Blikstein 2013), (Cavallo 2000), (O'Flaherty and Phillips 2015)	
Teamwork ; to be intended as working in a group or as part of a community.	(Blikstein 2013), (Do and Gross 2007)	
The Relationship between Teachers and Students .	(Barkley 2010), (Bryson and Hand 2007)	
The Teaching Method that is used to deliver DiDIY concepts or to carry out DiDIY activities; in particular, it would be relevant to focus on studying the application of a " <i>Flipped Classroom</i> " approach.	(Pantò and Comas-Quinn 2013), (Trinder et al. 2008)	
The Context in which DiDIY is applied.	(Blikstein 2013), (Trinder et al. 2008)	
The dual perspective of DiDIY as an Activity and as a Mindset ; this should be intended considering the fact that it is possible to focus on DiDIY as an activity or to focus on the mindset that lies at its base.	(Apple 2008)	

Table 3: Conceptual Framework Variables (generated by the author)

In particular, it is relevant to study how these variables affect the successful deployment of DiDIY on one side, and on the other how DiDIY affects the development of such variables as skills or as methods. For example, a relevant question to explore would be: "*How can creativity as a skill affect the deployment of DiDIY in education?*"; but also "*How can engaging in DiDIY activities affect the development of creativity in students?*".

The conceptual framework that lies at the base of this research is outlined in the figure below:

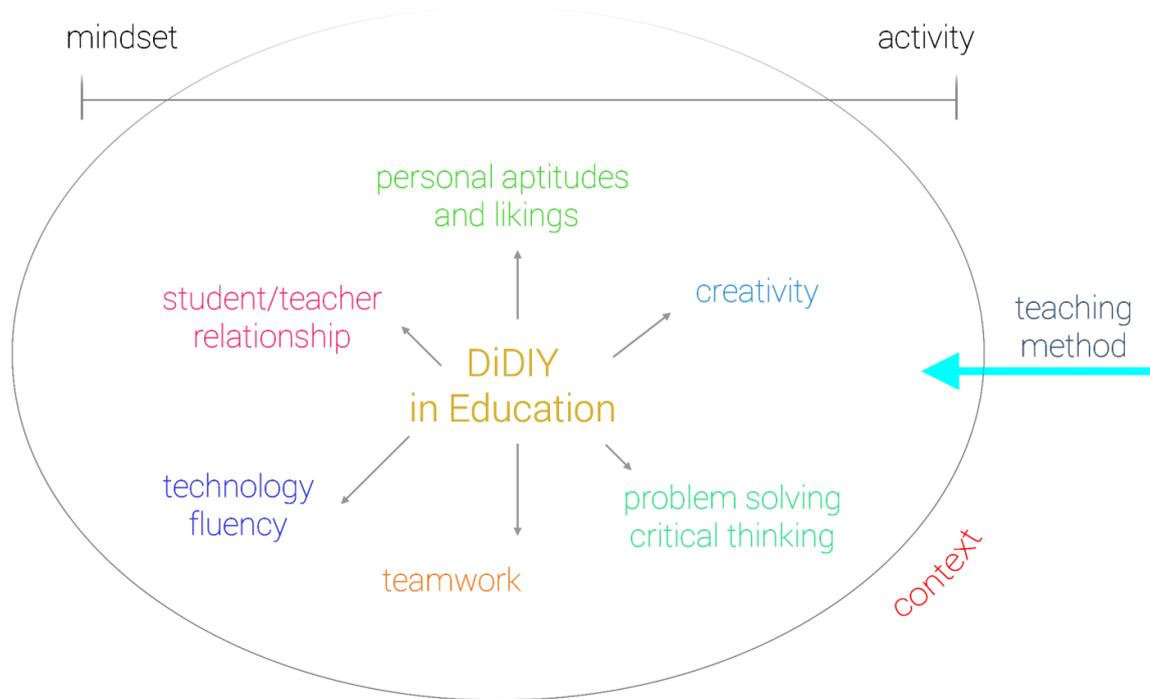


Figure 5: Conceptual Framework (generated by the author)

It should be noted that also the conceptual framework outlined in Figure 3 will be taken into account while developing this research.

3. RESEARCH METHODOLOGY

3.1 Source of Data

This research employs both primary and secondary sources of data.

According to Ghauri and Grønhaug (2005, p.91), secondary data consists of “*information collected by others for purposes that can be different from ours*”; this data can be gathered and interpreted in order to generate new knowledge or reach different conclusions (Hakim 1987). Secondary data will be used in the literature review of this research. Relevant sources of secondary data are books, publications, conference proceedings and most importantly academic journals (Saunders, Lewis and Adrian 2015).

According to Bryman and Bell (2015), information that is directly collected by the researcher through observation, questionnaires and/or interviews is called primary data. Primary data provided genuine and relevant information to be analysed for the research and was collected by the author through workshops, questionnaires and interviews, following the plan described in section 3.2.2 of this document.

3.2 Research Methods

3.2.1 Research Approaches

Creswell (2013) states that there are mainly three possible approaches to research: quantitative, qualitative and mixed methods.

Quantitative	Quantitative research is used to identify “ <i>data collection techniques or procedures that generate or use numerical data</i> ” such as questionnaires (Saunders, Lewis and Adrian 2015, p.166) and can be defined as the empirical investigation of phenomenon through the adoption of statistical, mathematical or computational approaches (Given 2008).
Qualitative	On the contrary of a quantitative approach, qualitative research adopts the use of non-numerical data (Saunders, Lewis and Adrian 2015), such as interviews; qualitative research is exploratory in its nature and aims at understanding the meaning and/or the relationship among different concepts and themes (Creswell 2013): in this process, a vital role is played by the interpretation of data by the author of the research (Strauss and Corbin 1990). It is important to note that qualitative research is also specifically relevant in the study of social relations (Flick 2009) and processes such as education.

Table 4: Qualitative and quantitative research approaches (generated by the author)

The main differences between quantitative and qualitative data are outlined below:

Quantitative data	Qualitative data
Based on meanings derived from numbers	Based on meanings expressed through words (spoken and textual) and images
Collection results in numerical and standardised data	Collection results in non-standardised data requiring classification into categories
Analysis conducted through the use of diagrams and statistics	Analysis conducted through the use of conceptualisation

Figure 6: Differences between qualitative and quantitative data (Saunders, Lewis and Adrian 2015)

Despite the stark difference, quantitative and qualitative research methods “*may be viewed as two ends of a continuum, which in practice are often mixed*” (Saunders, Lewis and Adrian 2015, p.167). The adoption of both quantitative and qualitative methods is in fact called mixed or integrative research (Cooper 1982).

This research adopts a qualitative approach and its purpose is mainly exploratory. The main method that will be used to analyse data is thematic analysis (Braun and Clarke 2006).

3.3 Research Design

Research design represents the “*overall plan for relating the conceptual research problem to relevant and practicable empirical research*” (Ghauri and Grønhaug 2005, p.56). The section below outlines how research instruments were designed and used:

3.3.1 Population Sample

It is essential to engage with subjects (both teachers and students) that have previous experience with DiDIY and digital manufacturing technologies but given the novelty and low degree of diffusion in formal education of such technologies, identifying relevant subjects proved challenging. To this extent, the researcher decided to adopt the use of interviews with a selected sample of students and teachers. In particular, the students that were selected to be interviewed are either university students or people who recently finished their studies. In order to extend the research sample, the author also decided to interview researchers or educators as members of the “teachers” group. Gender equality was respected by ensuring that participants of both genders were included in the sample.

To extend the scope of the research and to ensure that relevant research subjects would be reached, he also decided to develop the experimental workshops; however, a problem of bias could have occurred, due to the fact that it is possible that the workshops delivered by the author could be the first source of contact that participants had with DiDIY themes. In order to avoid this, the workshops aimed at providing an unbiased perspective on DiDIY to the participants. Unfortunately, there were limitations to the number of people who could attend the workshops (since the location could only host a limited number of people at once) and as such, questionnaires were mainly adopted for qualitative research purposes, despite some questions being of a more quantitative nature.

3.3.2 Literature Review

The aim of the literature review was the identification of the main themes and issues regarding the application of DiDIY in education in order to provide a context to understand and frame the research. Given the novelty of the theme, it proved relevant to study practical applications of DiDIY, since a formal and widely accepted conceptual framework is yet to be developed (DiDIY 2015a). The literature review was also used as a base for the development of the questionnaire, workshops and interviews. Table 24 and 25 in the Appendix outline some of the identified relevant journals and key-words that were used in the research.

3.3.3 Workshops

Workshops are organized with the scope of collecting primary data through observation. It is agreed that four different kinds of observation techniques exist, as displayed in the figure below:

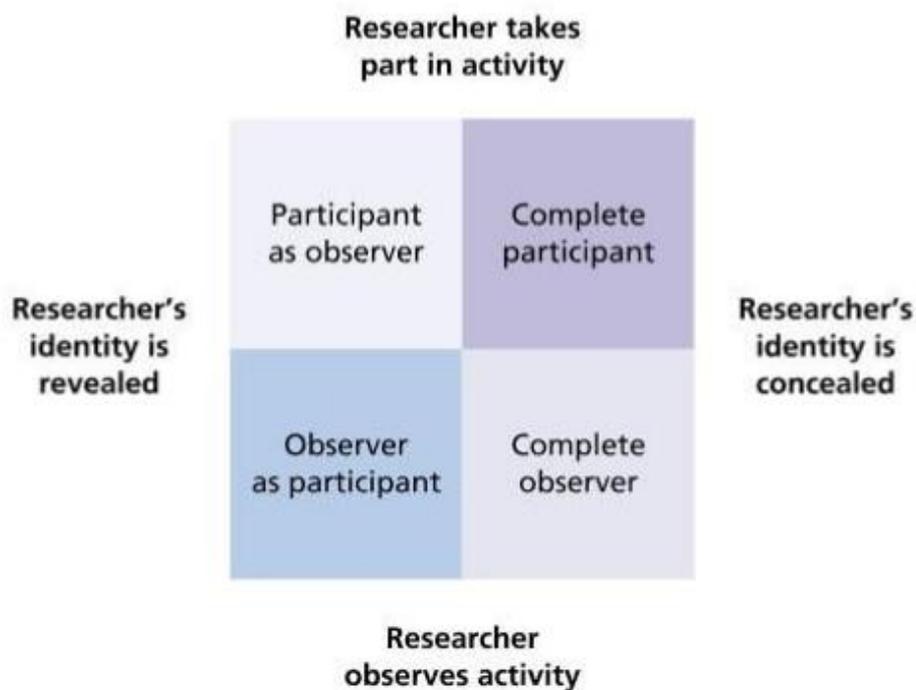


Figure 8: Different methods of observation (Saunders, Lewis and Adrian 2015)

This research adopted the “*Participant as Observer*” method, since the author disclosed his identity as a researcher and also actively participated in the workshops.

The workshop’s content and structure was designed according to the relevant themes that were identified during the preliminary literature review conducted during the Research Proposal (Di Fulvio 2016) of this dissertation. The main themes, other than the ones outlined in the conceptual framework, are: the importance of working cooperatively in a team, the importance and educational value of failure, the concept of just-in-time learning, the ease with which DiDIY activities can be approached. Other themes were also included, such as: the adoption of a “design” approach to creation, the importance of a trial and error approach in prototyping, Social Manufacturing, the rising movement of the “Makers” and the strengths and limitations of consumer 3D Printing. The workshops were designed with a qualitative research approach.

The events were organized in cooperation with “*MAKE Aberdeen*”, who provided the location and the equipment needed to carry out the event. The Robert Gordon University and MAKE also helped in the marketing of the event by advertising it on social media channels. The author advertised the event by printing posters (which can be seen in Figure 15 in the Appendix) and by promoting the event on the main Facebook Groups related to the city of Aberdeen (such as “*Events in Aberdeen*” or “*What’s on in Aberdeen and Aberdeenshire*”).

The two workshops were identical and scheduled to last 4 hours, from 4 to 8 pm; however, both ended up lasting approximately one hour longer (to accommodate for printing time). The main topic of the workshops was 3D Printing: “*Learn the basics of 3D Printing and work in a team to design and print a real prototype*”. The event was free of charge but requested a registration on-line through a “*Google Form*”. The number of participants was capped at 12 people per workshop, given the constraints of location and

available equipment. The effective number of participants was respectively of 10 and 16 people (out of 33 total registrations, which accounted for people who later relinquished their place). The event was open to participants of all ages: some children participated and explicit consent was requested from their parents or guardian.

Structure

At the beginning of the workshop participants were informed that they would be asked to fill in two short questionnaires at the end of the event. The first one was a standard DiDIY questionnaire which is distributed in most of DiDIY events and the second a questionnaire devised by the author which focused more specifically on the theme of education (and especially on informal education, given the context). Unfortunately, not all participants honoured their promise to compile the questionnaire and only 16 answers were recorded for the general DiDIY questionnaire and 14 for the one of the author (both questionnaires can be found in the Appendix in section A.6 and A.6)

The event opened up with a short introduction in which a representative of MAKE, Ben, welcomed the participants and explained them about MAKE and the activities they carry out. This was followed by a short introduction of the author, who explained the purpose of the workshop and its research aim as part of the DiDIY project.

A theoretical background was then delivered by the author, first explaining the concept of DiDIY and later giving a brief overview of 3D Printing. This section was concluded by asking a question to participants: “*3D printing is not a new technology: what are the causes of the recent mass diffusion of 3D printers and the newly found interest for making things and digital manufacturing?*” (which would then later be answered). During this phase participant were also shown different 3D printed parts created with different technologies, in order to better explain the possibilities offered by 3D printing.

Participants were then asked to form groups of two and were assigned a challenge. Ben and the author prepared a 3D Printed windmill before the event, composed of 4 parts: the base, three blades, a pin and a ball bearing housing for the blades.



Figure 9: The windmill and the blades created by Ben and the author (in white and blue) and the ones created by participants (in green and black). Photo taken by the author

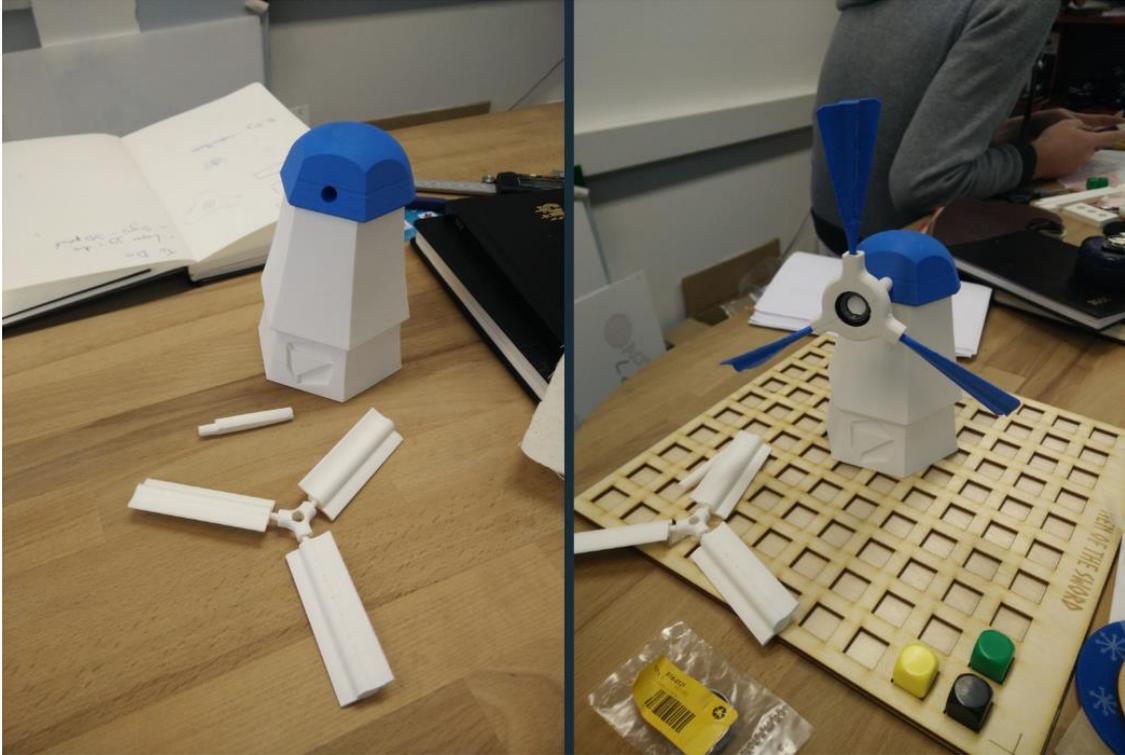
Participants were asked to design and 3D print their own interpretation of a windmill blade. If the participants could create blades that could make the windmill spin faster than the model created by Ben and the author, they would win. The blades would have been spun by using a blow dryer set on cold air mode. The only limitation that was given to participants was that their final model could not exceed given constraints of height, width and length (namely to ensure that a short printing time would be required to print the parts).

The event continued with an overview of the online design tool “*Onshape*”. Ben gave a quick tour of the software and modelled a simple blade through a step-by-step approach. This explanation was thorough but purposively did not explain in depth how every tool worked, in order to foster curiosity in the participants and to encourage them to learn while trying to model their ideas. Paper and pencils were distributed so that participants could draw their ideas before moving on to the modelling software. Each group was encouraged to model its own creative solution. During this phase the author and Ben walked around the participants and helped them in case they had troubles with the software.

Once the design phase was over, the models were converted into *Stl* format and moved to the main computer of the lab, where the parts were prepared for print. During this phase Ben and the author explained the main elements to consider when printing an object and setting up the print, going over each parameter (such as temperature, layer height, infill percentage etc.). Given the time constraint it was only possible to print one blade per group so three groups would have to merge their blades in order to complete a set for the windmill.

After the print was started, participants proved to be amazed by the 3D printers in action and some time was given for a short break. After the break, while the blades were being printed, the author continued his theoretical explanation and answered the question that was previously left unanswered. The explanation covered the theme of Rapid Prototyping and gave an insight on the industrial applications of 3D printing and the concept of the prototyping cycle, stressing the importance of failure and iteration. To this extent, it is important to note that some of the designs that were created by participants were impossible to be printed correctly; in order to stress the importance of failure and learning from one’s mistake, it was decided to print them anyways without informing the participants. The theoretical explanation also touched other themes, such as the one of

Social Manufacturing and IOT (Internet Of Things). After the explanation, participants were asked to fill in the questionnaires.



**Figure 10: The original prototype of the windmill (left) and the final version (right).
Photo taken by the author**

Once the blades were printed, their build quality was discussed. Some prints failed due to poor design choices, while others failed due to machine error (unfortunately one of the extruders of one of the 3D printers had a cooling problem and this resulted in distorting the final print). These examples proved especially useful in explaining several concepts, such as the importance of learning from one's mistakes and the iterative nature of prototyping; to stress this, the initial blade prototypes created by Ben were shown and he explained how he gradually reached the final design for his windmill by trying different designs and gradually adapting them to his needs as he progressed (for example, the ball bearing was only included later in the design after realizing that without it there would have been too much friction for the blades to spin at all). This also helped underline the

fact that while 3D printing can be very exciting and offer countless opportunities to express one's creativity, a certain approach and certain knowledge of the process is needed to use it effectively; however, due to the cheap cost of material (which makes an iterative approach possible) and the diffusion of knowledge through online communities or laboratories such as MAKE virtually anyone has access to the necessary means to use 3D printing and become a DiDIY-er.

One participant was then given a blow dryer and was asked to direct the air flow towards the windmill to see how the blades would spin. At first, a try was made using the original design of Ben and the author and a video was recorded. After the initial try the participants created groups of three blades and mounted them on the windmill to see how their combinations would spin. The author is proud to state that in both workshops the participants managed to win the challenge!

Resource Requirements

The workshop required a location, which was offered by "*MAKE Aberdeen*". Both workshops were held in MAKE's laboratory (17 Belmont St, Aberdeen AB10 1JR). The computers were also offered by MAKE (MAC computers were used) as well as the 3D Printers (two Ultimaker 2 were used), the PLA filament for the prints and a portable projector. The educational material for the workshop was prepared by the author and revised with MAKE.

3.3.4 Questionnaires

Questionnaires can be used for different types of data collection, although they are usually adopted for descriptive or explanatory research; it is also often suggested to associate questionnaires with other data collection techniques in order to improve the quality of a research (Saunders, Lewis and Adrian 2015).

This research adopted questionnaires as a qualitative tool to collect information to support and integrate the primary data collected through observation during the workshops.

Two questionnaires aimed at testing the subjects' opinion on DiDIY and its implications on education were designed and delivered online through "*Google Forms*" at the end of the workshops. Given the fact that the author expected a limited number of responses, a qualitative approach was followed in the design of the questionnaire.

The first questionnaire is the standard questionnaire that is usually delivered to participants to DiDIY events by the members of the DiDIY Research Team; in this dissertation it is referred to as the "*General Questionnaire*" and can be found in the Appendix, section A.6.

The second questionnaire is more focused on the theme of Education and was devised by the author. It is referred to as the "*Education Questionnaire*" and can be found in the Appendix, section A.5.

3.3.5 Interviews

"The interview method involves questioning or discussing issues with people; it can be a very useful technique for collecting data which would probably not be accessible using techniques such as observation or questionnaires" (Blaxter 2010, p.172).

Interviews are a qualitative research tool and can be of three kinds: structured, unstructured and semi-structured (Saunders, Lewis and Adrian 2015). Structured interviews are carried out following a rigid structure of questions to be asked to participants. Unstructured interviews are not based on a prepared set of questions but allow the participant and the researcher to engage in a discussion aimed at exploring different relevant themes. Semi-structured interviews adopt a mixed approach of the two

methods: usually a set of questions is prepared but it is encouraged to deviate from the structure and explore other themes if they arise during the discussion.

The table below outlines the main purposes for which different types of interviews are often used:

Table 10.1 Uses of different types of interview in each of the main research categories

	Exploratory	Descriptive	Explanatory
Structured		✓✓	✓
Semi-structured	✓		✓✓
Unstructured	✓✓		

✓✓ = more frequent, ✓ = less frequent.

Figure 11: Purposes of different types of interview (Saunders, Lewis and Adrian 2015)

This research adopted semi-structured interviews.

The interviews were designed based on the most relevant themes identified in the literature review and further reinforced by the analysis of workshops and questionnaires. A double qualitative perspective of teachers/students was considered and the main focus lied in identifying the common trends and opinions among the two groups (it should be noted that the group “*teachers*” also includes educators and researchers).

Structure

The interviews were carried out using “*Skype*” and recorded with the use of the “*MP3 Skype Recorder (v4.26)*” software. The participants were contacted beforehand and made aware of the themes and purpose of the interview. They were also given a short PDF (which can be found in the Appendix, A.3) containing a brief overview of the theme of DiDIY and the outline of the questions, other than other practical information about the interviews such as scheduling and duration.

The online website “*Doodle*” was used to schedule some interviews, so that participants could choose what time and day would suit them best and be able to place their preferred choice also in base of the one of the others.

The identity of the participants has been kept anonymous, unless they specifically asked for it to be made explicit. Despite anonymity, a short brief about the background of every participant can be found: the information that is shown in those sections represent the will of participants about what information to share about themselves.

Participants were either students or teachers/educators and researchers. The age group of the students can be included in the 20-25 years old range; not all teachers and researchers, however, agreed to share their age so this information is not displayed on each person’s profile and a relative age group cannot be defined.

The recordings of the interview have been stored on the personal hard drive disk of the author and a backup copy was created on his personal “*Google Drive*” account. They will remain stored for the duration of the legal period defined by the rules of The Robert Gordon University in case the author would be required to present an actual proof of the interviews (the period lasts until the final grade for this dissertation will be awarded). After this period the author will delete all the recordings to protect the participants’ privacy.

Before starting an interview, the author thanked every participant for his/her help and requested their permission to record the interview. He also asked participants if they desired a clarification of the concept of DiDIY and then explained the structure of the interview, the nature of the questions and the approximate duration. Participants were made aware of their right not to answer questions they felt uncomfortable with and of the fact that the author would refrain from commenting on the answers and discussing his own point of view until the end of the interview.

As a token of his gratitude, the author offered to deliver to every participant a digital copy of this work once he would have finished writing it; every participant appeared enthusiastic and opted to receive a copy.

Interviews were carried out in Italian or English depending on which language the interviewee preferred.

The Questions

The questions that were asked during the interview can be found in the Appendix, section A.1. All of the questions except the last one about negative implications and challenges posed by a DiDIY approach were included in the PDF that was delivered to participants before their interview. The reason behind this is the fact that the author did not want the participants to think of such negative implications beforehand (in case they read the PDF guide) but was interested to observe how they would naturally arise during the discussion. In case participants spontaneously thought of such negative factors during the interview the author would then either not ask the question entirely or ask participants to clarify on the matter by elaborating further on the theme.

The questions are divided in topics based on the main factors outlined in the conceptual framework. The first three questions do not concern any specific topic and were conceived as warm-up questions. More specifically, the first question was aimed at collecting the information that participants wished to be included in their profile section of this dissertation.

The questions were the same for both teachers and students, except for a few questions which were adapted to fit the two different perspectives. The concept of education is broad and varied; the author encouraged participants to think about DiDIY and to frame it in their own context based on their experiences. It was encouraged to think about all stages of education (primary, secondary and higher). The author especially encouraged

teachers who had experience as trainers or consultants in companies to also elaborate on education in those contexts.

Two types of questions were asked during the interview:

- Open ended questions which were discussed with participants.
- Questions in which participants were asked to rate their agreements with a given statement based on a Likert scale (Cooper, Schindler and Sun 2003): “*Strongly Agree*”, “*Agree*”, “*Neutral*”, “*Disagree*”, “*Strongly Disagree*”, “*Do not Know*.” It was encouraged but not strictly required that participants briefly commented about their agreement choice.

3.4 Research Strategy

A research can adopt either a deductive or inductive strategy (Ary et al. 2013). According to Neuman (2003) inductive research begins with an observation of the world and moves towards a generalization of concepts and the development of ideas and theories through the identification of patterns and recurring themes, following a “*bottom-up*” approach (Alexandiris 2006). On the contrary, deductive research follows a “*top-down*” approach which is essentially the reverse process (Lancaster 2005): the researcher develops a theory and then structures its research in order to find supporting evidence and test the initial assumptions.

This research adopted both strategies in different phases, as outlined below:

Phases	Literature Review	Workshops	Questionnaires	Interviews
Strategy	Inductive	Inductive and Deductive	Inductive and Deductive	Inductive and Deductive
Data	Secondary	Primary	Primary	Primary
Method	Qualitative	Qualitative	Qualitative	Qualitative

Table 5: Research Strategy (generated by the author)

3.5 Rationale of the Chosen Approach

The greatest limiting factor that influenced the author's decisions on how to proceed with the research was the available time.

He initially speculated to adopt questionnaires as the primary data collection tool, adopting both a qualitative and a quantitative approach. However, given the difficulty of ensuring a full or even partial understanding of the themes of DiDIY in potential research subjects, the author then decided to discard the decision of using online-based questionnaires delivered to a wide audience.

He then realized that the need for identifying relevant research subjects could be addressed by developing an experiential workshop (hence ensuring that participants had at least one previous experience in DiDIY and that they fully understood its meaning). This is the reason which convinced the author to organize the two workshops; given the low number of people that could take part in the event (given the constraints imposed by the location), he decided to adopt a qualitative questionnaire as a mean to support observation for the purpose of data collection.

The difficulty of identifying research subject could also be addressed by directly asking relevant people to help the author in his research. To this extent, the author decided to adopt semi-structured interviews as the main data collection technique, especially given their high potential in exploratory research (Saunders, Lewis and Adrian 2015). Research subjects were chosen by the author himself or suggested to him by other interviewees.

3.6 Resource Requirements

This research required several resources, which are outlined below.

For the first phase, books, articles and journals were required in order to carry out the initial literature review. The database provided by The Robert Gordon University proved

vital, however, despite its depth and vastness, it was not sufficient; the author also integrated his research accessing other books and journals outside of RGU's catalogue. The resources developed by the DiDIY Research Team proved especially valuable for the development of this work.

The resource requirements for the organization of the workshop has already been discussed above. The interviews required the use of a computer, of the "Skype" software to conduct the calls and of the "*MP3 Skype Recorder (v4.26)*" software for recording them. The software "*Sonocent Audio Notetaker*" was also used to elaborate the recordings and to take notes.

The drafting of the thesis required the use of the "*Microsoft Office Suite*" and in particular of the "*Word 2016*" and "*Excel 2016*" software, which were downloaded through The Robert Gordon University. "*Adobe Photoshop CS6*" was also used to edit images and to draft contents such as the PDF shared with interviewees.

The most critical resources proved to be the availability of relevant subjects to interview, given the novelty of the theme, and time.

3.7 Ethical Considerations

The research was conducted following good moral principles and respecting all parties involved. The author obtained permission from the institutions that helped him in the research ("*Università Cattaneo LIUC*" and "*MAKE Aberdeen*"); while these entities proved crucial to the successful development of the research, the author ensured to maintain a clear and objective perspective in order to avoid any kind of bias in the analysis. For example, the author avoided interviewing members of the DiDIY Research Team or his supervisors.

Workshops were open to the public, and a pre-registration was required; participants were made aware of the research purpose of the event and of the fact that two questionnaires would have been distributed at the end. In case minors wanted to participate, a written consent was asked from their parents or guardian.

The interviews were carried out with the permission of the participants and only if such permission was granted. Participants were made aware of the purpose of the research but in order to avoid bias, the author never disclosed his opinion with any interviewee until the interview was completed. The author personally knew all the interviewed students and most of the teachers; to avoid bias, he remained impartial during the interviews and specifically asked participants to express their true opinion.

The author ensures to have properly cited and referenced all the relevant sources of data used in the research. The author affirms, to the best of his possibilities, that the research was conducted following ethic principles and avoiding any kind of conflict of interests with other studies or third parties.

3.5 Confidentiality

All the data collected from research subjects has been treated in the strictest confidentiality and participants were made aware beforehand about the way their data would have been handled and for what research purpose.

Questionnaire answers have been stored and saved online using the software application "*Google Forms*"; access to this data is only possible to the author and his supervisors; part of it, namely the answers regarding the feedback about the workshop itself, were privately shared with "*MAKE Aberdeen*".

Workshop participants were informed about the purpose of the event; participants granted their permission prior to starting the event, including allowing the author the possibility of taking the pictures that are shown in this work.

Confidentiality information about the interviews was presented in the previous section.

4. FINDINGS

4.1 Workshop Findings

Based on questionnaire responses, the average age of participants was 30 years. The number of males and females attending was well-balanced, with 8 participants of each gender. Most of participants were Scottish (7), Spanish (3) and Polish (3), with the remaining three being Italian, Russian and German. The figure below outlines their background:

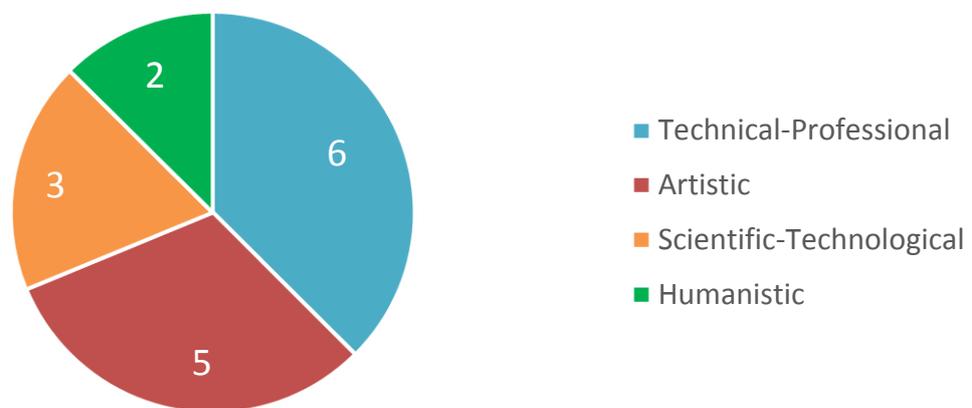


Figure 12: Background of workshop participants (generated by the author)

(It should be noted that more people participated who did not complete the questionnaire and as such they cannot be included in the statistics above).

The main factors that the author observed during the workshops are outlined below:

- Participants strongly interacted with one another; not only people turned to others for help in case they had troubles but also by engaging together in the same task they developed a social interaction and ended up sharing experiences and opinions.

- The informal and relaxed atmosphere helped participants feel at ease and encouraged them to express their creativity.
- Giving only a limited perspective on the functionalities of the 3D modelling software encouraged some participants to explore but also proved negative or challenging for others who struggled in effectively understanding how to use the it. This proved especially true for the kids who participated.
- Getting participants to engage in a practical activity almost right from the start was a good choice. Not only this proved important from a time-management point of view, but also helped focusing the participant's attention.
- Being motivated by their achievements, participants well received the theoretical perspective that followed the practical challenge; while the majority of the participants grew tired after about 3 hours of workshop, the majority of them still genuinely showed interest in learning about the concepts that lied at the base of their practical experience.
- Participants had fun and most showed interest to continue their experiences in 3D Printing. Some also showed interest in DIDIY and the DiDIY research as well; many participants asked Ben to explain them more about MAKE and how they could get a membership to the laboratory and develop some of their own projects and ideas.
- The initial theoretical explanation was very well received by adults but kids struggled in understanding some of the concepts; to solve the issue, the author took time to explain the concepts to kids again by adopting a simpler language. The same applied to the 3D modelling software. In the end, most of the kids grew frustrated by the difficulties they were meeting and their interest on the activity faded. However, their experience still proved positive, since their curiosity was

heavily stimulated by the environment of MAKE and most especially by seeing the 3D printers in action.

4.2 Questionnaire Findings

Unfortunately, as it will be discussed in the next Chapter, only few participants to the workshop actually answered the questionnaire. The amount of answers received is not statistically relevant to conduct a quantitative analysis (Saunders, Lewis and Adrian 2015). The following section will present the outline the main qualitative findings of both questionnaires:

4.2.1 General Questionnaire

This questionnaire received 16 answers.

All participants had previous experience with digital technologies and mostly agree about the potential represented by DiDIY. Participants also agreed on the importance of the role played by creativity and teamwork in DiDIY, especially as drivers of new and innovative ideas. Participants also proved to appreciate the social value of sharing ideas and projects and the fact that DiDIY can foster a more practical and “*outside-of-the-box*” thinking. Participant’s opinion about the way DiDIY will affect the role of the teachers are mixed; however, most agree that teachers will need to develop more competencies and that their role as the main source of knowledge in the classroom will be challenged in the near future.

Some interesting quotes from the open-ended questions are presented below:

Commenting about Creativity	<ul style="list-style-type: none">- “The digital way of making things should not be encouraged in detriment of traditional (and every-day) methods of fabrication. There is a place for the new, but it most probably cannot and will not replace the current way”;- “Any tool that allows for creativity is valid and should be encouraged, although it can be daunting if the technology that allows DiDIY is too difficult to handle”;
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Commenting about Flows of Communication	"Students learn from teachers but the opposite is also true. A teacher brings value to a class through things other than academic knowledge, e.g. experience in their field, whereas a student can bring valuable ideas in other ways, by challenging preconceived thoughts"
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Table 6: Quotes from the General Questionnaire (generated by the author)

4.2.2 Education Questionnaire

This questionnaire received 14 answers.

Participants agreed in the value of establishing a more informal and friendly relationship with their educator and in the value of sharing and communication in learning. Very few participants, however, proved to know about the Flipped Classroom approach. Participants agree that DiDIY will have a great impact on Science, Technology and Engineering and a moderate impact on Art; they disagree that DiDIY will play a relevant role in Mathematics.

All participants would like to see DiDIY implemented in schools, either in limited applications or across all disciplines. Also, everyone except one person agreed that students would learn better by engaging in DiDIY.

Some quotes from the open-ended questions are presented below:

Commenting about the event	<ul style="list-style-type: none"> - "I really enjoyed the presentation and the challenge, it is really good to have a short tutorial and then learn by doing - and failing!"; - "Prior knowledge to some things was expected, however anything that wasn't known was quickly explained to the group well";
Commenting about the differences between formal and informal education	<ul style="list-style-type: none"> - "I like informal as it feels like it's "okay to fail" and make mistakes, and try lots of different approaches to solving a problem"; - "The main difference is the balance between the practical skills and the theory-based knowledge. I think that informal education is an alternative way of learning and should be incorporated more in terms of modern educational systems"; - "Informal education is usually used for hobbies and is not considered to be "serious" in most of the cases, while formal education is given more weight. However, these days you can learn more and more things informally and even base your career on it";

<p>Commenting about the benefits of introducing DiDIY in education</p>	<ul style="list-style-type: none"> - “I think it helps as it is practical training, which is great at trying out new techniques and different creative solutions, and encourages groups to work together to learn about a subject. It’s more engaging than a typical classroom environment”; - “More students having a shot at using technologies previously only available to a narrow group of people, resulting in more ideas making it through”; - “The possibility to have a learning by doing approach, instead of relying on teacher’s words and theories from textbooks only”;
<p>Commenting about why DiDIY could improve learning</p>	<ul style="list-style-type: none"> - “You can never learn/know enough. To add a new dimension to learning only makes us better equipped for the future”; - “This is a format that students are more familiar with and therefore they are more comfortable and will learn more. With DiDIY, asking questions and experimentation is encouraged better than in traditional teaching”;
<p>Commenting about the relationship between DiDIY and Creativity</p>	<p>“It’s very much related. Non creative people tend to have “non-makeable” things in their head, and are not worried about what surrounds them. They are worried about words, numbers, feelings, dance moves, religion... Although I do believe there’s a little bit of a “maker” in all of us.”</p>

Table 7: Quotes from the Education Questionnaire (generated by the author)

4.3 Summary of the Interviews

A total of six students and six teachers were interviewed. Their profiles and a brief overview of their opinion on the theme of DiDIY is presented in the following section.

Quotes from each participant are also displayed, which either well represent their personal opinion or struck the author as particularly interesting; in order to keep the original quotes faithful, explanations in brackets about their contextualization is given if needed. Some adjustments were made to accommodate the transition from spoken to written language but the original meaning of the quotes has not been altered. In case the interview was carried out in Italian the displayed quotes are a close translation of the original ones, made by the author.

The names are either the real ones of the participants who agreed for their real name to be displayed or a fictional one given by the author to the ones who didn’t.

The table below outlines the nationality and gender of the students (if a person has more than one nationality, the birth one is displayed):

Name	Anna	Annie	Anya	Dat	Elvis	Mirko
Nationality	Italian	Spanish	Russian	German	Ecuadorian	Italian
Gender	Female	Female	Female	Male	Male	Male

Table 8: Nationality of Interviewees - Students (generated by the author)

The table below outlines the nationality and gender of the teachers, researchers and educators:

Name	Ben	Giuseppe	Massimo	Mauro	Rosie	Sara
Nationality	Belgian	Italian	Italian	Italian	British	Italian
Gender	Male	Male	Male	Male	Female	Female

Table 9: Nationality of Interviewees - Teachers (generated by the author)

The table below explains the legend used in the ratings table:

SA	A	N	D	SD	DK
Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	Do not Know

Table 10: Rating Legend (generated by the author)

Each number next to the rating reflects the correspondent rating question of the interview. The full list of rating questions can be found in the Appendix in Section A.1.

The interviews are summarized in the section below.

4.3.1 Anna

Gender: Female

Nationality: Italian

Bio: Anna is a master’s student in Industrial Engineering in “*Universita’ Cattaneo LIUC*” and she is especially interested in the Healthcare field; in fact, she took her bachelor’s degree in Biomedical Engineering. Furthermore, she took part in a double-degree exchange with “*The Robert Gordon University*” of Aberdeen together with the author, where she is currently graduating in Project Management. Also, she really likes seals.

Ratings:

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
A	A	A	A	DK	A	A	DK	A	D	A	D	A	D	D	A	DK

Profile:

Brief	<p>Anna thinks that adopting DiDIY in education could be beneficial in terms of stimulating students and improving their learning capabilities; however, she points out that a practical DiDIY approach alone is absolutely not adequate unless coupled with a solid theoretical approach. She is also concerned that DiDIY could polarize the attention of students on single technologies and as a result decrease their creativity, since this could lead them to adopting a certain polarized perspective or point of view.</p> <p>She thinks that DiDIY could be applied in every discipline and should be used to stimulate students and especially as a tool to show them the practical implications of the theoretical concepts that they study; however, DiDIY should be adopted depending on specific contexts and learning objectives, since in certain cases it could prove superfluous. As such, she also suggests that the teaching methodology should be tailored to each single activity accordingly.</p> <p>She also underlines the critical role of the teacher, which should be very well trained and adopt a critical perspective when dealing with DiDIY; she especially pointed out that, in order to avoid a loss of authority, teachers should be prepared to deal with situations in which their own knowledge could be limited or even inferior to the one of students. She thinks that teamwork would be a key component of DiDIY activities and especially provide value thanks to the social interactions that happen among peers in a group. In her opinion, a high degree of creativity, technology fluency, creative thinking or problem solving is not needed to engage in DiDIY.</p> <p>Overall, she is interested in the opportunities that DiDIY could bring forth but also concerned that it could shift the focus away from the core learning contents.</p>
DiDIY Pros	<ul style="list-style-type: none"> - DiDIY can open up interesting opportunities in virtually any field. - DiDIY can stimulate students and offer them a practical perspective on the theoretical concepts that they study.
DiDIY Cons	<ul style="list-style-type: none"> - DiDIY could be superfluous or useless in certain cases. - DiDIY could shift the focus on a more practical perspective and overshadow the theoretical one.
Quotes	<ul style="list-style-type: none"> - “From a practical point of view, someone who is not really knowledgeable about a certain technology could actually bring forth new ideas, since he will completely overlook the theoretical perspective behind it (the technology) and simply focus on the practical results, possibly overcoming limits and challenges”; - “Everybody faces DiDIY on a daily basis, maybe even without acknowledging it... everyone is a part of it, from the three years old kid to the eighty-five years old grandfather”; - “Being able to bring in a topic that students love to the classroom would be absolutely beneficial (regarding how DiDIY could stimulate learning)”;

Table 11: Anna's Profile (generated by the author)

4.3.2 Annie

Gender: Female

Nationality: Spanish

Bio: Student of History of Art in “*Aberdeen University*”, Annie is also a proud mother of two beautiful kids. Born in Spain, she loves travelling and has lived in many different countries, including Australia and the UK; as such, she speaks different languages and likes to think of herself as a true global citizen. She loves art and culture and likes to get involved in activities related to these fields every time she can. The author had the pleasure to meet Annie and her family during the workshop organized in Aberdeen and she was so kind to help him out by deciding to also taking part in the interview.

Ratings:

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
SA	A	SA	SA	A	SA	SA	N	SA	A	A	D	SA	D	D	A	D

Profile:

Brief	<p>Annie believes that DiDIY has a great potential in revolutionizing education. She argues that especially in schools it should be implemented as an integrative part of every discipline and not as a separate subject, especially with the purpose of accustoming students to the use of technologies since young age. She also argues that a DiDIY approach in education should be gradual and intensify as students progress through primary and secondary education.</p> <p>She thinks that DiDIY can foster creativity and help students adopt a more practical perspective on the world around them. She does not think that a high degree of technology fluency or problem solving and critical thinking skills are strictly necessary in order to engage in DiDIY: these skills can in fact be developed by practicing DiDIY activities. In her opinion teamwork is a key element that should not be overlooked: learning from one’s peers is in fact an invaluable experience.</p> <p>She does not think that DiDIY should revolutionize the curricula as it is, but should rather be employed as a complementary approach or as a self-learning practice tool (especially in universities). She sees the teacher as a guide and would gladly welcome a more equal, less hierarchical relationship among teachers and students. Related to her fields of interest, she would especially like to see Virtual Reality being implemented in schools to teach Art: for example, it could be used to allow students to walk through museums they could not visit otherwise or to be able to fully experience paintings in a three-dimensional way (like Van Gogh’s peculiar brush style, for example).</p>
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	Overall, she is confident that DiDIY could bring value in the field of education. She is however concerned about the difficulty of training teachers to become competent deliverers of DiDIY-centered education.
DiDIY Pros	- DiDIY can encourage creativity and teamwork. - DiDIY can be used to foster technology fluency and help future generations to be more comfortable working within technological areas.
DiDIY Cons	- It would be hard to find or train competent teachers. - Teachers must be able to inspire their students in engaging in DiDIY, especially at young age.
Quotes	- "I think it is essential to be creative in all aspects of our life"; - "Yes I am a Maker! I like to think that we are all Makers!"; - "Children should not lose touch with the old things (intending analog technologies) so that they can also understand where digital technologies come from... it is a balance of both (digital and analog)"; - "[...] the teacher stands there on the pedestal in front of the class and we all sit below, and we are less (important) than the teacher... maybe digital technologies can break this barrier, so that everyone is more equal in the classroom";

Table 12: Annie's Profile (generated by the author)

4.3.3 Anya

Gender: Female

Nationality: Russian

Bio: Anya is a Production Logistics Engineering student. Originally from Russia, she is currently studying in "*JAMK University*" in Jyväskylä, Finland, where she met the author during his exchange program.

Ratings:

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
A	A	SA	A	N	A	SA	DK	SA	D	D	DK	A	D	A	SA	D

Profile:

Brief	<p>Anya is very interested in DiDIY and thinks that people should be motivated to express their creativity, as long as this does not lead to negative ethical implications as a result. She underlined the fact that creative people will likely be naturally drawn to DiDIY but that ultimately, it is impossible to force people in engaging in it if they are unwilling to do so. She thinks that DiDIY should be implemented in schools in practical laboratory activities and especially in self-learning activities through homework or self-study (either directed by a teacher or by the student him/herself depending on their own interests).</p> <p>Ideally, she would imagine DiDIY being formally implemented in the curricula in primary and secondary education and then used as a self-study tool in universities.</p>
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	<p>She especially suggests that universities should provide students with an e-learning platform that they could use to direct their self-study based on their interests: this platform would contain theoretical lessons as well as practical suggestions or projects that would help students put what they study into practice.</p> <p>She thinks that working in a group could prove beneficial for students largely for the social aspects related to teamwork but that students can only really master a discipline and enhance their skills through rigorous self-study. In this view, one of the key elements is represented by a problem solving attitude, which drives students to look for answers to practical problems and develop themselves.</p> <p>She is especially concerned with the quality of information that would be delivered to students during DiDIY activities and pointed out that teachers must be fluent with technologies and be very well prepared in order to be effective educators and not to risk a loss of authority.</p> <p>Ultimately, she sees DiDIY as an opportunity to develop oneself and become more creative and independent.</p>
DiDIY Pros	- DiDIY can be used by students to develop their interests and learn more in the fields they are most passionate about.
DiDIY Cons	- DiDIY could lead to a loss of teacher authority. - Information used in DiDIY activities should be well structured and accurate.
Quotes	- "The desire of a person to do stuff depends on their creativity"; - "[...] a group could influence a single person and lead to this one individual not expressing its full range of knowledge... it is limiting (about DiDIY in teamwork)"; - "DiDIY should not influence the authority of teachers [...] if authority is ruined there is no respect and students will never accept the knowledge given out by the teacher";

Table 13: Anya's Profile (generated by the author)

4.3.4 Ben

Gender: Male

Nationality: Belgian

Bio: Ben, originally from Belgium, moved to the UK after finishing high-school. He studied Product Design at "*Loughborough University*" and did his master's degree in Product Design Engineering at the "*Glasgow School of Art*" and the "*University of Glasgow*". He worked as a product design engineer for a product development consultancy firm in Glasgow and now he works at "*MAKE Aberdeen*", where he met the author and helped him design the experiential workshops. He has experience as a teacher in informal contexts and has run many different workshops based on the use of digital manufacturing technologies.

Ratings:

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
SA	A	A	SA	SA	A	SA	SA	A	D	SA	N	SA	A	SA	SA	D

Profile:

Brief	<p>Ben thinks that it is essential for people to create and experiment in their everyday life. He thinks that by engaging in creative activities people can develop a new mindset and transition from being simple consumers to producers, discovering new ways to interact with products, people and the world. He is excited about the fact that DiDIY could inspire society to re-engage in making: when young, children are in fact encouraged to create and experiment but this mindset is gradually lost as they progress through traditional education. He also believes that it is incredibly important that people are given the possibility to fail and see the results of their mistakes in order to learn and eventually succeed.</p> <p>In his opinion, creativity plays a key role in any DIY and DiDIY activity. Other skills such as technological fluency or critical thinking are not really necessary for students to engage in DiDIY: learning to develop and apply a design thinking mindset is much more important, in his opinion.</p> <p>When it comes to teachers, however, these skills become critical: teachers should be very well trained and competent in order to be able to inspire their students and be effective educators. Regarding technologies, he thinks that depending on the situation and educational purpose almost any technology could be adopted in DiDIY. He sees a lot of potential in Laser Cutting, which he personally exploited in several workshops (some of which aimed at teaching kids to develop a design thinking mindset).</p> <p>He also would like to see DiDIY foster a change in the relationship between students and teachers, especially making it more informal; he is aware that some think this could lead to a loss in authority but does not believe so to be an issue.</p> <p>Regarding the implementation of DiDIY in schools, he would like to see it used as a tool to integrate the existing curriculum and to adopt different teaching methods depending on different learning objectives; he also encourages not to lose focus on the theoretical learning content, which should always lie at the base of every DiDIY experience.</p>
DiDIY Pros	<ul style="list-style-type: none"> - DiDIY can help fostering a new, more practical and inspiring type of mindset. - A DiDIY approach could be used to teach the concept of failure, and how to cope with it. In certain cases, it is in fact easier to learn by failing and seeing the direct consequences of our mistakes.
DiDIY Cons	<ul style="list-style-type: none"> - The implementation of a DiDIY approach would be very difficult, both from an institutional (laws, regulations) and day-to-day (how it is implemented in each school, how it is carried out) point of view. - Teacher should be very well trained and proficient in the subject and the use of technologies in order to be able to inspire students and motivate them. - The public perception of DiDIY could be controversial, since it involves a change of mindset from a result-oriented towards a more process-oriented type of education.
Quotes	<ul style="list-style-type: none"> - “[...] to learn things through trial and error, by mistake... having the opportunity to fail in order to succeed... I think it is quite powerful”;

	<ul style="list-style-type: none"> - “The whole concept of DIY, forgetting the digital aspect of it, is freedom to fail, is doing things yourself [...] you’re not looking for that perfect outcome, you’re looking for your own version of it”; - “Mixing the artistic, creative side with the cold, engineering side [...] lots of people see them as polar opposites and don’t understand how they can go together, they don’t understand how you can see things purely logically and also have a sort of creative freedom to come up with new innovative ideas”; - “In MAKE we have fantastic machines but what’s exciting to me is not the engineering (of the machines), it is allowing the public to come in [...] (it is) what comes out of the machines, what people produce, the creativity that’s involved in what they produce”; - “The larger life skills that you learn from workshops that encourage you to work in teams are hugely important [...] teamwork is critical, having an understanding how to compromise, express yourself within a group, how to be democratic... I feel there’s a lot of really important skills in there that a lot of people don’t have so I feel that the more we can expose people to that, the better”; - “The whole concept of making is questioning why someone has done it in another way, which then introduces you to wanting to make it another way”; - “The philosophy of DIDY, (the philosophy) of learning to fail, and being ok with that... that in itself is inspiring, because it hasn’t been encouraged before”; - “The whole thing behind DIY to me is finding your own method, with the idea that one method does not work for everyone”; - “Any time there is an advancement in technology or a new way of thinking, you’re going to find that position (referring to a sceptical, change-resistant mindset) because there’s always people that go ‘but we have been doing things this way and this way is fine’, not understanding that if you’re open to the idea of change, things can improve”;
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Table 14: Ben's Profile (generated by the author)

4.3.5 Dat

Gender: Male

Nationality: German

Bio: Dat attended high school in Germany and then moved to the United States for an exchange during his final year, where he met the author. He then decided to study Computer Science in the US but due to a series of problems he had to move back to Germany, where he continued his studies in Informatics. However, he soon started to realize that the teaching method adopted in his German university was too traditional and theoretical, which he didn’t appreciate. So he moved to The Netherlands, where he is now attending the “*University of Trente*” and studying Creative Technology, a program

which combines Electrical Engineering, Computer Science and Design offering a very practical and hands-on learning experience, which Dat loves.

Ratings:

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
SA	SA	SA	SA	SA	A	SA	N	DK	A	SA	N	SA	N	D	A	D

Profile:

Brief	<p>Dat is enthusiastic about the possibilities that DiDIY could bring into the field of education. He believes that humans learn best when participating in projects that have a specific structure and a clear objective, especially if carried out as a teamwork experience. In fact, he strongly believes in the benefits of working in a group: on one hand it will take time to organize the members, divide the tasks and choose how a problem should be approached but on the other people from different backgrounds can get together sharing ideas, talents and efforts to deliver a final result of really high value; the social aspect of teamwork is crucial, and in his opinion DiDIY would be a perfect tool to foster this perspective. He also advocates against a more traditional, overly theoretical method of teaching, which is also the reason why he left his university in Germany: he believes that students should also learn how to do things and see the practical implications and possibilities offered by what they study.</p> <p>In his opinion almost any technology could be adopted for DiDIY purposes: if he were to choose only one he would pick Virtual Reality or Augmented Reality depending on the situation. During the interview he made examples of how different tools could be used for DiDIY purposes. One of these examples was to use tools such as “<i>CRISPR</i>”, a DIY genome manipulation kit, to motivate students in learning biology and chemistry.</p> <p>He does not think that a person needs to be highly creative or fluent with technologies to engage in DiDIY. Even if a person is not the best at any particular skill there will always be something that he/she wants to do and even if somebody is not that creative, he/she can still learn by applying solutions rather than inventing new ones. He thinks, however, that as a person progresses through education he/she should develop technological skills which will form his personal and professional background.</p> <p>Ultimately, he thinks that schools should adopt new technologies in their curricula and that a DiDIY approach could make education more efficient and simply more fun and rewarding. He especially values the real life approach and the social aspect tied to DiDIY. In his opinion, governments and policy makers should advocate to create an open-source team of developers to create DiDIY educational content that schools all over the world could then use as a base to develop their educational programs. In terms of methodology, he believes that one of the best ways to deliver DiDIY would be using a flipped classroom approach, especially in higher stages of education and if coupled with appropriate e-learning tools that allow students to access digital content and interact with their peers and teachers to track their learning.</p>
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DiDIY Pros	<ul style="list-style-type: none"> - DiDIY can offer a more engaging, hands-on experience to students. - DiDIY can encourage group-works, especially if they are structured with a clear objective that the group should meet.
DiDIY Cons	<ul style="list-style-type: none"> - DiDIY can be applied to a multitude of areas but every single activity needs to be very well designed, contextualized and the right technologies should be adopted based on the specific case.
Quotes	<ul style="list-style-type: none"> - "I like to build physical things! Because I think it's fun! Especially when you work in groups, you sit down, you make it... I am definitely a maker!"; - "The sweetest thing about project time is when everything worked out fine and all your team members are happy and you learned a lot of stuff and people praise you for your work... because it's good stuff!"; - "[...] people like to use the blanket statement 'Digital Revolution' but in reality the revolution is just people coming together all over the world collaborating on the best ways to learn things... but not only learn, also create things"; - "You could use VR to put a classroom of kids inside the battlefield, you know, in front of the gates of Troy"; - "Governments and people who design the curriculum should advocate to create a way for people to create that (DiDIY) type of content for educational purposes. If there's a few hundred designers who work on an open source course and a bunch of translators, we can put something together that's under common license, like Wikipedia, and that everybody can use... [...] it needs a lot of coordination, but then everybody can use it and there is no company behind it holding the rights and pawning it off for money... [...] the best way would be to have an open system... make it FREE!"; - "Regardless of DiDIY, the job of a teacher is changing rapidly because there is so much content out there that could reach and is reaching students [...] the game changer for teachers is that they are going to be social facilitators [...] the teaching profession will evolve that way naturally, because of how much good content we have out there"; - "DiDIY can make learning more fun and at the end of the day, that's what education is all about: to learn stuff that you actually get information from and not to just pass some sort of test";

Table 15: Dat's Profile (generated by the author)

4.3.6 Elvis

Gender: Male

Nationality: Ecuadorian and Italian

Bio: Elvis, originally from Ecuador, moved to Italy with his family during his teen years. He works as a software developer and specializes in front end programming. He thinks of himself as a creative and inventive person: however, he would not identify himself as a Maker since he considers most of his creative skills to concern the digital world rather than the real one. Most of what he knows he learnt through a hands-on, do-it-yourself

approach based on the need to overcome study or work related challenges. During his student years he attended an educational program based on the use of different technologies developed by “*Regione Lombardia*”, during which the author had the pleasure of having him as a student for a brief time.

Ratings:

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
A	A	SA	SA	SA	A	SA	A	SA	A	SA	D	A	N	A	A	A

Profile:

Brief	<p>Elvis thinks that DiDIY could be beneficial in linking topics and concepts and create inter-curricular connections between subjects. He also thinks that DiDIY could be used as a practical tool for students to develop their skills on their own based on their interests or whatever learning need they might come across during their studies or career. He envisions technologies like 3D Printing and Virtual Reality to be adopted in schools in interactive and practical learning experiences. In fact, he strongly values a practical component in education and thinks that DiDIY could help breaking a purely theoretical mentality that is currently adopted in many institutions across Italy.</p> <p>He also underlines the potential of DiDIY as a mean to learn new technologies or tools, especially through workshops that are focused on a specific learning objective; to this extent, he thinks that it is important for students to be fluent with technologies but that this fluency does not need to be a prerequisite to engage in DiDIY but can be developed on the go through DiDIY itself.</p> <p>During the interview he gave a very interesting example of a DiDIY project (Leonardo 101) which focuses on teaching the programming mindset to young children through a practical workshop (Brito Grandes 2016).</p> <p>Elvis also suggest that traditional teaching methods should be abandoned, as they are heritage of the culture of the nineteenth century and express a mentality which was developed following a tightly industrial point of view; ultimately, they don't fit with the smart world we live in anymore. In their place he suggests that new inter-curricular methods and approaches should be developed, in which students learn theoretical concepts by engaging in practical projects that are meaningful for several subjects: for example, students could be asked to create a small rocket and study principles of aerodynamics, chemistry, engineering and mathematics in order to reach the final solution. This approach would help students understand the practical implications of what they study and as such, motivate them.</p> <p>Ultimately, Elvis thinks that DiDIY could represent the solution to the new educational needs that he envisioned.</p>
DiDIY Pros	<ul style="list-style-type: none"> - DiDIY can help people develop themselves and their skills. - DiDIY can help people develop social skills and help learning how to interact and work in a group.
DiDIY Cons	<ul style="list-style-type: none"> - DiDIY activities should be carefully planned and tailored to serve a specific educational purpose.

Quotes	<ul style="list-style-type: none"> - “(with DiDIY) You can experiment, make thing, and then you understand when you finally reached your objective”; - “Creativity is the freedom to express oneself without limits, if not the ones we directly impose on ourselves”; - “A person does not need to have all the needed knowledge before starting a project... or no project would ever be started at all!”; - “It is difficult to create relationships in a group because we can’t fully understand the skills of the people, they sometimes remain unexpressed and DiDIY could help in this factor... it could improve the quality of teamwork”; - “A person is motivated to do something especially if he has a certain degree of freedom and autonomy [...] in school it is certainly not possible to be highly creative and certain topics can’t be approached”; - “The relationship between students and teachers is already influenced by countless external factors [...] DiDIY could allow for a more human relationship and a closer sharing of thoughts and ideas [...] there could be a certain interaction between students and teachers [...] it (DiDIY) could allow students to reach their objectives through their own strengths and resources [...] the teacher would become a sort of counsellor, a guide”;
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Table 16: Elvis' Profile (generated by the author)

4.3.7 Giuseppe

Gender: Male

Nationality: Italian

Bio: Giuseppe is an Electronics Engineer and works as a researcher and as a teacher in the Design department of the “*Politecnico di Milano*”. He is also the coordinator of the “*Design for Healthcare*” group and his main research fields are ergonomics, wearable sensors and biomechanics.

Ratings:

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
A	SA	SA	SA	SA	A	SA	A	SA	N	SA	D	N	D	D	N	SD

Profile:

Brief	Giuseppe is very interested in the practical applications of DiDIY. During his life he participated in many projects, some of which aimed at solving social issues or at helping people in third world contexts. He thinks that a DiDIY approach could be beneficial in these fields, other than in education. As an example, he spoke of a very interesting project in which robot-companions were created to interact with autistic children and mitigate their feeling of loneliness.
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	<p>He prefers to use the term innovation rather than creation, since it focuses on a broader perception of the context and should imply a strategical perspective aimed at the future; he underlined how there are two types of innovation: incremental and disrupting. He thinks that DiDIY could be a major driver of incremental innovation and also, to a lesser extent, of disrupting innovation. When creating, or innovating, he stresses how important it is to follow a rigorous methodology: a problem should be fully analysed, the requirements of the solution should be defined and then the solution should be reached by iterating the prototyping phase and adjusting/revising the initial concept.</p> <p>He thinks that DiDIY could find application in many different areas of education, in order to fill the gap between the theoretical and practical perspective of studying. He is especially convinced about the importance of introducing young children to technology as early as possible during their life in order to get them used to it and also develop a certain mindset towards it.</p> <p>He thinks that working in a group is fundamental, since a person's knowledge will always be limited. He also affirms that by engaging in DiDIY, a person can train and learn new skills also by just looking at its peers and applying the solutions they came up with: this means that anyone could take part in DiDIY activities and even if not particularly skilled, one can improve until he/she will be comfortable to engage in DiDIY on his/her own by developing his/her own methodology of approach; this is further mitigated by the fact that most of digital technologies nowadays are relatively user-friendly.</p> <p>In his opinion, the distinction between the role of the teacher and that of students should be clearly defined and allowing for a very informal relationship among them could be, in certain cases, very detrimental. He is concerned that some students could see the teacher as a sort of "dispenser of solutions": if he/she would help students too much in solving a task, they could become accustomed to adopt a very superficial or lazy approach, knowing that the teacher will eventually help them to the solution anyways. This is also reinforced by the fact that students can easily find online "ready-made" solutions that were devised for apparently similar problems but that often are not applicable to the problems they are trying to solve.</p> <p>Another critical factor that he identifies is the fact that engaging in DiDIY activities could polarize the mindset of students into thinking that almost any problem could be tackled and solved with a DiDIY approach and have a simple solution.</p> <p>Regarding methodology, he thinks that student should follow a rigorous engineering-like approach, in which the analysis is foremost based on a clear study of the problem and a solid theoretical background.</p> <p>Ultimately, he recommends using DiDIY as a tool to stimulate and train students in developing problem solving skills, following a Galilean approach. DiDIY activities should always be focused on a learning objective and a rigorous methodology should be followed when approaching a DiDIY task.</p>
<p>DiDIY Pros</p>	<ul style="list-style-type: none"> - DiDIY should be used to support and enhance existing methods of education. - DiDIY can bridge the gap between theory and practice. - DiDIY could help introducing students to practices and technologies adopted in the industrial and production fields.
<p>DiDIY Cons</p>	<ul style="list-style-type: none"> - DiDIY should not substitute existing methods of education. - DiDIY could lead to the risk of over-simplification, inducing students to think that every problem has a smart, simple solution and dismissing the search for a more elaborate and in-depth solution. - DiDIY could shift the focus away from learning contents.

Quotes	<ul style="list-style-type: none"> - “Stimulating children’s brain since young age is incredibly positive”; - “Demonstrating that extremely complicated mathematical functions have a practical applicability could help overcoming that cultural barrier or that prudery of students which, especially in high schools, question ‘when will I ever need this stuff in my life?’ ”; - “(DiDIY technologies) are enabling technologies, not in the meaning that they represent high-tech, complex technologies, but that they allow to reach a practical and extremely functional result in a very short time”; - “Experience is knowledge; the rest is information (adapted quote by Albert Einstein)”; - “Creativity is a process of divergent convergence, meaning that we diverge from an idea to explore countless others which will then converge in the final product”; - “It could be beneficial to exploit a student’s interests and his passions to motivate him, but at the same time you could risk to make him lose other perspectives or points of view [...] the exploration of the world, of activities and of things is fundamental!”; - “Sometimes, easy to use technologies could lead to an excess of practicality in the beginning phase of a project, which dramatically risks to negatively affect the development of the entire project”; - “The risk is that of falling in the trap of simplification: thinking that every problem could have a simple solution!”;
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Table 17: Giuseppe's Profile (generated by the author)

4.3.8 Massimo

Gender: Male

Nationality: Italian

Bio: Massimo graduated in Physics and then earned his PhD at the “*Massachusetts Institute of Technology*” in Fluid Dynamics and Plasma Physics. He now works as a researcher in this field and also teaches part-time in a technical high-school in Italy, where he manages an educational laboratory and coordinates the Physics department. He has experience in the industrial and manufacturing fields, especially in Project Management, and is active in the field of applied research and technology transfer. He is the owner of “*Project Scientific & Applied Solutions*”, a firm whose offered services include Research and Development, Innovation Support and Coaching, Marketing and Communication; it also offers support for EU-funded projects, especially in building and management of the projects. Massimo is also member of “*Nanofutures*”, a European

initiative for sustainable development by Nanotechnologies, and technical director of the “*Trattamenti & Finiture*” review.

Ratings:

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
A	A	A	A	A	SA	SA	N	SA	D	SA	D	SA	D	SA	A	D

Profile:

Brief	<p>Massimo pointed out that unfortunately, in today’s society a lot of people are mere consumers and only a handful can be defined as makers: tinkering is not encouraged and generally products are received as is, with few people actually trying to adapt them to their specific purposes or being more critical about them. He would very welcome a DiDIY approach in schools, since it could help shifting the interest back to making and creating things. In fact, he believes that the practical side of education is incredibly important and should be encouraged.</p> <p>He thinks that DiDIY could be used to foster students in creating their own personalized and customized tools and methodologies, other than fostering the development of a scientific consciousness and a quantitative problem solving approach based on experimentation; implementing this in schools would have a strong pedagogic and educational value, since it would encourage students to questions themselves and their skills and learn in a more critical manner.</p> <p>He thinks that the main prerequisite to engage in DiDIY is the will of “playing the game”: skills and competencies can be developed later, while doing things. He is especially interested in the applications that DiDIY could have in high-schools: in fact, he thinks that it is highly important for students to be able to express themselves and get involved in activities they are passionate about in order to motivate their learning. To this extent, in higher stages of education he would suggest that the role of a DiDIY teacher would become that of a guide, a counsellor, which steps in the game only when strictly necessary and leaves students the freedom to experiment, while also making sure that they do not stray too far from the original learning objective. This is very important in his opinion, especially because failure in using digital technologies could lead to frustration or abandonment: being able to rely on a person with more experience that can act as a guide (whether a teacher, a mentor or a friend) could ease this process.</p> <p>He also thinks that the maximum potential of DiDIY would be achieved through teamwork: brainstorming and peer-to-peer learning is positive, but on the other hand care should be taken that all group members have the same opportunities and that single students do not become overshadowed or crushed by the group.</p> <p>He thinks that DiDIY will bring a great challenge to human relationships and put existing role models in discussion. More specifically, he envisions that teachers should be able to adopt a more inter-curricular approach and closely cooperate with one another in order to offer students a complete learning experience. He would adopt DiDIY as a tool to enhance existing teaching methods, since it can offer new opportunities to extend the boundaries of education as it is today.</p>
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	Ultimately, he thinks that DiDIY could help re-discovering a more creative, practical and material approach with the world, encouraging a pragmatic problem solving mindset that has almost been lost in today's society.
DiDIY Pros	<ul style="list-style-type: none"> - DiDIY can help speed up educational processes, other than making them more engaging and rewarding. - DiDIY can be used to create practical experiences and effectively see their results in a very short time. - DiDIY can allow students to become the real protagonists of learning. - DiDIY could foster the development of a mindset based on reaching solutions employing the minimal amount of resources and energies that are actually required.
DiDIY Cons	<ul style="list-style-type: none"> - DiDIY could lead to a “technological black-hole”, risking that a large amount of time and resources would become wasted on solving technical problems that might arise rather than actually learning. - DiDIY will introduce a challenge regarding the way people relate to each other and might put existing roles in discussion. - It will be challenging to give students a certain degree of creative freedom while also maintaining a focus on educational objectives. - DiDIY should not be used as a substitute for existing teaching methods
Quotes	<ul style="list-style-type: none"> - “DiDIY can be used to build personalized tool that allow to reach custom, not standardized objectives, while also developing a work methodology that is more suited to one’s attitude, one’s way of communicating and interacting both with the machine and pees [...] creativity should be re-awakened in our times! [...] (we should) put a little of ourselves in the things we use”; - “DiDIY allows to materialize thoughts and through our own approach and our own interaction with the real world, it allows creativity to get out of our minds and transition from a wish, from something abstract, directly into the real world”; - “(DiDIY) [...] it is a tool that allows us to transcend our minds and let us enter into the real world, affirming ourselves by applying our creativity and our problem solving skills”; - “Teamwork can help avoiding that digital tools become the (only) work companions and that human interactions and the concept of turning to others and their own creativity for help is lost [...] in my opinion, working in a team is essential!” - “The teacher might learn while teaching and this must be accepted [...] the teaching process is dialectical and collaborative, it becomes a team experience in which the teacher is not the main player anymore but rather is a member of a team [...] a team that can bring an incredible value to the educational process through an experience and methodological related perspective, other than a perspective only focused on knowledge”; - “DiDIY should not become a sort of black hole: we should not invest the vast majority of energies allocated to reaching a specific learning objective in solving technical problems”; - “We should never forget where we came from... there is a strong human value in the past that must be preserved... it is not a matter of nostalgia but a matter of valorising what, from teacher to teacher, has been handed down to us through time (commenting about the fact that DiDIY should not revolutionize educational methods but rather be employed as an enhancing tool)”;

Table 18: Massimo's Profile (generated by the author)

4.3.9 Mauro

Gender: Male

Nationality: Italian

Bio: Mauro graduated in Mechanical Engineering in “*Politecnico di Torino*” and then started his career as Production Manager. He then moved to the “*FIAT Research Centre*” where he was responsible for research and development of new materials and production systems. He was also responsible of educating students participating in a scholarship program offered by “*FIAT*” to young graduates. He also worked as a trainer for “*ISVOR FIAT*” in industrial fields, especially teaching about machine tools and production systems. He now focuses on Research as project manager at “*Diad Group Company*” and is currently participating in different EC-funded projects, such as the MMTECH Project (H2020, n. 633776) and the Borealis Project (H2020, n.636992). In the past, he also participated in the RAPOLAC Project (FP6-Aerospace, n.30953).

Ratings:

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
A	D	SA	A	A	N	SA	DK	A	A	SA	D	SA	D	SA	SA	A

Profile:

Brief	<p>Mauro believes that DiDIY, being a creative process, holds a great potential but also the risk to be a dispersive too. DiDIY can allow to rapidly develop solutions, tools and methodologies to face the tasks at hand. In schools it should be used to stimulate students and to give them the possibility to approach problems in a practical perspective and to extrapolate concepts and methodologies from their practical experiences, teaching them a mindset that they could then also use autonomously in other extra-scholastic contexts.</p> <p>He believes that students should be guided through such processes but also that the role of the teacher is rapidly evolving and will continue to do so in the future. He thinks that teachers should gradually become less and less present in the classroom as the students progress through their studies, assuming the role of a facilitator or that of a guide (to further understand this concept, the author recommends to consult the quote sections and read about the IKEA example).</p> <p>He also thinks that DiDIY could prove very valuable in companies, especially in training: it can be used to give employees a valid tool to improve their competences or to solve various issues. He made an example of how Virtual or Augmented</p>
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	<p>Reality could be used to teach operators to perform tasks and operations such as picking or repair, even if they have no pre-competence in the field.</p> <p>He thinks that DiDIY should not be adopted in every discipline but should rather find application in the contexts in which such approach could prove beneficial depending on the objectives that need to be met. In schools he would suggest adopting it especially in STEM. He is particularly thrilled by the different opportunities that different technologies can offer and how they can be combined to create unique experiences: he made an example how LEGO Mindstorms could be used in conjunction with 3D Printings (to allow students to create their own parts rather than just needing to resort to existing LEGO pieces) to engage students in Robotics. He thinks that DiDIY could allow schools to independently explore several fields that could have previously been impossible or very difficult to approach, due to the need of high investments. The need for highly-specialized machinery or the need to be dependent on external factors or agents. He is also convinced that DiDIY activities should be structured to spark in students the interests to then autonomously go and study the theoretical principles that lied at the base of their practical experiences.</p> <p>In his opinion creativity is the primary stimulus that induces people to approach DiDIY. Technology fluency is important, as students should develop it in order to become truly independent in their activities. DiDIY also offers great opportunities for fostering teamwork.</p> <p>He thinks that the role of the teachers is changing and that DiDIY will pose a further challenge in the future. He believes that teachers should be one step ahead of students, but in today's world this is nearly impossible, given the high number of stimuli that students receive and content that they can access. The teacher should transition to assuming the role of a guide, helping students and monitoring their learning, while 'acting in the background', in order to leave the stage to the students and their independence. In his opinion, DiDIY could help adopting this perspective, while also fostering a real and concrete learning approach.</p> <p>Ultimately, he believes that DiDIY could be a very powerful tool to improve learning: it should be applied in different ways depending on the learning objectives and especially the age of students. On the other hand, though, Mauro also believes that a careless implementation of DiDIY might prove extremely dangerous and detrimental for students.</p>
<p>DiDIY Pros</p>	<ul style="list-style-type: none"> - Through DiDIY students can learn a methodological approach and become more independent. - DiDIY can allow students to engage in activities and explore fields that would otherwise require the use of complex technologies or complex processes, such as robotics. - DiDIY could help motivate students that are not particularly technological-savvy: this way, they can learn that DiDIY exists and how to use it and be motivated, if they want, to autonomously adopt it for their own purposes. - Especially at work, DiDIY can be used to learn the use of tools and technologies.
<p>DiDIY Cons</p>	<ul style="list-style-type: none"> - If DiDIY is introduced too early in education it could prove detrimental for kids as it would take time away from other key learning activities. It would be like giving students a tool to do things so that they can effectively use it to create, but without understanding the theoretical principles and implications behind what they do. - DiDIY can foster incremental innovation but at the same time also shift the focus away from breakthrough innovation.
<p>Quotes</p>	<ul style="list-style-type: none"> - "Nowadays lots of innovations are incremental and only few go beyond the existing schemes and think outside the box [...] that creativity has somehow been lost, the

kind that pushed you into creating totally different things from then ones that already existed, but on the other hand it is now easier to engage in incremental innovation [...] drawing the line, I think that in the past there was more creativity in society”;

- “Individual creativity is the main stimulus to approach this type of tools; a person will not engage in DiDIY because forced but rather because he/she wants to achieve something, and this will be born from his/her creativity”;
- “University students could have a more advanced perspective than the one of institutions and can perceive needs in the reality that they experience every day that most likely universities can’t perceive or can’t rework the curriculum fast enough to accommodate to these new needs”;
- “The role of teachers is evolving and from my point of view they should no more offer a standard educational experience... teaching should become more flexible and adaptable to the surrounding world [...] I see the role of the teacher more as the one of a trainer, and educator, a person that encourages to think critically [...] it is important that someone stimulate the students, makes them think beyond the simple object or project that they are working on, helps them extrapolate knowledge, concepts and methodologies [...] I am far less convinced about the concept of the teacher that sits at the desk and (simply) gives the lesson”;
- “Montaigne believed that young kids should approach science and understand its principles autonomously, by learning from the real world [...] you can’t just explain that a formula is used to do a certain thing [...] they must discover themselves by observing nature [...] obviously, they must be accompanied by someone who can guide them through this autonomous process [...] it is the natural learning process of humans!”;
- “The Montessori method emphasizes and puts at the center of the attention the importance of the boy as an autonomous individual and with his own dignity since young age, independently of his knowledge... this happened in an historical context in which kids only had dignity the moment in which they started to work and bring home some money [...] I believe in this kind of principles [...] (to) giving kids the idea that they are doing things by themselves, that they are autonomously learning something new is something fantastic! The skill that a teacher should have is that of teaching students while also giving them the feeling that he never actually taught them anything... students should have the feeling that they are learning as the result of personal experiences”;
- “Kids love going to IKEA because they can go around, look, touch things, they can deal with material objects and see installations that make them imagine what you could accomplish with those objects, like bedrooms or kitchens... they imagine homes, they imagine lives... being able to visit such a place and imagine a reality that at the moment does not exist but that you could make real if you wanted is a very powerful experience... and the other important factor is the fact that in IKEA there is no salesperson... nobody is there asking you to buy but the salesperson is a neutral figure, a person that you actively refer to if you need to ask something or don’t know what to do [...] IKEA embodies the concept of autonomous building and creation and in shops, customers continuously look for salespersons to ask for help [...] it is not like in traditional shops where people usually flee from salespersons [...] I think, under certain aspects and especially as students grow older, that school should be something similar. At the beginning the teacher is like the substitute of the parents and as they grow up this role becomes less and less important and the teacher becomes an educator, someone who helps understanding things... the teacher should shift to the background, become a sort of IKEA salesperson, a figure

	that you don't necessarily need and is able to give students the space and freedom they need";
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Table 19: Mauro's Profile (generated by the author)

4.3.10 Mirko

Gender: Male

Nationality: Italian

Bio: Mirko is an Italian software developer. His background is scientific-technological and in the past he attended an educational program based on the use of different technologies developed by “*Regione Lombardia*”, during which the author had the pleasure of having him as a student for a brief time. He likes to interpret reality through numbers and understand what rules define certain contexts, creating models that represent them. He is in fact a big fan of role-playing games and loves to create software applications. In his free time, he also cooperates with the local Catholic community working as an educator for both kids and teenagers.

Ratings:

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
SA	N	D	A	SA	A	SA	A	A	N	A	SD	SA	A	SD	A	N

Profile:

Brief	<p>Mirko believes that humans learn by stimulating their minds and creating things is one of the best ways to do so. He believes that DiDIY could be employed in several disciplines to improve the way education is delivered but also thinks that while it might be relevant in some cases, in others it could prove superfluous or redundant; to an extent, DiDIY could even prove negative if it would lead to losing a sensorial perspective. In fact, he believes that the brain uses all five senses when learning and every one of them is equally important: losing a sensorial perspective would impoverish a learning experience.</p> <p>He is especially thrilled by the fact that DiDIY offers students the opportunity to make mistakes; then make more mistakes: he thinks that learning to fail and to cope with failure is a very powerful tool and being able to concretely experience the results of failure is even more so.</p> <p>He thinks that DiDIY should not be adopted in primary education.</p>
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	<p>Based on his experience, he believes that kids need to learn using material tools and most importantly, having access to limited resources: this would lead them to develop lateral thinking and learn how to approach problems only with the resources at hand. He states that digital natives today are used to always have access to information and as such to potential solutions to problems: this leads to the fact that some children grow distracted and are not able to make do with what they have around, since they are used to look for ready-made solutions rather than creating their own. For this reason, he would avoid excessively exposing young children to digital technologies but still recommends engaging in more analog-based DiDIY activities.</p> <p>He sees teamwork as an essential component of DiDIY. Learning to work in a group can help students develop social skills and also be more ready for when they will start working: it can encourage to think in a more open way and more importantly, it can develop trust in one's peers and their capabilities. To this extent, DiDIY can also be used to teach the importance of other social factors, such as the possibility of looking for help online and learning from others; furthermore, a group helps levelling one's weaknesses and exalts one's strengths.</p> <p>He thinks that the role of the teacher will not change in the classroom but will shift to that of a guide when it comes to self-learning: he should be able to direct students and show them a possible way in which problems could be approached, helping them develop a critical perspective.</p> <p>He believes that "digital blackboards" could be especially useful in classrooms, since they would help teachers be more creative (by easily using different colours) and foster a more lateral teaching perspective (by being able to easily switch between topics – and screens, pictures, drawings etc.).</p> <p>Ultimately he thinks that DiDIY could be successfully deployed across various disciplines and that the creative perspective is one of its main elements. However, he is concerned with its implementation and thinks that currently, our society is not yet ready to welcome a DiDIY approach.</p>
DiDIY Pros	<ul style="list-style-type: none"> - DiDIY can help approach certain subjects and develop a creative approach. - DiDIY can help students become more critical and lead them to develop their own tools, rather than accepting what is given to them.
DiDIY Cons	<ul style="list-style-type: none"> - DiDIY should be adopted with caution: especially with young students, it could lead to negative consequences if they are overwhelmingly exposed to digital technologies. - DiDIY could lead to a decrease in the authority of teachers in some cases. - Training competent teachers and creating high quality educational content is not an easy task. - DiDIY could lead to losing focus of the theoretical perspective and what should be learnt, since it encourages to focus on a practical perspective.
Quotes	<ul style="list-style-type: none"> - "A good way to use 3D Printing would be to print objects based on certain parameters or functions and then vary these parameters and repeat the print [...] to show students what would change in the real world if we changed a theoretical parameter"; - "Seeing the concrete results of failure is very strong and important for learning"; - "Our brain does not use a single sense when it comes to learning [...] some people could find it difficult to learn if the use of digital technologies would lead to the disappearance of a sensorial component [...] for example, by substituting a book with an iPad the tactile experience would be lost";

	<ul style="list-style-type: none"> - “[...] a creative approach could stimulate (students) to be more critical and not just copy the (learning) method given by the teacher [...] you could end up building your own learning method, in tune with the do-it-yourself paradigm”; - “Are we really ready for DiDIY yet?”
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Table 20: Mirko's Profile (generated by the author)

4.3.11 Rosemary

Gender: Female

Nationality: British

Bio: Rosemary graduated in Physics and then earned her PhD in Engineering, specifically in Additive Manufacturing. She then moved to proposal writings and running research projects concerning additive manufacturing of metal components and additive manufacturing for repairs in the automotive and aerospace fields. She currently works at the “*Sheffield University*”, where she manages the MMTECH Research Project (H2020, n. 633776) and the AMOS Project (H2020, n. 690608). She was also the manager of the RAPOLAC Project (FP6-Aerospace, n.30953).

Ratings:

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
SA	A	A	A	SA	A	SA	SA	A	D	SA	SD	SA	D	D	A	D

Profile:

Brief	<p>Rosemary agrees that DiDIY could be useful to improve the way certain subjects are taught but underlines that this approach might not necessarily be relevant in every discipline. She sees it adopted especially in practical applications and in technical fields such as Engineering or Architecture or Mathematics.</p> <p>She is interested by the possibility of creating things through several iterations, so that students have a chance to put what they studied into practice.</p> <p>In her opinion creativity in DiDIY and especially when working in a group it can represent a major driver of true innovation. She does not deem technological fluency, problem solving or critical thinking skills an enabling factor of participating in DiDIY activities, since the practical perspective can help overcome a lack of such skill and also help a person in developing them while doing.</p> <p>She is especially interested in the possibilities offered by CAD software and would like to see a “building-block” CAD software to be created with the purpose of encouraging even young children in approaching this technology. She suggests that</p>
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	<p>when adopting technologies in schools, the main decisional factors that should be considered are safety and affordability (in terms of cost of purchasing, of use, of maintenance and of disposal). She suggests to adopt different technologies depending on the age and level of expertise of students, other than the learning content that should be delivered; she thinks, in fact, that DiDIY tasks should be centered and designed based on a specific learning objective.</p> <p>She thinks that DiDIY could be especially useful to engage students and motivate them. Students could especially be encouraged to engage in DiDIY during their free time: in order to ensure that they follow a certain structure and that they actually learn something instead of simply tinkering, she suggests that teachers design lists of activities based on different topics so that students can then choose what they wish to learn based on their needs and interests. From a methodological point of view, she suggests to structure DiDIY activities by first giving a brief theoretical perspective and then move on to a practical phase, during which students can learn as they progress; it is especially important, from time to time, to take a moment to formalize the practical lessons learnt while tinkering into concepts and at the end of the experience the teacher should draw conclusions and present students a possible solution to the given task.</p> <p>Ultimately, she sees DiDIY as a support to the existing curriculum, which could be used to enhance the way several subjects are delivered.</p>
DiDIY Pros	<ul style="list-style-type: none"> - DiDIY can help engaging students and make them more enthusiastic about learning. - DiDIY could help discovering or exploring new concepts in the classroom, which might not have been otherwise tackled through the standard curriculum.
DiDIY Cons	<ul style="list-style-type: none"> - DiDIY requires great investments of time, money and resources. It would be difficult to get funding to adopt it, so the challenge lies in implementing it in schools within existing funding structures.
Quotes	<ul style="list-style-type: none"> - “[...] with DiDIY you could get to do things and multiple iterations of a design, and see some of the concepts in action. If you could do things and try them out rather than just learn things theoretically I think you would understand them a lot better”; - “I think that, obviously, if you are fluent (with a technology) and you have been taught how to use it in some way you are going to be less creative because maybe, you are not going to be thinking around the topic so well... whereas if you are struggling and don’t know how to use it you would probably explore the space of options in a lot more detail [...] because you don’t know what the capabilities of the technology are, you don’t have it in your head that it can and can’t do some things”; - “I think any good teacher should be happy to learn from its students, if some of them do know more of the teacher, since that is obviously possible”; - “I always enjoyed projects in which you did some theory, then you did some practical work where you could develop and build and design things, and then you would learn lessons as you are developing... you find out new things and then you can go back into the classroom and do a bit more theory to explain the things that people have been finding doing their practical work... [...] (the teacher can) explain how things can go wrong, how they should be done correctly...”; - “I would have loved to do this sort of things (DiDIY) when I was younger!”;

Table 21: Rosemary's Profile (generated by the author)

4.3.12 Sara

Gender: Female

Nationality: Italian

Bio: Sara works in “*Politecnico di Torino*” as associate professor, where she teaches Science and technology of Materials. She is also an active researcher, focused in the field of additive manufacturing and especially that of metal components.

Ratings:

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
A	A	A	A	A	A	SA	N	SA	A	SA	D	SA	A	D	A	D

Profile:

Brief	<p>Sara believes that a DiDIY approach in education could be beneficial, if adopted as an auxiliary tool to support traditional education. She is especially convinced about the importance of showing students the existence of a DiDIY approach, so that they can later decide to adopt it, if needed, to overcome challenges that they might face during their studying, professional or private lives. A “just-in-time” learning mindset could be fostered, in which people are encouraged to seek knowledge and learn about specific contexts based on their contextual needs.</p> <p>She thinks that teachers should be highly fluent with technologies and set examples for students, to inspire them about the ways in which certain technologies could be used. She sees creativity as an important factor, which could improve DiDIY activities and their depth; however, the main focus of DiDIY activities should not be the creative side, since every person is different and has a varying degree of creativity; in her opinion, the core of a DiDIY activity should be a clear learning objective that is supported by both a practical and theoretical perspective. She would recommend adopting 3D printing in DiDIY, and especially metal 3D Printing, since it offers a great set of advantages over other more affordable 3D printing technologies.</p> <p>She thinks that it is important for students to learn in a group but also that they should be assigned individual tasks: individual learning is in fact a key element in acquiring new knowledge and competencies. She thinks that it would be beneficial for students to have an e-learning platform where they can access content and interact with their peers and possibly other people from all over the world, in a perspective of shared, mutual learning. However, in this context it would be quite challenging to regulate the information that is being shared and guarantee a high quality of content; it is crucial to avoid sharing incomplete or false information and also make sure that this information is not exploited for illicit activities.</p> <p>She is convinced that the role of the teacher has already been changing due to several social drivers and that the trend is leading to a gradual decrease in the</p>
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	<p>authority of the role of the teacher. This could represent an issue, but also provide a more informal context in which DiDIY could be applied.</p> <p>From a methodological perspective, she would suggest to engage students in practical DiDIY activities to stimulate them in acknowledging their knowledge gaps/needs; later, the teacher should show them a possible solution and they should then be encouraged, by themselves, to learn what they need to solve the task at hand.</p>
DiDIY Pros	<ul style="list-style-type: none"> - DiDIY can be an effective tool to improve one's knowledge and competencies. - DiDIY can foster a "just-in-time" learning mindset.
DiDIY Cons	<ul style="list-style-type: none"> - The implementation of a DiDIY approach in education faces serious bureaucratic, legislative and economic challenges. - It is impossible to assess the quality of every DiDIY content that students can access through online or local communities. As such, DiDIY could easily become a double-edged sword, especially when used in self-study activities without the guidance of a teacher. Students could access incomplete, erroneous or even illicit information, given the incredible amount of content that can be found online and the fact that a DiDIY perspective does encourage sharing and communicating with others.
Quotes	<ul style="list-style-type: none"> - "I believe that DiDIY could be useful to improve learning and should be used as an auxiliary or enhancing tool"; - "Students could look at their teachers and see the examples they set [...] (they can) know that DiDIY exists. Otherwise, it would be dependent on a student's own initiative (whether or not to engage in DiDIY) and maybe, some people who would actually like the approach would never get to know it if it isn't shown to them"; - "A critical factor of teamwork is the fact that some people might become crushed by the weight of the group [...] while others could be inspired";

Table 22: Sara's Profile (generated by the author)

4.4 Interview Findings

This chapter presents the findings of the interviews. First, a perspective on the answers to the Likert Scale rating questions is presented and then the main findings of the open ended questions are outlined.

4.4.1 Likert Scale Questions

The following table summarizes the ratings given by participants to the rating questions; students and teachers (indicated as "educators" in the figures below) are grouped together to facilitate a comparison of the opinion of the two groups:

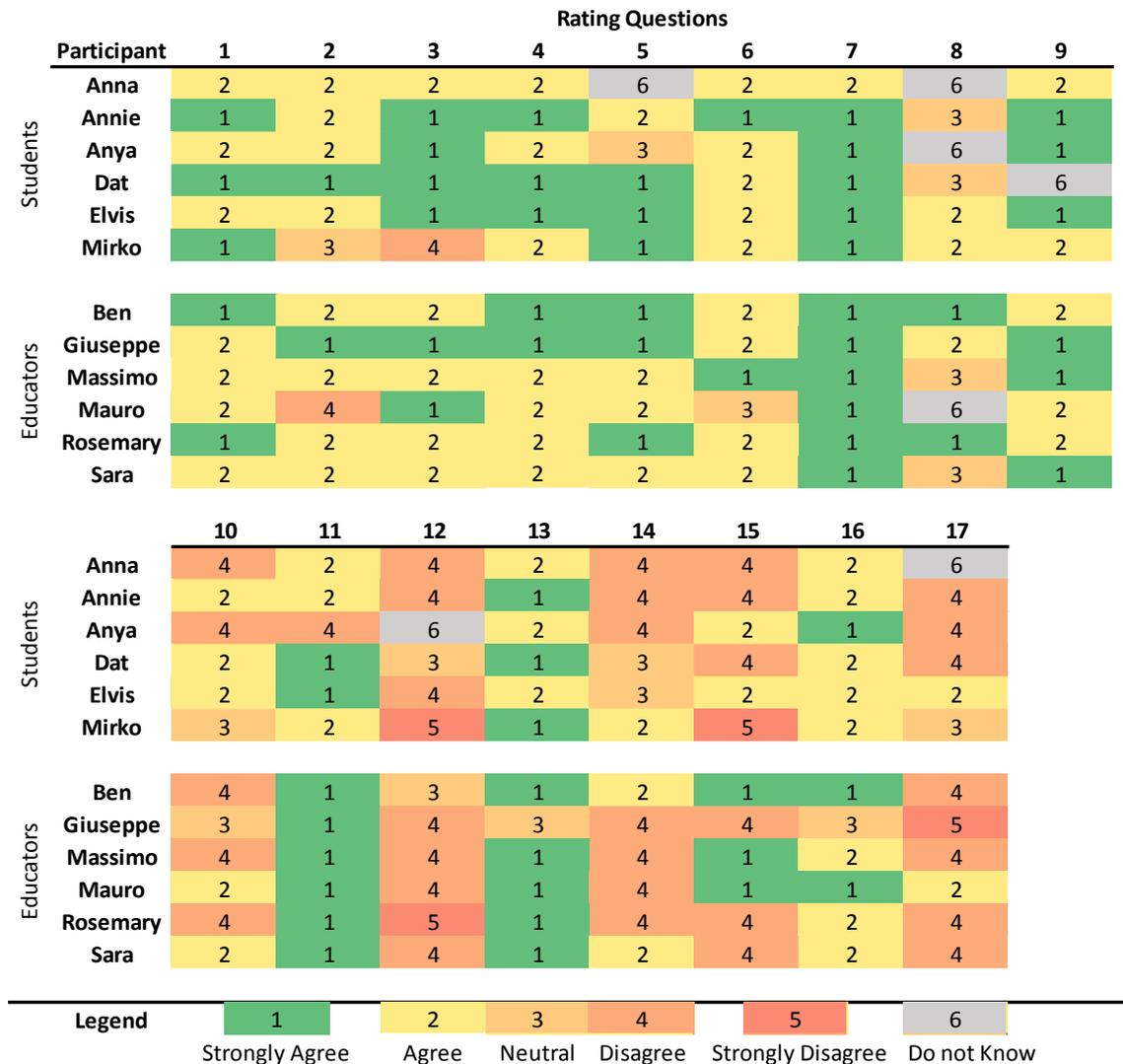


Figure 13: Ratings given by participants (generated by the author)

The following table summarizes the most common opinion about each question, in the perspective of all participants, of students and of teachers. In case a dominant opinion did not exist among the groups the author indicated the closest least extreme value on the scale (so if for example 6 participants voted “Agree” and six voted “Strongly Agree”, “Agree” would be interpreted as the general opinion). An exception is made for Question 15 in the group of teachers, in which an average opinion could not be indicated since the

method explained above would not yield an accurate result (3 teachers “*Strongly Agree*” and 3 “*Disagree*”).

		Rating Question								
		1	2	3	4	5	6	7	8	9
General		2	2	1	2	1	2	1	3	1
Students		2	2	1	2	1	1	1	3	1
Educators		2	2	2	2	1	2	1	2	2
		10	11	12	13	14	15	16	17	
General		3	1	4	1	4	4	2	4	
Students		2	2	4	2	4	4	2	4	
Educators		4	1	4	1	4	X	2	4	

Figure 14: Most common opinion of all participants, of students and of teachers in regards to the rating questions (generated by the author)

It is interesting to note how Question 7 (*DiDIY should be used to teach the use of technology*) is the most agreed upon, both by teachers and students. This underlines the fact that interviewees deem that DiDIY should primarily be employed as a tool to teach the use of technologies.

The most disagreed upon Question is number 12 (*It is impossible for a student that does not possess particularly developed critical thinking and problem solving skills to engage in DiDIY*). Interviewees generally agree on the fact that a person can improve his/her problem solving and critical thinking skills by engaging in DiDIY, but also that these skills should not be conceived as a necessary enabling factor to participate in DiDIY activities. It is agreed that people with low critical thinking and problem solving skills could still be able to carry out DiDIY activities.

Question 8 (*DiDIY should be used to teach a mindset, an attitude*) is the one that raised the highest amount of “*Do not Know*” answers. Interviewees generally agree that DiDIY could be used to teach a mindset, especially among teachers. Some specifically stressed how DiDIY could be adopted to teach a problem solving methodology. On the other hand, other interviewees appear unsure: some participants in fact commented that given their

limited understanding of DiDIY, they did not feel capable of reasonably addressing this question.

Question 15 (*The adoption of a DiDIY approach will lead to a change in the authority of teachers and the relationship they have with their students*) is the one with the highest degree of variation in answers: while students generally disagree with the given statement, teachers appear divided on the topic. It is especially interesting to note how students disagree on the fact that DiDIY would foster a change in the relationship with their teachers, while some teachers envision the possibility of change. It should also be noted that some interviewees who disagreed with the statement commented that they did so not because they did not believe that the role of the teachers would change in the future but because they did not consider DiDIY to be a major driver of such change. Considering this, it should be noted that most of the participants agree on the fact that the role of teacher will change in the future and that to a certain extent it is already evolving. They also agree that DiDIY could help accommodating the transition of this change, while not playing a major role in causing it.

Question 10 (*It is important for students to be fluent with the adopted technologies when engaging in DiDIY activities*) presents the highest discrepancy between the opinion of teachers and students, which respectively generally disagree and agree with the given statement. Students are open to the possibility that by engaging in DiDIY it is possible to improve in terms of technology fluency, but do not see this factor as an access-barrier. Teachers, on the other side, place more emphasis on the relevance of technology fluency as a skill; this discrepancy is partially explained by the difference in perspective among the two groups. Students think in terms of participating in DiDIY activities, focusing on the activity itself; teachers, on the other side, focus their perspective on the learning objectives behind DiDIY activities and as such give a higher value to technology fluency skills. In fact, many teachers stressed the importance of the fact that DiDIY

should be used as an educational tool to teach students a methodology that they could then apply in self-study practices or in other aspects of their life; in this perspective, teachers underlined the importance of the students being able to explore autonomously, an activity that directly depends on the students' degree of technology fluency (hence explaining why teachers appear more concerned about this factor than students).

4.4.2 Open Ended Questions

The following table outlines the most common opinion of the interviewees about different topics, presented following the structure of the interviews. The “*Context*” and “*Conclusion*” sections are not included, since they are more thoroughly discussed in the next section. The same applies for the “*Warm-Up*” section.

 <p>Creativity</p>	<p>Creativity is a very important factor and can be stimulated by DiDIY. A creative person could find it easier to carry out DiDIY activities than a person who is not. The more a person is creative, the more there is potential to realize innovation by engaging in DiDIY. Furthermore, creativity should not be conceived as a prerequisite to engage in DiDIY activities.</p>
 <p>Technology Fluency</p>	<p>Similarly to creativity, technology fluency is an important factor but not a necessary prerequisite to engage in DiDIY. Participating in DiDIY activities can be an effective way to improve technology fluency. The higher the technology fluency of a person, the easier it should be for him/her to master the use of a technology and exploit it to its full potential.</p>
 <p>Teamwork</p>	<p>Working in a group is beneficial when engaging in DiDIY. The group could help limiting one's weaknesses while also exalting one's talents. Also, by working in a group it is possible to tackle complex problems which can offer high value in terms of learning or skill development. The creative potential of a group is also higher than that of single individuals. On a different note, working in a group can foster the development of social skills which can prove extremely useful in a professional environment. It should also be remembered, however, that group activities should be strictly designed and managed by a teacher in order to maintain focus on a given task and to avoid that some members crush the opinions of others and do not give them possibility to develop themselves.</p>

 <p>Critical Thinking and Problem Solving:</p>	<p>Critical thinking and Problem solving skills are seen as factors that can facilitate one's approach to DiDIY but do not represent a prerequisite. Adopting a problem solving approach would especially be useful when engaging in DiDIY if a proper methodology is followed, since in these terms DiDIY could be used to teach students a practical mindset to tackle and solve problems.</p>
 <p>Interests and Aptitudes:</p>	<p>Students can be drawn to DiDIY by exploiting their interests; however, these interests should not become the main focus of DiDIY activities. By engaging in DiDIY it is especially suggested that teachers stimulate the interests of the students, in order to spark in them the interest to autonomously deepen their knowledge around certain topics, such as the ones directly related to DiDIY activities carried out in class.</p>
 <p>Teacher/Student Relationship:</p>	<p>The views about this topic appear controversial. While students advocate for a more informal relationship with their teachers, the former seem to disagree. Despite this, both agree that the role of the teacher is evolving, mostly due to social drivers not related to DiDIY. The introduction of DiDIY in education will pose a challenge but also represent an opportunity that can help accommodating the transition of the evolving role of the teacher.</p>
 <p>Teaching Methods:</p>	<p>A theoretical perspective should lie at the base of DiDIY activities. It is suggested that DiDIY is encouraged as a self-study practice, other than as an activity to be carried out in schools. Regarding which methodology to approach, two solutions are particularly suggested: one view is that students should explore theoretical concepts and then practice their application; the other is that students should engage in practical, structured activities and then extrapolate theoretical concepts from their experiences. In both cases the guidance of the teacher is fundamental.</p>

Table 23: Common opinion of participants about the main themes of the interview (generated by the author) (icons by Icons8 - www.icons8.com)

The main themes that emerged during the discussion and that should be further explained are outlined below, in no particular order of importance:

- **The role of the teacher is evolving, rapidly.** Interviewees agreed about the fact that the role of the teacher as we know it will change in the future. Despite a general agreement with this statement, interviewees do not share a common view about the nature and causes of this change. For example, some think that the

role might change if DiDIY is introduced into education while a more common opinion sees social factors as the major drivers.

Some interviewees also elaborated on their vision of what the teacher should become in the future. It is agreed that he/she should become a sort of guide, a counsellor that helps students in their learning processes by guiding them through their learning experiences and then, once students would become independent, he/she would step down and be able to give them the freedom to express themselves, while still monitoring their learning and helping them not losing focus on the learning objectives. To this extent, Mauro's example of the teacher and the IKEA salesperson is quite fitting: *"Kids love going to IKEA because they can go around, look, touch things, they can deal with material objects and see installations that make them imagine what you could accomplish with those objects, like bedrooms or kitchens... they imagine homes, they imagine lives... being able to visit such a place and imagine a reality that at the moment does not exist but that you could make real if you wanted is a very powerful experience... and the other important factor is the fact that in IKEA there is no salesperson... nobody is there asking you to buy but the salesperson is a neutral figure, a person that you actively refer to if you need to ask something or don't know what to do [...] IKEA embodies the concept of autonomous building and creation and in shops, customers continuously look for salespersons to ask for help [...] it is not like in traditional shops where people usually flee from salespersons [...] I think, under certain aspects and especially as students grow older, that school should be something similar. At the beginning the teacher is like the substitute of the parents and as they grow up this role becomes less and less important and the teacher becomes an educator, someone who helps understanding things... the teacher should shift to the background, become a*

sort of IKEA salesperson, a figure that you don't necessarily need and is able to give students the space and freedom they need".

Regarding the role of the teachers, interviewees also agreed that he/she must be highly skilled and fluent with technologies in order to teach DiDIY. A challenge that teachers must also be prepared to face is the one that in some contexts, students might be more knowledgeable than them.

It is disagreed whether a more formal type of relationship among students and teachers would be beneficial. Students tend to agree with this statement, also underlining the fact that a more informal relationship could foster collaboration and also be more closely related with the philosophy of DiDIY. Teachers, on the other hand, stress the importance of roles as an educational tool and think that the distinction between students and teachers should be clear. Also, some explained how a more informal relationship could negatively affect students, since it could encourage them to adopt a lazy approach if they get used to the fact that teachers would help them too often or always present a solution to their problems.

- **DiDIY should be used both as a tool and as a mindset.** DiDIY can be effectively used as a tool to reach customized and personalized learning objectives depending on the needs at hand. Interviewees especially agree about the validity of using DiDIY to teach the use of technology. DiDIY could also be employed as a motivating tool to catch the attention of the students and foster their learning, as an enhancing tool to increase the efficiency and/or effectiveness of teaching or as an exploratory tool opening up possibilities for students to engage in previously difficult-to-approach fields such as robotics.

The validity of DiDIY as a mindset is also underlined. Teachers proved especially positive about the implications of using DiDIY to teach students a methodological approach, a problem solving approach or a more concrete and material

relationship with the world they live in. It is agreed that by teaching DiDIY as a mindset, students would become equipped with a powerful tool that they could then apply in school, during their free time or at work.

- **The importance of DiDIY as a self-study practice.** Interviewees outlined the importance for students to engage in DiDIY as a form of self-study practice. In this perspective, schools should approach students to DiDIY and teach them the possibilities and limitations that it offers, other than giving insights on the its technological perspective. In this way, students would be made aware of the possibility of engaging in DiDIY and could decide whether they would like to further explore it or not. To this extent, schools and teachers should still give students a sort of guidance on which activities to carry out on their own, either by proposing a set of exercises that they could choose or by assigning homework projects. It is important that students explore individually and autonomously but it is also important for them to have a guide through this process, which could otherwise become dispersive and void of any concrete learning outcome.
- **Schools should offer students a mean to access high-quality DiDIY material.** Especially given the fact that students should be encourage in practicing DiDIY in their free time, it is important that schools offer their students a way to access relevant and curated DiDIY content that they could use as a guide for their own exploration. Some interviewees in fact expressed concern about the wide availability of DiDIY content that students can access online, which is often inaccurate or not suited for learning objectives. They also pointed out that if schools were to offer this material, they could tailor it to fit specific learning objectives. Some interviewees claim that the solution would be to develop e-learning platforms in which students could also access forums in which they could discuss with their teachers and peers about their activities.

- **DiDIY activities should be designed to support existing curricula.** Interviewees disagree about the fact that a DiDIY-based approach should substitute traditional teaching methods and lead to the creation of a new type of curriculum in education. However, they agree that DiDIY can represent a valid tool to enhance the existing curriculum. Interviewees do not assent whether DiDIY should be included in the curriculum as a separate subject, as a cross-disciplinary activity or as single activities scheduled in the context of a discipline, despite the latter one being the most popular opinion among them.
- **DiDIY activities should be designed with a specific objective.** Interviewees agree that every DiDIY activity should be structured based on a well-defined and concrete learning objective. Furthermore, DiDIY activities should be based on solid theoretical concepts or a methodology. Adopting DiDIY in schools as a mean of creative exploration is also considered valid, as long as this type of activity does not overshadow the importance of others which focus more closely on the learning objectives of the students.
- **The implementation of DiDIY faces several challenges.** Interviewees agree on the difficulty of implementing DiDIY in education. Some underlined the economic perspective, especially considering the required high investments in technology and materials and training for teachers and other members of staff that would be required to implement DiDIY. Some also talked about their hope that policy makers and institutions recognize the value of DiDIY and offer funding for its implementations. Some stated that without considering external funding, at the moment the only real possibility is that schools accommodate investments for DiDIY into the existing budget, which could only lead to limited applications. Other interviewees pointed their attention towards the institutional and legislative barriers that could affect the deployment of DiDIY, while some others proved

concerned about ethical issues. Public perception could also prove to be a challenge: a DiDIY approach could be regarded as too revolutionary by some and the general public is often resistant to change and could perceive it as something negative.

- **DiDIY can find applications in many different fields of education.**

Interviewees agree that DiDIY can find application in virtually every discipline. While it is more agreed that DiDIY could be adopted in STEM, its value in arts and humanities is also recognized, even if to a lesser extent.

- **DiDIY can allow to create truly customized learning experiences at a minimal expense of resources.**

Interviewees agree that DiDIY is a very versatile tool. Quoting Ben: "*The whole thing behind DIY to me is finding your own method, with the idea that one method does not work for everyone*". DiDIY could be used to create customized learning experiences to respond to different needs and also to encourage students and teachers alike to experiment and develop their own learning/teaching methods or tools. A particularly inspiring example was given by Giuseppe, who explained how he participated in a project in which a DiDIY approach was used to create robotic companions aimed at assisting autistic children. In this perspective, the very own philosophy of DiDIY, which encourages exploration and personalization, can be used to develop responsive educational tools and methodologies.

- **DiDIY can be used to teach students how to cope with failure and to realize the consequences of their mistakes.**

This perspective was only mentioned by a few interviewees. They argue that DiDIY can help students to cope with the concept of failure, which in schools is usually not encouraged or treated as something negative. DiDIY can also be used to give students the possibility to see the practical implications of their mistakes and to teach them the mindset

behind an iterative approach to problem solving. A quote by Ben is especially fitting: “*The philosophy of DIDY, (the philosophy) of learning to fail, and being ok with that... that in itself is inspiring, because it hasn’t been encouraged before*”.

- **The only real prerequisite to engage in DiDIY (for students) is the will of doing so.** While interviewees agreed on the fact that teachers should be highly skilled and fluent with technologies in order to teach DiDIY, the same does not apply for students. The majority thinks that the most important factor is represented by creativity, but also that it represents a bonus, a facilitating factor rather than a necessary requirement. Interviewees generally either agree or hope that it is possible for students to improve their critical thinking, problem solving and technology fluency skills by engaging in DiDIY but do not see these as a necessary requirement either. It is also important to note that some teachers underlined the importance of a problem solving attitude or mindset and the fact that DiDIY could be used to teach students such methodology. However, also in this case teachers agree that possessing such a mindset is not a prerequisite in order to engage in DiDIY.
- **DiDIY should be implemented in teamwork experiences.** The importance of adopting DiDIY as a teamwork exercise is strongly approved by interviewees. They pointed out how DiDIY would be suited for the development of teamwork educational experiences, especially given how important the social perspective of the phenomenon is. Working in a group could benefit students and also help them develop real-life social skills which could later prove useful in their professional life. DiDIY could also easily allow to encourage work division and shared development, facilitating the creation of a team experience.
- **Children should be introduced to DiDIY as early as possible.** Interviewees agree that DiDIY should be introduced in schools to expose children to the

approach since young age. This would be beneficial in increasing technology literacy or to encourage creativity and exploration. Some interviewees outlined that in the earlier stages of education DiDIY should be adopted as a sort of game or playful experience especially aimed at encouraging children to explore the world by tinkering while also fostering the development of a practical and concrete approach to problem solving. It was a common opinion among interviewees that humans in fact naturally learn through their experiences and that as children progress through their studies this practical perspective fades away from the curriculum. A claim could be made that DIY alone would be enough to answer the creative needs of young students, but at the same time it should be considered that DiDIY offers a wider array of possibilities and could also foster technology literacy.

Only one person out of the interviewees especially disagreed on this matter: Mirko thinks that is important to keep young students away from digital technologies during the first years of their education, since having access to scarce and strictly material resources could greatly stimulate the creativity of students by encouraging them to think outside the box and to make do with what they have at hand.

- **DiDIY activities can exploit a wide range of technologies.** From the interviews it emerged how interviewees deem that almost any technology could be used for DiDIY purposes. Depending on the specific needs, a suitable technology or set of technologies could then be identified and exploited in customized experiences which can be tailored to specific objectives, age groups, contexts etc. The flexibility offered by the possibility of exploiting such a wide array of technologies proved to be very important to interviewees. Some of them also especially expressed their opinion about the versatility offered by Virtual Reality and

Augmented Reality, while others outlined how 3D Printing and CAD software could be adopted in STEM and arts.

- **DiDIY could prove extremely dangerous.** Interviewees agree that if not properly regulated and contextualized, a DiDIY approach could prove detrimental for education. The most common concern is represented by the belief that by encouraging a more practical and concrete leaning approach students could lose focus of the theoretical perspective and as a result, their learning experience would be impoverished. Some are also concerned by the fact that DiDIY activities could sap resources (mostly time) which could be better spent on more effective learning activities. Another issue that interviewees identified is the challenges represented by actually deploying DiDIY in schools, which were previously outlined above. Problems could and would most likely arise if the necessary prerequisites for an effective deployment of DiDIY are not met, especially considering the importance of teachers and their preparation.

The following section outlines the general opinion expressed by interviewees regarding the application and main purposes of DiDIY in different stages of education:

- **Primary Education:** it is generally agreed that young children should be exposed to digital technologies as early as possible. DiDIY could represent an opportunity to get children used to interacting with digital technologies while also encouraging them to play and explore. As kids grow older, DiDIY activities should become more structured and a theoretical perspective should always be related to the practical experiences.
- **Secondary Education:** DiDIY in secondary education should mainly be adopted in practical laboratories aimed at supporting and enhancing the study of specific concepts. In this regard, DiDIY should be adopted within each discipline or as a cross-disciplinary activity. It is important that teachers guide students through

these activities in order to maintain the focus on the learning objectives. However, it is also important that teachers leave students the freedom to experiment and express themselves, other than giving them the freedom to fail (if the context allows for it). In this regard, DiDIY is especially useful in teaching students how to cope with failure, a theme that is usually not tackled in traditional curricula.

- **Higher Education:** DiDIY in higher education should mainly be adopted as a self-study tool. This could happen as a result of assigned homework or projects or because students spontaneously decide to engage in DiDIY. In any case, it is advised that teachers offer guidance and encourage students in practicing DiDIY. To this extent, universities should also give students access to relevant material that can support them in their study.
- **At work:** while not specifically included in the contextualization of the interviews, some interviewees shared their insights about the implications of DiDIY at work. They outlined the possibility of using DiDIY in corporate training. DiDIY could also be employed as a tool to encourage employees to develop their own competencies (by providing them with the required material and resources, similarly to what was explained in the paragraph above about universities). DiDIY could also be used to foster the development of a design thinking mindset and to encourage the adoption of a more open and creative approach to problem solving. For example, employees could be encouraged to create their own tools based on the needs dictated by the task at hand.

5. DISCUSSION

5.1 Workshop Discussion

The workshops were very well received and participants enjoyed them, as the feedback they left in the questionnaires testifies.

The author initially planned to revise the questionnaire and workshop structure after the first one was carried out. He then decided to abandon this idea and to maintain both workshops and questionnaires identical for both events; this decision was based on methodological reasons, since it allowed to study the reactions and responses to a single event twice, rather than observing two reactions to two different events and questionnaires.

5.1.1 Issues

The biggest issue that arose during the workshops was the difficulty for participants to use the 3D modelling software. While a simple software was chosen and a step-by-step overview was also presented, some participants and especially kids still found the modelling experience quite challenging; on the other hand, some participants had no problems at all and managed to come up with and model brilliant designs in as little as 20 minutes. Another issue was presented by technical problems with one of the two 3D Printers. Ben and the author performed maintenance on the machines prior to the event but this did not avoid the fact that one of the cooling fans failed during the print. Despite the negative consequences on the final quality of the print, this issue actually proved valuable in showing participants the technical problems that could be associated with desktop 3D printing.

Another issue that was encountered is that some participants, despite having made a reservation, did not show up to the event. This unfortunately resulted in taking away

spaces that could have been assigned to other people. To compensate for this issue, the author allowed an overbooking margin for the second workshop.

5.1.1 Recommendations

If similar workshops were to be organized in the future, the author would recommend to adopt a friendlier 3D design software. Another suggestion would be limiting the workshop to certain age groups, so that its contents and methodologies could then be better tailored to the specific age targets. This would allow to deliver a better experience, since there would be no limit imposed by focusing on the creation of content that people of any age group could understand.

Ultimately, the author would suggest adopting a different approach in handing out questionnaires at the end of the event. Perhaps a possible solution would be to force participants to fill in the questionnaire in order to proceed with the workshop, for example by not letting them export their 3D model unless they completed the questionnaire; this solution, however, would require the implementation of custom software and might be perceived as imposing by participants. The author would also like to point out that if possible, paper based questionnaires should be avoided, considering their environmental impact; however, they could prove to be the only solution in contexts in which a PC or Internet connection are not available (especially if there is a low number of participants involved).

5.2 Questionnaire Discussion

The questionnaires received only a limited number of responses and as such, their validity in the broader perspective of the research is limited; the responses were analysed from a qualitative point of view.

5.2.1 Issues

Despite the overall good and enthusiastic reception of the workshop, a low number of responses was expected (given the constraints of the location). The author initially speculated in his Research Proposal (Di Fulvio 2016) that a possible solution to this issue would have been to deliver the same questionnaires online to a wider audience; however, this choice was later reconsidered and deemed inappropriate. During the workshops (and through the interviews) the author in fact noticed that the concept of DiDIY is easily misunderstood. As such, even delivering a written explanation of the concept of DiDIY to accompany the questionnaire would have not ensured that participants correctly understood its meaning. As such, delivering the questionnaires online was deemed an unwise choice, since the risk of receiving many off-topic or irrelevant responses would have been quite high.

Another issue was presented by the adoption of “*Google Forms*” to deliver the questionnaires. The author chose this method since the participants would be using a PC and an on-line questionnaire would have been easier to manage than a paper-based one. However, given the fact that many participants lied about actually completing the questionnaire, handing out paper copies could have been a wiser solution, since the author could then effectively understand whether a participant filled in the questionnaires or not.

Regarding the answers, an issue that arose when analysing the responses and that should be noted is the fact that one respondent decided to answer ironically or sarcastically to certain open ended questions; as a result, this questionnaire was discarded and excluded from the analysis.

5.2.2 Recommendations

Regarding the design of the questionnaires, it could have been wise to merge the two questionnaires into a single one, in order to make the process more streamlined. Regarding the questions, some of them could have been formulated in a way to make them less ambiguous or less implicitly biased. Further questions could have been included to analyse other relevant themes.

5.3 Interview Discussion

5.3.1 Issues

The main issues that impacted the interviews are listed below:

- **Technical Difficulties;** the Skype call between the author and the interviewee often dropped due to server or connection issues. To solve this problem, the author used a portable router to act as a backup for the times in which his wired Internet connection would drop.
As a result of some of these call interruptions the recording software incurred in a curious bug, in which during the first 10 to 15 minutes of the recording either the voice of the author or that of the interviewee (only one at a time and never both together) would not be saved in the final recording. Fortunately, this only happened a total of 3 times and the author solved the problem by integrating the missing parts with the notes he took during the interviews or by contacting participants by email asking them to kindly fill in the missing information.
- **Off-topic Discussion;** while this can only be seen as a partial problem, especially considering the adoption of semi-structured interviews, the discussion sometimes wandered off the topic of DiDIY and developed towards other themes. This surely increased the depth of the interviews but in case the discussion would

stray for a long time the author informed the participants about this and led the conversation back on the original topic.

- **Participants did not fully understand the concept of DiDIY;** during some interviews it became clear to the author that some participants had not fully understood the concept of DiDIY and as such, their answers would reflect this issue. In case this happened the author offered to give a further explanation and set some examples in order to clarify the concept of DiDIY. In most cases, the misunderstandings came mostly from acknowledging only the digital part of DiDIY and ignoring its analog perspective: for example, participants often focused on digital technologies and did not consider more traditional, analog ones such as sewing or soldering. Another common misunderstanding was to confuse DiDIY as a whole with the use of digital technologies: in this perspective, any use of digital technologies was mistakenly perceived as a DiDIY activity. In these cases, the author reminded participants of the purpose of using digital technologies in DiDIY; DiDIY activities can in fact exploit digital technologies either directly for the creation of things (such as 3D printing an item) or as a support element to the creation process itself (to acquire knowledge, to inspire, to share the final result etc.).

For similar methodological reasons that were previously explained in section 5.1. the author decided not to modify the structure of the interviews based on the insights gathered by progressively conducting them. It is still worth noting that depending on the adopted research methodology, in some contexts modifying the structure of the interviews as they are carried out could represent a wise choice.

5.3.1 Recommendations

The author would suggest the adoption of a more reliable software or tool to record the interviews. Improvements could also be made to the interview structure to encourage a

more streamlined discussion. Other than this, the author is satisfied about the way the interviews were carried out and about the quality of the collected information.

5.4 Research Design Discussion

It is important to consider that this research has been deeply influenced by an array of limiting factors, the strictest ones being the limited availability of time and the difficulty of identifying potential research subjects.

The research was carried out using both an inductive and deductive strategy and mainly followed a qualitative approach. In particular, the adoption of semi-structured interviews proved especially fitting to the exploratory nature of this research (Saunders, Lewis and Thornhill 2015).

A discussion could be made about the approach taken in regards to sampling. The author ensured to engage with research subjects that had previous experience with either DiDIY technologies or DiDIY activities. While this could be considered to have biased the research, it was explained how this choice was born from the awareness that the concept of DiDIY could be easily misunderstood. Given the fact that the initial plan to distribute the questionnaires online had to be abandoned and that the amount of time was limited, the author could not afford to waste any by risking to interview non relevant subjects.

The workshops were organized with the main purpose of collecting data through observation. Adopting the "*Participant as Observer*" technique proved especially helpful in analysing the point of view of the participants as a group. However, the workshop was organized so that anybody could participate: in this regards, it could be argued that it was not possible to observe a sample of participants that shared certain common traits and how these traits could have affected their interactions. For example, by designing a workshop aimed specifically at high school student it would be possible to generalize the findings and through adequate hypotheses speculate whether a similar behaviour would

be observed in another sample of high school students. It would be interesting to conduct further research addressing how the deployment of DiDIY is affected by individual factors such as age, background, culture, race or profession.

Also, only two workshops could be carried out and given the constraints of the location, only a limited number of people could participate. The research would have surely benefitted from the adoption of a quantitative research based on the questionnaires or from further observation of other workshops. However, the author had to abandon the quantitative perspective of the questionnaires due to the low expected amount of responses.

The author knew the majority of the interviewees, and this could have led to bias. However, the themes that were discussed during the interviews did not concern or could have been affected by the fact that the interviewee knew the interviewer. In any case, the author never disclosed his true opinion about the discussed themes with interviewees until the interview was over.

Twelve people were interviewed, six students and six teachers. The balance between the two groups has been respected. Also, the author ensured to include as participants a balanced number of interviewees representing both genders. A point can be made that while the background of the teachers was varied and included both professors, researchers and educators, the same cannot be stated in regards to students. The majority of students were in fact university students or people who finished their studies in the past recent years. It would have been valuable to include students from different age groups into the analysis, such as high school students and primary/secondary school students. At the same time, though, given the difficulty of the themes of the research a point could be made that the answers of younger students could not be as structured or well-rounded when compared to those of older students.

On a final note, it should be acknowledged that the integration of a quantitative analysis could have increased the quality and reliability of the findings.

Ultimately, the author considers that the main exploratory objective of this research has been achieved and that the variables and factors outlined in the conceptual framework have been analysed. However, further research should be carried out to better understand the implications and opportunities of DiDIY in education.

5.5 Research Discussion

This research is based on the perception that in the recent years, a new phenomenon regarding the theme of DIY is emerging (Fox 2013 and 2014) and that this phenomenon, which can be defined as DiDIY (LIUC et al. 2014) has the potential to impact different areas of society.

Authors such as Gersehenfeld (2008 and 2012), Anderson (2012), Dougherty (2012), Blikstein (2013) or Blinkstein and Krannich (2013) show awareness of the existence of this new trend. Their works especially concern how a new mindset is developing in the way things are manufactured and created, along with the possibilities that this shift in paradigm is bringing forth. Some in fact already speak of a new Industrial Revolution (Berman 2012), especially considering the rise of Digital Manufacturing (The Economist 2012).

However, given the novelty of this phenomenon, only few academic studies have been carried out to explore the concept of DiDIY and the existing ones mainly focus on analysing applications of DiDIY in specific contexts or are aimed at outlining its consequences, its possible implications for the future or the way in which the evolution of this phenomenon should be handled, rather than taking a more holistic approach to the theme. For example, the study of Behrens et al. (2010) focuses on the adoption of tools such as Lego Mindstorms in engineering, while the one of Boy (2013) focuses on

the implications of adopting a different and more human-centered teaching approach. Furthermore, only few studies actually approach the theme of DiDIY as it is defined by the DiDIY Research Team (LIUC et al. 2014) (DiDIY 2015a and 2015b) and an even smaller number actually analyses its implications in the field education.

Fox (2014) also underlines the fact that at the moment, only a limited number of academic sources can be found regarding this topic: the majority of the material is in fact to be researched in websites, blogs and magazines.

In this perspective, this research represents one of the first formal approaches to the theme of DiDIY and its application in the field of education. As such, it is not directly possible to frame this study in existing literature.

The nature of this research is mostly exploratory and its contribution to existing literature should be interpreted as a valid reference and starting point for other researchers to base further investigations on. In particular, this research proposes to adopt a dual perspective, by taking both the opinions of students and teachers into consideration.

5.6 Suggestions for Future Research

The author suggests to conduct further research to include other themes or further explore the relationship between different factors and DiDIY. The table below outlines some suggestions:

- How can DiDIY help in solving the issue of women discrimination in technology fields (Lemons and Parzinger 2007)?
- How can DiDIY be deployed to help and assist students with disabilities or special needs? Or how could it be deployed in Third World scenarios?
- How do factors such as age, culture or a person's own background affect his/her ability or likelihood to engage in DiDIY?

- How is DiDIY perceived by students used to different methods and approaches of learning? In this case it is suggested to analyse student's response based on their nationality after the prevailing teaching method of their schools has been assessed and categorized.
- How is DiDIY revolutionizing informal education? What is the role of laboratories such as Fab Labs in DiDIY?
- How is DiDIY revolutionizing corporate training?

The author also suggests to conduct experiential workshops in different contexts and aimed at different age groups in order to obtain a more complete and broad perspective about the way DiDIY is perceived.

It is important to maintain focus on analysing the opportunities and also the threats that DiDIY can offer and to strive to understand what the best practices for introducing a DiDIY approach in different stages of education would be.

The author also suggests that future researchers interested in studying DiDIY periodically consult the website www.didiy.eu to stay updated on the latest project results published by the DiDIY Research Team.

6. CONCLUSION AND RECOMMENDATIONS

DiDIY is a rising socio-technological phenomenon that is currently developing and holds the potential to significantly reshape and alter society as we know it and potentially lead to what some already call a new Industrial Revolution.

The widespread availability and affordability of digital fabrication technologies and the democratization of knowledge fostered in open online communities are the main catalysts of this dynamic process, which finds applications in many different fields, such as education.

Examples of the use of DiDIY in schools are already present, like the development of Fab-Labs or the integration of robotics, electronics and 3D printing in curricular activities; however, such applications are still limited in scope and diffusion. In fact, the majority of such applications are carried out in informal contexts such as laboratories or museums.

Despite the novelty of the phenomenon, academics already agree that understanding the dynamic nature of DiDIY and implications could prove vital in the development of future educational programs.

This research was developed to address this need and was aimed at exploring the opportunities and challenges that DiDIY can bring in education, by applying a double point of view of both teachers and students.

The findings show that the adoption of DiDIY in education holds a great potential and can represent a valid opportunity for schools and universities alike. DiDIY can in fact be adopted as an especially versatile tool that can find application in virtually any stage of education and be deployed in almost any subject or discipline.

While DiDIY can be adopted for various purposes, the findings show that using it as a tool to teach the use of technology and to foster technology literacy could prove

especially effective. Also, DiDIY could be exploited to create extremely customized and personalized learning experiences aimed at the achievement of specific learning objectives. In this regard, it is suggested that DiDIY is used as a tool to support and enhance how teaching is delivered, other than expanding its scope.

Findings also suggest that DiDIY activities could be especially valuable if carried out as group exercises that encourage teamwork and collaboration among students and teachers alike. However, a self-study perspective should also be explored; it is suggested that teachers heavily encourage students to engage in DiDIY on their own, either by assigning/recommending projects to be carried out or by simply motivating them to explore their own interests.

Any DiDIY activity should always be based on a sound theoretical background and be structured to reach a specific set of learning objectives. Students should also be given the opportunity to experiment, to express themselves and to make mistakes; however, it is important that DiDIY activities are not carried out for their own sake and that the theoretical perspective is not overshadowed by the practical one.

The main challenges associated with the adoption of DiDIY mostly regard the amount of resources required for its implementation. Financial resources are often limited in schools and universities and including DiDIY expenditures in existing budgets could be challenging, especially if institutions and nation states would not support the implementation of DiDIY with subsidies or dedicated funding.

Another challenge is represented by the changing role of the teachers and the fact that teaching is evolving, as the relationship between educators and learners shifts. In particular, it will become increasingly difficult to train teachers and to equip them with the skills needed to deal with this evolving context and be able to successfully adopt a DiDIY approach in their courses. The findings suggest that the role of the teacher in the future

could become that of a counsellor, a person who guides students through their learning experiences.

The author recommends that efforts are made to convince institutions and policy makers of the importance of DiDIY and of the opportunities that it can bring into the field of education; in fact, this is also one of the main purposes of the research carried out by the DiDIY Research Team.

Given the challenges represented by implementation, especially in financial terms, the existence of subsidies or regulations that foster the adoption of a DiDIY approach might prove vital in realizing the true potential that DiDIY holds. The author also recommends that further studies are conducted upon the subject of DiDIY, to better assess the implications of this rising phenomenon.

Ultimately, this research represents the first, formal approach to the theme of DiDIY in education; in particular, it strived to transcend limited applications of DiDIY in favour of adopting a more holistic and wider perspective on the matter.

However, given the constraints that limited this research and the relatively low number of participants in the sample, while the findings provide valuable insights on the theme, it should be remembered the research purpose of this study was exploratory, rather than descriptive or explanatory.

As such, the author suggests that this research should be considered as an initial approach to the theme and that the findings should be regarded as a preliminary framework that should prove valuable for researchers to base further studies on. To this extent, in the previous chapter the author specifically suggested a range of topics that could be explored.

Also, the author would like to remind the reader that the DiDIY Research Team is currently researching this theme and that the findings of the research about Education will be published in the coming months on www.didiy.eu. As such, he suggests that future researches should also be based on the findings that will be presented in the Education report or at least draw insights from it.

On a personal note, the author would like to conclude stating that he finds extremely interesting how DiDIY could foster the development of a more practical and concrete mindset, reverting the interest of a society based on mass production and mass consumerism back to inventing, creating and making things. DiDIY could bring a revolution in the paradigm of creation: in this context, the intellectual capabilities and creativity of a single person would assume new importance and could become the new focal point, like it once was during the Renaissance. DiDIY could help individuals transition from being passive consumers to becoming critical prosumers or even active creators, people who not only use existing tools or products but also rearrange them and modify them to fit their own purposes. A new mindset could develop, one that would foster a more critical approach to reality, one that would encourage people to regard the world around them as an infinite array of possibilities that simply awaits to be moulded and shaped by their own creativity. Quoting Massimo Banzi, creator of Arduino: “*You don’t need anyone’s permission to create something great*” (2012). The mere awareness of this simple concept is already incredibly powerful in its own; its potential implications could be even more so.

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APPENDIX

A.1 Interview Questions

Warm-Up:

- **[open 1]** Could you please tell me a little about your background?
- **[open 2]** What do you think about the process of inventing and creating things (both physical and informational)? Would you define yourself as a “MAKER”?
- **[open 3]** (*Student version*) Could you please describe me a learning experience in which you were required to create your own solution to a problem, especially if it involved exploiting digital technologies? How did you feel about it? Please elaborate on the creation process you experienced.
[open 3] (*Teacher version*) Could you please describe me a teaching experience in which you requested your students to create their own solution to a problem, especially if it involved exploiting digital technologies? How did you feel about it? Please elaborate on the creation process that was followed.

Context:

- **[rate 1]** DiDIY should be used to teach STEM subjects (Science, Technology, Engineering, Mathematics).
- **[rate 2]** DiDIY should be used to teach arts and humanities.
- **[rate 3]** DiDIY should be employed in primary education.
- **[rate 4]** DiDIY should be employed in secondary education.
- **[rate 5]** DiDIY should be employed in higher education.
- **[rate 6]** DiDIY should be used to teach content and concepts.
- **[rate 7]** DiDIY should be used to teach the use of technology.
- **[rate 8]** DiDIY should be used to teach a mindset, an attitude
- **[open 4]** Could you please elaborate on how you think DiDIY should be adopted in education and for what purposes?
- **[open 5]** Please, give me an example of how you would use DiDIY to improve the way your favorite subject is taught.

Creativity:

- **[rate 9]** Individual creativity plays a key role in DiDIY activities.
- **[open 5]** Please, could you elaborate more on what relationship you think exists between creativity and the adoption of DiDIY in education?

Technology Fluency:

- **[rate 10]** It is important for students to be fluent with the adopted technologies when engaging in DiDIY activities.
- **[open 6]** Please, could you elaborate more on what relationship you think exists between technology fluency and the adoption of DiDIY in education?
- **[open 7]** (*Student version*) Considering the wide array of technologies that can be used for DiDIY activities, which one/s would you recommend to adopt in education? Please, give a practical example of how you would use it/them in a learning experience.
[open 7] (*Teacher version*) Considering the wide array of technologies that can be used for DiDIY activities, which one/s would you recommend to adopt in education? Please, give a practical example of how you would use it/them in a teaching experience.

Teamwork:

- **[rate 11]** DiDIY activities should be structured as a cooperative teamwork experience.
- **[open 8]** Please, could you elaborate more on what relationship you think exists between working in a group and the adoption of DiDIY in education?

Critical Thinking and Problem Solving:

- **[rate 12]** It is impossible for a student that does not possess particularly developed critical thinking and problem solving skills to engage in DiDIY.
- **[open 9]** Please, could you elaborate more on what relationship exists between critical thinking and problem solving skills and the adoption of DiDIY in education?

Interests and Aptitudes:

- **[rate 13]** Engaging in meaningful and interesting activities can empower students and improve their learning capabilities.
- **[rate 14]** Adopting a DiDIY approach centered on the interests of the students rather than the learning content is detrimental to their learning.
- **[open 10]** Please, could you elaborate more on what relationship you think exists between a student's own interests and aptitudes and the adoption of DiDIY in education?

Teacher/Student Relationship:

- **[rate 15]** The adoption of a DiDIY approach will lead to a change in the authority of teachers and the relationship they have with their students.
- **[open 11]** Please, could you elaborate more on how you think the adoption of a DiDIY approach might affect the relationship between students and their teachers?

Teaching Methods:

- **[rate 16]** DiDIY should be used as a complement to traditional teaching methods.
- **[rate 17]** A DiDIY-centered approach should substitute traditional teaching methods.
- **[open 12]** What teaching method would you use in regards to adopting DiDIY in education? Please, give me an example.

Conclusion:

- **[open 13]** Considering what we discussed so far, do you think it would be valuable to adopt DiDIY in education? Please, explain why.
- **[open 14]** Anything else you would like to add?
- **[open 15]** (*this question was not displayed in the PDF that was sent to participants*) Let us focus on the negative aspects that the adoption of DiDIY in education could bring forth. What do you think the main challenges, issues or threats would be? What would the most critical factors for its implementation be?



The poster features a light grey background with a white border. At the top center is the MAKE ABERDEEN logo, consisting of a dark blue cube icon and the text 'MAKE ABERDEEN'. Below this, the main title '3D PRINTING WORKSHOPS' is displayed in large, bold, blue and black letters. To the right of the title is a dark blue icon of a briefcase containing a cube. Below the title, the dates 'June 1st and 8th' and time '4 - 8 pm @ MAKE Aberdeen' are written in blue and black. To the right of this text is the word 'FREE' in large, bold, black letters. A vertical line separates the text from the 'FREE' text. Below the dates and time, a paragraph of text reads: 'Learn the basics of 3D Printing and work in a team to design and print a real prototype!'. Underneath this text is a row of five blue icons: a lightbulb, two people with speech bubbles, a cube with arrows indicating dimensions, a pencil drawing a square, and a dark blue cube. Below the icons, the text 'LIMITED AVAILABILITY!' is written in bold black letters, followed by 'Sign up today at bit.ly/1WFhws6' in blue. At the bottom of the poster, there are three logos: the Robert Gordon University Aberdeen logo (RGU), the DiDIY Digital Do It Yourself logo, and the European Union flag. To the right of these logos is a disclaimer: 'This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 644344. Disclaimer: The views expressed in this event do not necessarily reflect the views of the EC.'

MAKE
ABERDEEN

3D PRINTING WORKSHOPS

June 1st and 8th
4 - 8 pm @ MAKE Aberdeen

FREE

Learn the basics of 3D Printing and work in a team to design and print a real prototype!

LIMITED AVAILABILITY!
Sign up today at bit.ly/1WFhws6

RGU ROBERT GORDON
UNIVERSITY ABERDEEN

DiDIY
DIGITAL
DO IT YOURSELF



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 644344.
Disclaimer: The views expressed in this event do not necessarily reflect the views of the EC.

Figure 15: Promotional poster of the Workshops (generated by the author)

A.3 Interview Brief Shared with Interviewees

Hello.

First of all, I would like to [thank you](#) for your attention and for your time.

My name is Lorenzo Di Fulvio and I am currently writing my master thesis under a research project financed by the European Commission aimed at studying the emerging phenomenon of [digital do-it-yourself \(DiDIY\)](#) and its implications on society (DiDIY project, H2020, n.644344, January 2015 - June 2017; www.didiy.eu). To be precise, my work is focused on studying the opportunities and threats that DiDIY can bring into the field of [education](#).

But what exactly is DiDIY? "[Digital Do-it-Yourself](#)" should not be conceived as a particular form of Do-It-Yourself that exploits digital technologies. DiDIY can in fact be defined as a new [socio-technological phenomenon](#), which stems from the widespread availability of digital devices that support the convergence of physical (atoms) and informational (bits) components (such as 3D Printers or Arduino boards) and the growing accessibility of related information through open online communities, which foster concepts of open innovation and democratization of knowledge.

Concretely, DiDIY can have [various expressions](#), such as an experiential workshop on digital manufacturing or an amateur 3D printing his own custom models. A common factor is the fact that thanks to the growing inter-connectedness of the world, activities that before took place on a personal or local scale now hold the potential to have global reach; furthermore, [practically anyone can have access to the tools and knowledge needed to engage in DiDIY](#). Ultimately, what is produced by an individual could not be the mere result of a single mind anymore but the final outcome of multiple contributions coming from an interconnected, world-wide network of developers.

In this perspective, it is easy to understand how [DiDIY could lead to the emergence of new scenarios and opportunities in different aspects of society](#) and impact not only people and organizations but also nation states and, to a wider extent, the way these entities relate. However, due to the novelty of the phenomenon and its dynamic nature, it is not yet possible to predict and outline its evolution.

This is why it is important to study DiDIY as it is developing and why I am now asking for your help in participating in this interview. [I really appreciate your contribution, and would like to take the chance to thank you again.](#)

The next page gives an outline of the questions that will be asked during the interview. There is no right or wrong answer, there is only your genuine opinion. In the meantime, if you would like to know more about DiDIY, please consult the website of the project www.didiy.eu

Figure 16: PDF Handout given to participants of the interview - Page 1 (generated by the author)

HOW TO

In the interview there will be two types of questions:

- * open ended questions that will be answered in a discussion
- * questions where you will be asked to rate how much you agree with a given statement based on a fixed scale



QUESTIONS



- * Could you please tell me a little about your background?
- * What do you think about the process of inventing and creating things (both physical and informational)? Would you define yourself as a “MAKER”?
- * Could you please describe me a learning experience in which you were required to create your own solution to a problem, especially if it involved exploiting digital technologies? How did you feel about it? Please elaborate on the creation process you experienced.



- * DiDIY should be used to teach STEM subjects (Science, Technology, Engineering, Mathematics)
- * DiDIY should be used to teach arts and humanities
- * DiDIY should be employed in primary education
- * DiDIY should be employed in secondary education
- * DiDIY should be employed in higher education
- * DiDIY should be used to teach content and concepts
- * DiDIY should be used to teach the use of technology
- * DiDIY should be used to teach a mindset, an attitude
- * Could you please elaborate on how you think DiDIY should be adopted in education and for what purposes?
- * Please, give me an example of how you would use DiDIY to improve the way your favorite subject is taught.



- * Individual creativity plays a key role in DiDIY activities
- * Please, could you elaborate more on what relationship you think exists between creativity and the adoption of DiDIY in education?

Figure 17: PDF Handout given to participants of the interview - Page 2 (generated by the author)



* It is important for students to be fluent with the adopted technologies when engaging in DiDIY activities

* Please, could you elaborate more on what relationship you think exists between technology fluency and the adoption of DiDIY in education?

* Considering the wide array of technologies that can be used for DiDIY activities, which one/s would you recommend to adopt in education? Please, give a practical example of how you would use it/them in a learning experience.



* DiDIY activities should be structured as a cooperative teamwork experience

* Please, could you elaborate more on what relationship you think exists between working in a group and the adoption of DiDIY in education?



* It is impossible for a student that does not possess particularly developed critical thinking and problem solving skills to engage in DiDIY

* Please, could you elaborate more on what relationship exists between critical thinking and problem solving skills and the adoption of DiDIY in education?



* Engaging in meaningful and interesting activities can empower students and improve their learning capabilities

* Adopting a DiDIY approach centered on the interests of the students rather than the learning content is detrimental to their learning

* Please, could you elaborate more on what relationship you think exists between a student's own interests and aptitudes and the adoption of DiDIY in education?



* The adoption of a DiDIY approach will lead to a change in the authority of teachers and the relationship they have with their students

* Please, could you elaborate more on how you think the adoption of a DiDIY approach might affect the relationship between students and their teachers?



* DiDIY should be used as a complement to traditional teaching methods

* A DiDIY-centered approach should substitute traditional teaching methods

* What teaching method would you use in regards to adopting DiDIY in education? Please, give me an example.



* Considering what we discussed so far, do you think it would be valuable to adopt DiDIY in education? Please, explain why.

* Anything else you would like to add?

Figure 18: PDF Handout given to participants of the interview - Page 3 (generated by the author)

DATE/TIME

Using the link below you will be able to specify which date and time works best for you for scheduling the interview:

www.goo.gl/EGSYgr

DURATION

The expected duration of the interview will be of **1 hour**.

INFO

The interview will be carried out through **Skype** or any similar service you might prefer.

I would like, with your permission, **to record the interview** in order not to miss any relevant detail of our discussion.

Your **anonymity** will be respected and your identity will be protected and maintained secret, along with your data. Once I finished writing my thesis I will delete the recording of the interview, to further protect your privacy.

If you would like it, once finished it would be my pleasure to **share a copy of my work with you**, so that you can concretely realize how valuable your help has proven for my research.

CONTACTS

For anything, please do not hesitate to contact me:



lorenzoelba



lorenzodifulvio@gmail.com



+39 334-7795563

Thanks again and talk to you soon,



A.4 Workshop Signup Form

3D Printing Workshop @ MAKE Aberdeen

Join us in our introductory workshop to 3D Printing and experience first hand the design and creation of a real prototype!

The workshop will be held in two date, June 1st and June 8th, from 4 to 8 pm approximately at MAKE Aberdeen (17 Belmont St).

Places are limited so reserve yours today! You will receive an e-mail to confirm your participation after you applied.

**Campo obbligatorio*

Name and Last Name *

La tua risposta

Email *

La tua risposta

Which workshop would you like to attend? *

Both workshops will cover the same topics so choose the date that bes suits you! (Sorry June 8th is fully booked but if you want you can send an email to lorenzodifulvio@gmail.com and we will inform you if places free up!)

June 1st (2 space available)

How many people will attend? *

You can book for up to 2 people at once. If more, please just re-send this form again.

1

2

Are you younger than 18? *

(if yes, please bring a written consent from your parents/guardian in order to participate)

No

Yes, and i understand that I will need a written consent to participate

Figure 20: Workshop sign-up form (generated by the author)

A.5 Education Questionnaire

About Today's Event:

Where did you learn about the event? (choose one: Facebook; Instagram; Twitter; From Friends; From MAKE Staff; Other - please specify)

- **Please, give us some feedback** (open ended)

Thanks for taking part in the workshop! Please, take a moment to fill out the questionnaire below. You will most likely be sharing a PC with someone else but please, answer to the questions individually and do not consult with others while answering. Thanks!

- **How old are you?** (open ended)
- **Are you Male or Female?** (choose one: Male; Female)
- **What is your Nationality?** (open ended)
- **Your background is** (choose one: Humanistic; Scientific-Technological; Artistic; Technical Professional)
- **Did you ever use DiDIY tools before today?** (choose one: Yes; No)

When I learn...

Please rate the following statements based on your learning/studying preferences (choose one: Do not know; Don't like; Like)

- **I like to see teachers as helpers, friends**
- **I like to study theory and frameworks**
- **I like to adopt a practical approach to learning**
- **I like to learn together with others**
- **I like to study by myself**
- **I like to share what I learnt with others around me**
- **I like if I can establish a personal connection with my teacher**
- **I like to consult with others when I am unsure about something I am learning**
- **I like to learn using digital tools**
- **I like to learn and share my ideas online in social media or online communities**

Formal or Informal

Formal education is carried out in formal settings such as schools and universities. Informal education, on the contrary, happens in informal settings such as museums and laboratories or through social media channels or online communities

- **What do you think the main differences between formal and informal education are?** (open ended)

Please assign the following elements depending in which educational context you think they fit best (choose one: Formal; Informal; Both)

- **Strong, emotional connection with teachers**
- **Learning by doing**
- **Studying theory and frameworks**
- **Learning alone**
- **Learning in a group**
- **The teacher holds the knowledge and transmits it to the students**
- **The teacher and the students cooperate closely and learn together**
- **The teacher helps students, giving them the tools and guiding them through their own process of learning**

Flipped Classroom

- **Have you ever heard of the “Flipped Classroom”?** (*choose one: Yes; No*)
- *[not mandatory]* **If yes, name three words that come to mind when thinking about it** (*open ended*)
- *[not mandatory]* **If yes, do you think that a Flipped Classroom approach could substitute more traditional methods of teaching in formal settings?** (*choose one: Yes, as a complementary approach to more traditional ones; Yes, substituting it; No*)

DiDIY in Education

- **Describe how DiDIY could influence the way your favourite subject is taught** (*open ended*)
- **What do you think the main benefits of adopting DiDIY in education are?** (*open ended*)
- **Would you like to see DiDIY being implemented widely in formal education?** (*choose one: Yes; No; Only in specific fields or contexts*)
- **Do you think students would learn better with a DiDIY approach?** (*choose one: Yes; No*)
- **Why?** (*open ended*)
- **What do you think the relationship between DiDIY and creativity is?** (*open ended*)

On which fields do you think DiDIY will have the most impact?

Please, rate your perceived impact of DiDIY in the following fields (*choose one: Do not know; A low impact; A moderate impact; A high impact; A very high impact*)

- **Science**
- **Technology**
- **Engineering**
- **Art**
- **Mathematics**

Thank you for your help!

For my research, it would be really helpful to be able to conduct short anonymous interviews about the role of DiDIY in Education. I would be really thankful if you would agree to be interviewed later this summer in person or by Skype (or similar software). If so, please leave your email address below and come speak to me in person during the workshop if you would like further details.

Thanks again,
Lorenzo

- *[not mandatory]* **Your email address** (*open ended question*)

A.6 General Questionnaire

Thanks for taking part in the workshop! Please, take a moment to fill out the questionnaire below. You will most likely be sharing a PC with someone else but please, answer to the questions individually and do not consult with others while answering. Thanks!

- **Something about you** (*open ended*)
- **How old are you?** (*open ended*)
- **Are you Male or Female?** (*choose one: Male; Female*)
- **What is your Nationality?** (*open ended*)
- **Your background is** (*choose one: Humanistic; Scientific-Technological; Artistic; Technical Professional*)
- **Write two adjectives that come to your mind when thinking of a MAKER** (*open ended*)

Making something with my hands...

(*choose one: Do not know; False; Sometimes; Often; True*)

- **Gives me satisfaction**
- **Is useless, a waste of time**
- **Is boring**
- **Makes me save money**
- **Is fun**
- **Is a hobby, a leisure**
- **Helps me develop my competences**
- **Is reassuring**
- **Reduces wastes**
- **Something for nerds**
- **Makes my inspiration real**
- **Is useful to find a job**

What do you think of Digital Do It Yourself – DiDIY?

(*choose one: Do not know; Do not agree; Partially agree; Almost true; True*)

- **Is just a game**
- **Good ideas will save our world**
- **Better to leave it to professionals**
- **Is a way of making lots of money fast**
- **You cannot be an entrepreneur without technology**
- **Finally an active use of technology**
- **Good to show off**
- **Is useful to find a job**

Regarding the following tools...

(*choose one: Never heard of it; I know they exist; I used them sometimes; I used them often*)

- **Software to create and manage websites, blogs etc.**
- **Software and Hardware to create digital video/audio**
- **3D Printer and 3D Scanner**
- **Arduino, Raspberry Pi etc.**
- **3D Modelling Software (CAD)**

- [not mandatory] **If you used any of the tools from the previous question, please indicate which ones below** (*open ended*)
- **Where did you mostly use these tools?** (*choose one: School; FabLabs; Home; Never used them; Other - please specify*)

Congratulations!

If you have used any of the tools above, congratulations, you too are a DiDIY-er! Below you can find four topics and further questions that will allow us to better understand how DiDIY is reshaping education and help you use it at its best

Creativity

If and how is DiDIY promoting your creativity? *(choose one: Do not know; Do not agree; Partially agree; Almost true; True)*

- **When I use DiDIY I can fully express my creativity**
- **There are things left behind that students that use DiDIY do not do anymore**
- **Putting the tools in the hands of the learners empower them to solve their problems differently compared to traditional off-the-shelf products**
- **Different kinds of solutions to real problems emerge**
- **DiDIY is scaffolding new creativity (allows to do more, differently etc.)**
- [not mandatory] **Add comments if you wish** *(open ended)*

Sharing

How important is sharing in your DiDIY activities? *(choose one: Do not know; Do not agree; Partially agree; Almost true; True)*

- **DiDIY activities lead to conformism**
- **DiDIY communities are prompting new connections with people (digitally and/or physically)**
- **When I do a new project, I find pleasure in sharing it with my friends and online communities**
- **I gather information on possible projects through online sharing tools**
- [not mandatory] **Add comments if you wish** *(open ended)*

The role of Teachers and Trainers

How does training happen? *(choose one: Do not know; Do not agree; Partially agree; Almost true; True)*

- **DiDIY is transforming the role of teachers**
- **New competences are expected from teachers and trainers**
- **DiDIY activities lead move from a teacher/curriculum-centered school to a student/experimentation-centered education**
- **In DiDIY activities teachers and trainers are no more the main source of knowledge and competences**
- [not mandatory] **Add comments if you wish** *(open ended)*

Flows of Communication

Is DiDIY changing the way in which knowledge and competences flow between trainers and learners? *(choose one: Do not know; Do not agree; Partially agree; Almost true; True)*

- **Compared to traditional subjects, DiDIY is taught in the same way**
- **There are major changes in the traditional roles of education (teacher/student)**
- **Working in teams maximizes success in DiDIY activities**
- **In most cases learners actually know more than DiDIY trainers**
- [not mandatory] **Add comments if you wish** *(open ended)*

Thank You!

We heartily appreciate you taking the time to fill out this form. Thanks for having contributed to our research on DiDIY. You can learn more at www.didiy.eu

A.6 Examples of Relevant Academic Journals for the Research

MIS Quarterly	Education and Information Technologies
Technovation	Journal of Strategic Information Systems
Organization Studies	Industry and Innovation
The International Journal of Advanced Manufacturing Technology	Journal of Digital Learning in Teacher Education
Journal of Teacher Education	Digital Education Review
International Journal of Educational Research	Digital Culture & Education
Journal of Interactive Media in Education	New Media and Society
Media, Culture and Society	Technology in Society

Table 24: Overview of relevant academic journals (generated by the author)

A.7 Examples of Relevant Key Words

Digital + Education	Education + DIY	3D Print + DIY
Digital + Learning	Education + Flipped	3D Print + Education
Digital + Teaching	Education + Informal	3D Print + Arduino
Technology + Learning	Education + Workshop	3D Print + Flipped
Flipped + Classroom	Education + Fab-lab	3D Print + Workshop
Class + Fab-Lab	Education + Online	3D Print + Teaching
Education + Digital Manufacturing	Education + Prototyping	3D Print + Constructionism

Table 25: Examples of relevant key-words for literature review research (generated by the author)

A.8 Conceptual Model developed by Zappa (2014)

The model is displayed in the following page. A higher resolution version can be accessed at <http://envisioning.io/education>

Envisioning the future of education technology



Education lies at a peculiar crossroad in society. On one hand it has the responsibility of anticipating real-life skills by preparing us for an increasingly complex world – but education methodologies can only be formalized after practices have been defined. This dichotomy is particularly aggravated when it comes to technology, where fast-paced innovation and perpetual change is the only constant.

This visualization attempts to organize a series of emerging technologies that are likely to influence education in the upcoming decades. Despite its inherently speculative nature, the driving trends behind the technologies can already be observed, meaning it's a matter of time before these scenarios start panning out in learning environments around the world.

Classroom

The prevailing paradigm of a single teacher addressing dozens of students unidirectionally in a physical setting.

Studio

Peer to Peer learning environments where groups coalesce to discuss, learn and solve problems with each other and the teacher serves as a facilitator.

Virtual

Disembodied environments, where learning, discussion and assessment happen regardless of physicality or geography.

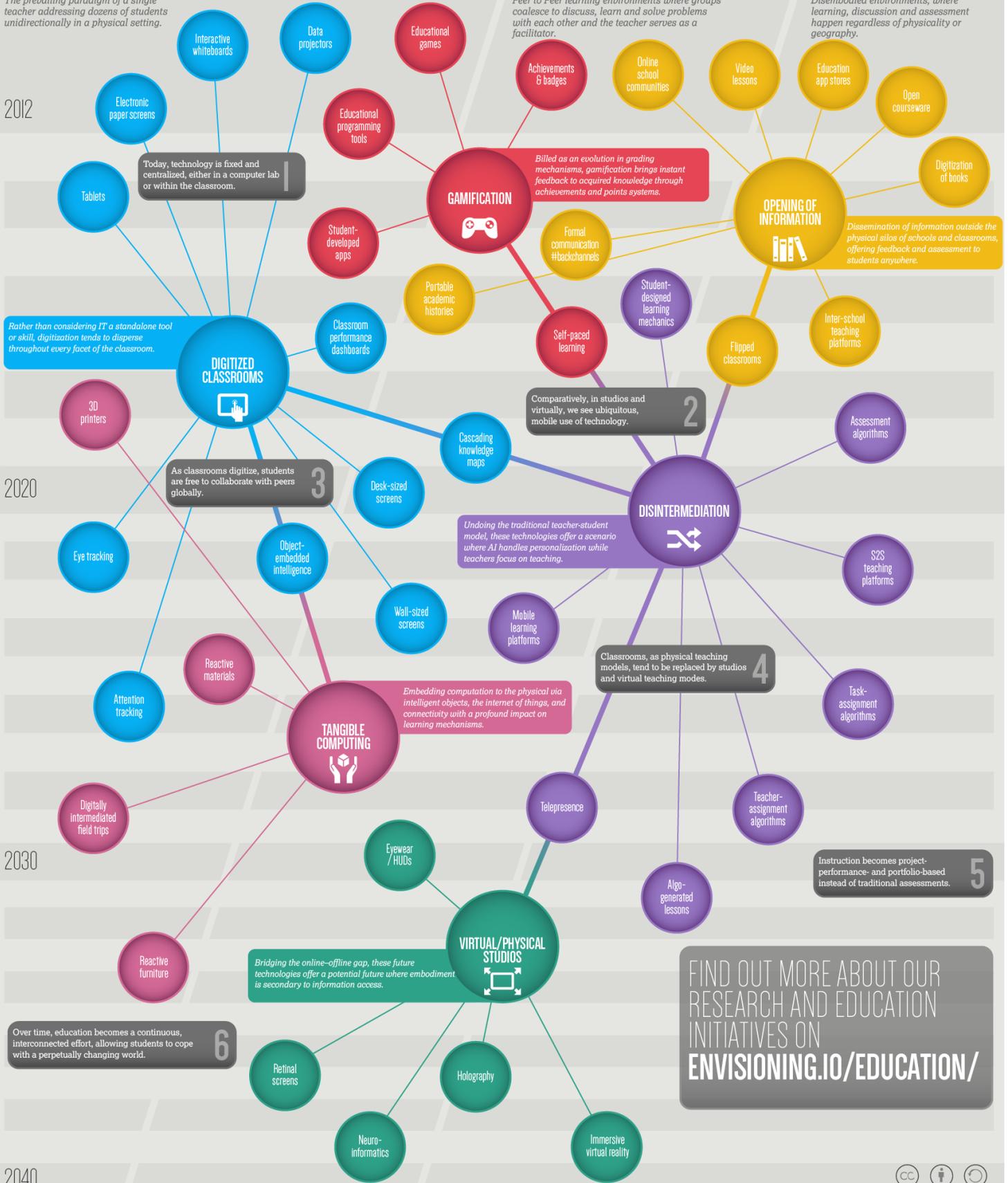


Figure 21: Envisioning the future of Education Technology (Zappa 2014)