ADVANCEMENTS IN DESIGN RESEARCH

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edited by Lucia Rampino and Ilaria Mariani

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The Materials Generation

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Abstract

The DIY movement is expanding beyond products to include the materials from which the products are made; namely, DIY-Materials. Designers around the globe are engaging in different experimental journeys encircling the materials development field before developing their projects. Self-made material sources are providing designers with a unique tool to develop new languages and new products with original and fresh materials experiences. As more designers take this path, a proper study around the phenomenon needs to be carried out.

This chapter presents an introduction to a doctoral study conducted to understand the DIY-Materials phenomenon as one of the emerging materials experiences in the field of design. The herein presented research structure shows the formulation of research questions and hypotheses, the qualitative methods and strategies to conduct the different tests, and how the different elements are attempting to clearly define this phenomenon together. The chapter does not act as a summary of the study. Instead, it is an invitation to read the doctoral dissertation. Within, it is possible to view and understand the opportunities DIY-Materials offer when considered as a possible practice in the design domain.

Introduction

Nowadays, the products surrounding us derive primarily from industrial materials, i.e., materials that are developed in order to answer mass production requirements and constraints. And it does not look like it will be chang-

ing any time soon. However, it is observable that over the last few years, another interesting phenomenon has emerged, bringing a new dimension to the relationship amongst designers, technologies, production processes, and materials. It is known as DIY-Materials (do it yourself materials) to highlight the principal characteristic of this "new class" of materials, which are conceived by the designer and their development is characterized by a tinkering approach and a self-production process (Rognoli *et al.*, 2015). This new approach to materials development is enhanced by the renaissance of craftsmanship, by the democratization of the technologies and all the practices combining making, crafting and personal fabrication (Bettiol and Micelli, 2014; Tanenbaum *et al.*, 2013).

The DIY movement expands beyond products to include the materials which make the products (Brownell, 2015). Starting from the DIY-Materials definition which describe these materials as created through individual or collective self-production practices, often by techniques and processes of the designer's invention (Rognoli *et al.*, 2015), we decided to add to the doctoral research we are presenting, the social innovation perspective, with the idea to better frame this remarkable and contemporary phenomenon.

The DIY-Materials Phenomenon

DIY practices are taking on different fields of knowledge and expertise. Among these, the materials for design domain is increasingly witnessing designers making use of this practices. In our opinion, it happened for several reasons including the interests related to more sustainable futures and attention to the social innovation perspective. Furthermore, the designers who have embarked on a path of development and self-production of materials, they also wanted to demonstrate their dissatisfaction with the monotonous uniformity of the industrial material landscape, and therefore they tried to generate original material experiences, even transforming themselves into real activists (Ribul, 2013) against the mass-production system. It seems that designers enjoy regaining control of the ideation and production processes, getting their hands dirty by experimenting with colors, textures, consistencies, mixing various ingredients and having fun looking for alternative and unconventional sources as raw materials.

DIY-Materials practices promote knowing in action (Schön, 1983), i.e., experiential knowledge with and through materials. The outcome of this process is often a self-produced material as a result of making things by hand, but also by thinking through the hand-manipulated materials (Nimkulrat,

2012). Thus, the process of making materials by hand can be identified as a way of thinking intellectually (Sennett, 2008) and a way of tinker manually (Parisi *et al.*, 2017). Designers, furthermore, require a dynamic process of learning and understanding through material experience (Gray and Burnett, 2009, p. 51) for designing with materials (Karana *et al.*, 2015).

The study began by asking: what is the origin of DIY Materials? Moreover, what can serve as a material source for their development? As there exists only a limited amount of literature in the emerging field and several types of research being applied on the subject around the globe, it was crucial to propose a more in-depth categorization and theory structure. There is a high chance for this phenomenon to continue to grow and become established, creating balance within the materials domain.

Theoretical requirements

The theoretical background of this study is composed of three macro-areas of research: materials for design theories, DIY practices, and design for sustainability (fig. 1). Through these three macro-areas, there is an opportunity to connect other significant theoretic contribution like the concepts of materials experience, the autarchic approach to materials and technologies (De Almeida Meroz, 2014; Bosoni and De Giorgi, 1983), and the circular economy principles and social innovation research.

The principal aim of this dissertation is to illustrate the possible paths for these areas to encounter. The study underlines the three agendas and topics coherently but does not intend to force the merge of the three topics as a whim or just for the sake it. Instead, it highlights the opportunities occurring when these topics encounter one another.

Motivations

Considering the evident connections that may emerge between the three macro-areas of research, examining also the relationship between people and things (material culture studies[1]), how human beings relate to their environ-

[1] Material Culture & Ecological Anthropology are defined by Ingold as recently opposite schools of thought. However, in this dissertation there are several moments in which both fields meet. Ingold, T. (2012). Toward an Ecology of Materials. *Annual Review of Anthropology, 41*, 427-42.

ment (ecological anthropology), and the issues of maintenance of the society and the planet (sustainability), the doctoral study focuses on the connections between topics and opportunities for the future of design materials.

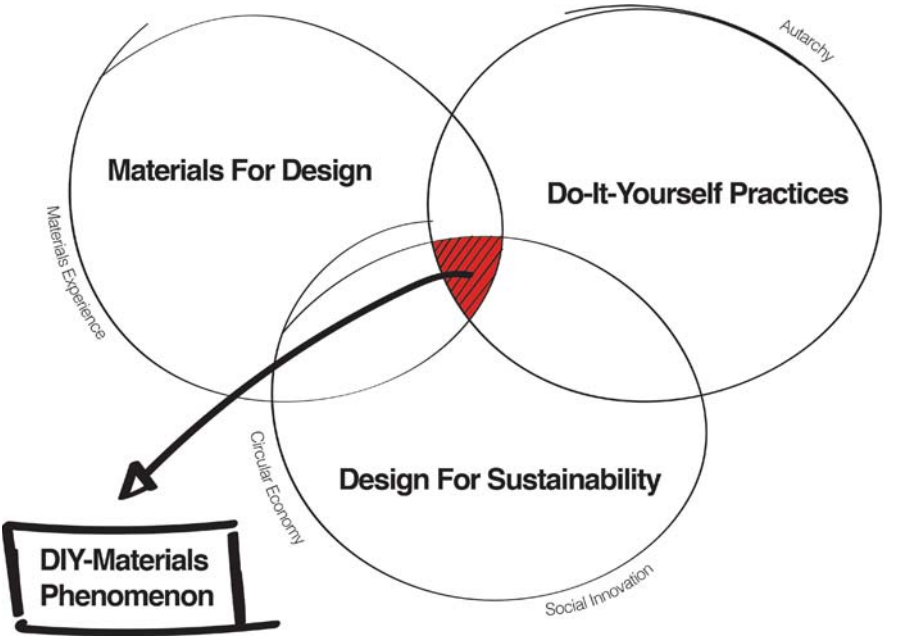

Fig. 1 – The three macro-areas that determine the theoretical support for the DIY-Materials phenomenon

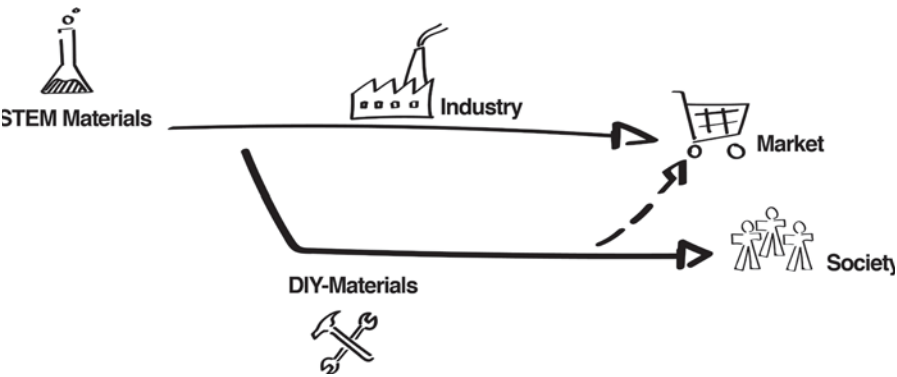

Fig. 2 – DIY-Materials as an alternative to traditional materials developed by science.

Societies need a driver which allows social innovation for the material culture. There is, and there always will be a technological innovation that is driven by the development of science and technology continuously investigating intelligence in materials (e.g., nanotechnology, memory, self-transformation). Nevertheless, materials in science always have the problem of accessibility, which means neither designers nor communities can gain quickly access to those materials that are developed in the lab. Unfortunately, some decades will have to pass before it will be possible to buy them in standard formats in a store.

This study focuses on another possible path for materials development and accessibility (fig. 2).

Humans beings must find alternative ways not only to produce but to use and dispose of materials.

Do-it-yourself practices, which arise as a social movement and which will presumably lead to social change, are now focusing on materials. It is a growing trend that we believe requires an ever-increasing study and investment.

The research questions

The research questions, sub-questions and the hypotheses guided the different stages of the research. One main question remained instrumental in guiding the process.

Research Question (RQ1)
What causes the DIY-Materials Phenomenon?

As it is a broad question that can be interpreted in many ways and can lead to many different results, the formulation of three sub-questions provide a more detailed focus:

(a) **Who** decides to embark in a DIY-Materials development?
(b) **Why** do people decide to do their materials?
(c) **What** are the differences between DIY-Materials and other materials?

This research question and its sub-questions helped to organize a research method and with it, a systematic collection of cases and best practices of this phenomenon.

After the findings obtained by developing a categorization of the different cases (Ayala-Garcia, Rognoli and Karana, 2017), a second research question emerged. It was evident that by determining the causes of the phenomenon and the reasons why people do materials will not provide enough contribution to the field of study. The questions of "what" and "why" needed to be expanded upon. They helped to create a better description, and surely the classification became an essential element for a better comprehension of the phenomenon. Nevertheless, if the phenomenon continues to grow, as it certainly did since the start of the doctoral research to the writing of this chapter, it was essential to explore where it would go. What difference could it make compared with traditional materials developed by STEM (science, technology engineering, and mathematics sciences)? [2]

On the evidence proved by the initial studies, where the essential knowledge on crafts is a determinant for a designer to embark on a materials development, the second research question shaped the rest of the doctoral study.

Research Question (RQ2)
Who can generate a DIY-Material?

Many artists, architects, and designers who have developed a material come either from a family of craftsmen, are trained to approach materials through their higher education or are DIY enthusiasts and believe in the open source and maker movements. This insight creates a niche inside the entire design field putting the willingness and capabilities to craft in the first place. All those with no intention to make with their hands will be hypothetically taken out.

Research objectives

General Objective

Develop a theoretical framework which allows the practice of DIY-Materials development to become available and implemented by a broader design audience.

[2] STEM is a term first used by the U.S. federal agencies to call the core sciences in the field of education for funding scientific research. Gonzalez, H., and Kuenzi, J. (2012). *Science, Technology, Engineering, an Mathematics (STEM) Education: A Primer*. Congressional Research Service.

Specific Objectives

The first objective is to highlight the possibilities that DIY-Materials can provide when considered as a possible practice in the field of design.

The second objective is to find and define a proper set of guidelines that can be utilized by a person who wants to develop a project starting from the material.

Key Words

- DIY-Materials
- Emerging Materials Experiences
- Tinkering with Materials
- Expressive-Sensorial Characterization of Materials
- Experiential Qualities of Materials
- Materials for Design
- Democratization of Materials

The research hypotheses

Theory building starts with propositions and hypotheses, where relationships among variables emerge. A series of hypotheses were proposed to guide the studies finding information to measure and encounter tendencies towards materials development patterns. According to Kaplan (1964), there are working hypotheses and test hypotheses. Working hypotheses serve to guide and organize the investigation providing something to go on with (p. 88).

In this research, the study started with two working hypotheses:

Working Hypothesis (WH1)
The DIY-Materials phenomenon tends to grow. There should be a way to organize it to allow a better understanding.

Working Hypothesis (WH2)
DIY-Materials emerged from the creative fields of humanities. There should be a gap that traditional STEM materials are unable to fill.

Test hypotheses on the other side come after the investigation is already on track. A series of inquiries may emerge to find the solution to a posed problem.

After being able to understand how in all the cases studied, it was of extreme importance to gain certain degree of familiarity and ability to work

with the hands to develop a material, a set of test hypotheses emerged providing further directions for the research. The test hypotheses suggest:

Test Hypothesis (TH1)
There is a relationship between knowing how to craft things and materials development.

Having concluded that classifying and organizing materials into different categories and sub-categories provides information about common elements the different cases share, a further observation on similar aesthetic patterns, common motivations and drivers to obtain a better understanding of the phenomenon emerged. A second test hypothesis then suggested:

Test Hypothesis (TH2)
Starting material development from a particular source has an effect on the final material developed.

If any DIY-Materials development starts from a particular kingdom, the designers of the material could carry out a focused research gathering information from similar cases understanding common elements, limitations, and advantages concerning properties and qualities of the material they want to develop as well as the benchmark ones.

Finally, another critical conclusion from the exploratory studies revealed that the designers unlike material scientists and engineers had some different motivations. Designers driven by concerns around sustainability and new aesthetics, propose alternatives for what the mass market provides. The third test hypothesis suggests:

Test Hypothesis (TH3)
DIY-Materials were the result of motivations other than what STEM materials commonly have.

The results would be different from what currently exists in the market not regarding performance and capabilities, but regarding what they have to offer to potential users.

The necessity to perform a fourth study followed the evidence of the potential for a DIY-Material to go further. The fourth research hypothesis allowed to move forward from the tinkering approaches which characterized

the third study into a more organized and accurate procedure. The fourth test hypothesis suggests:

Test Hypothesis (TH4)
DIY-Materials can achieve a mature level of qualitative development and it is possible to analyze them with standard methods to reveal qualitative data.

With the combination of data, it is possible to propose paths towards an application. To see the relationship between the proposed research questions, the hypotheses and the studies addressing both questions and hypotheses refer to fig. 8.

The structure of the doctoral dissertation

The dissertation consists of four main parts (fig. 3). There is the initial part where we provide an introduction and overview of the research as a whole, focusing attention on the organization and development of the study.

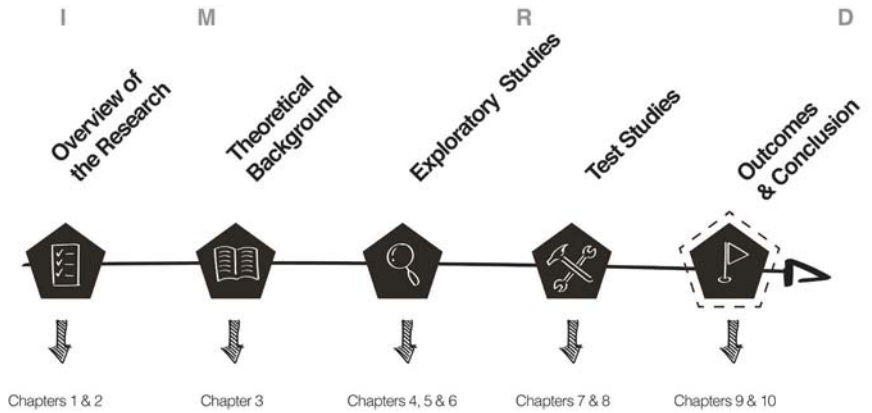

Fig. 3 – Structure of the Ph.D. Dissertation.

After that, we introduce various theoretical backgrounds and macro areas of research: materials for design, DIY practices, and sustainability-related theories. After that, we present the exploratory studies conducted to better understand the DIY-Materials phenomenon and start to define it. This part is composed of three exploratory studies: cases studies and best practices collection and their categorization, evaluation and aesthetical evaluation of

DIY-Materials. The following section presents the test studies conducted to validate hypotheses and gather insights for developing a DIY-Materials theory. This part is composed of two test studies: DIY-Materials development level I and DIY-Materials development level II. After the test studies, we illustrate the outputs of the different investigations, recommend a roadmap for the efficient development of a DIY-Material with a test study and present two strategies for the dissemination of the DIY-Materials theory. Finally, we discussed the research conducted, highlighting potential opportunities for the future of this phenomenon together with a report of activities, dissemination work and credits to all designers who participated in the study.

The doctoral dissertation is structured in such a way that it can be read continuously or separately according to the reader's interest. Each section stands by itself and contains references to connect and search for specific background topics in the other sections if needed. Regarding the theoretical background and introduction, the entire literature review is summarized and focuses on the different macro areas of research to better connect with the whole investigation.

The dissertation contains a series of figures and tables developed to facilitate the reader's understanding of the whole manuscript, support the introduction of concepts and enrich the research with visual aids. The numerous cases studied, the different evaluations and some of the work by the participants are made visible in a series of composed boards. By doing so, the focus of the visual aids goes to the materials and not to the product or a specific application. An appendix with various additional information, a number of examples of data collection, questionnaires and materials samples mark the final sections of the doctoral research.

Research Methodology

The whole PhD dissertation is composed of an explorative phase and a test phase. It builds upon several empirical studies aiming to produce a better understanding of the DIY-Materials phenomenon. Support from the different studies comes from the concepts of project-based research (Zimmermann, Forlizzi and Evanson, 2007). When studying a material from a designer's perspective the means by which to do it not only serve to explore the proposed theories physically but also allow for the description of the whole development afterwards. This method is known as design practice.

As DIY-Material practices promote knowing in action (Schön, 1983), which is a contemporary way of doing research (Mäkkela, 2007) artists and designers connect themselves with the field of research establishing a practice-led investigation. By looking at the different processes and the work produced through them, it is possible to acquire not only the skills but also the knowledge of the practice. This focus is the central constituent of the DIY-Materials theory.

Building blocks for a possible DIY-Materials Theory

Materials knowledge is a crucial element in the field of design. Designers understand physical properties and interact with qualitative attributes of materials all the time when developing products. Some designers are more aware than others about the role of a material in the products and can create meaningful experiences combining attributes of the product with the attributes of the materials that make it possible. Ezio Manzini provides an important definition to this matter by saying "Matter becomes material when it is included in a design project and becomes part of the product" (Manzini, 1986, p. 17). This definition can be considered a pillar in what is known today as materials for design, a section in the materials domain that moves away from the technical and complex understanding of materials in STEM (Science, Technology, Engineering and Mathematics) disciplines and concentrates on the experiential and behavioral interactions between people and the products. Recently in this section of the materials domain a concept known as the material experience appeared which defines the "experience that people have with and through the materials of a product" (Karana, Pedgley and Rognoli, 2014). This materials experience is rooted in a broader concept known as the product experience. Scholars proposed a framework to highlight how the relationship between user and product is mediated by three levels of experience: sensorial, emotional and meaning (Desmet and Hekkert, 2007). The concept of materials experience incorporates these three levels and adds a fourth one: the performative level (Giaccardi and Karana, 2015). The four levels affect each other and define the different experiences people obtain when interacting with a material (fig. 4). The materials experience concept and framework are quite broad and observable from different perspectives. One particular side of the materials experience, one that is relevant to this study, deals with the observation and understanding of three contemporary situations concerning materials that are impacting the field of design: dynamism, imperfection, and self-production.

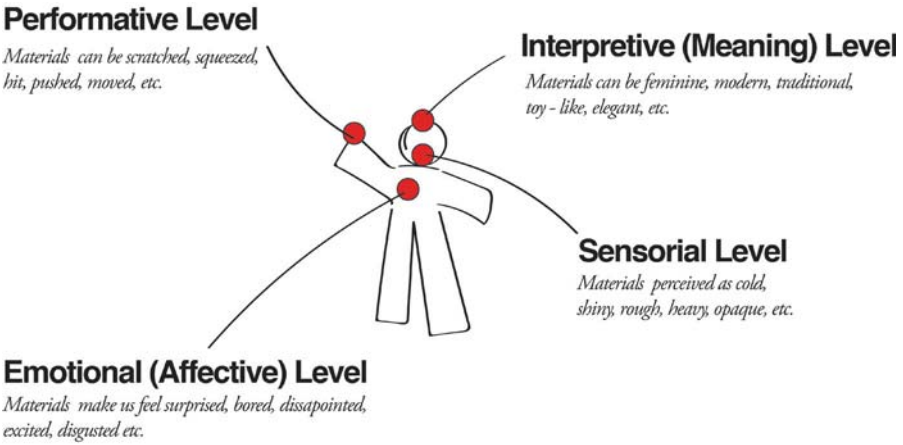

Fig. 4 – Four experiential levels how materials are experienced. Interpretation from the materials experience framework (Giaccardi and Karana, 2015).

Research strategies

As mentioned above, there is an opportunity to connect Materials Experiences research, Do-it-Yourself practices and autarchic processes research with Sustainability issues related to circular economy principles and social innovation research. These three topics became the three macro areas, and the intersection between them guided the investigation throughout the doctoral studies. To connect the three macro areas of research and derive an original and well-funded theory, a selection of two strategies for the first part and five strategies for the second part of the study improved as a crucial element (fig. 5).

The first part addresses the understanding of the phenomena of DIY-Materials that have emerged in the past decade and are growing exponentially. It was essential to understand why designers have embarked on this particular way of creating materials instead of selecting existing ones and, most importantly, how they do it. Cases Studies (Stake, 2000) helped to create a proper categorization of DIY-Materials into Kingdoms and Secondary Research (Booth *et al.*, 2008, p. 76) allowing to analyze the different cases inside each kingdom while gaining qualitative data from each material.

The second part was devoted to testing the initial categorization working as a guideline to train designers to develop DIY-Materials. The course

entitled "Designing Materials Experiences"[3] was created to test the theories and hypotheses of this doctoral study not with an academic focus, but with a practical one, as it was important for this study to collect more samples developed within a controlled environment and compare them with the ones from previous studies. With a total of 97 participants from 32 countries in the first edition and 81 participants from 29 countries in the second edition, it was possible to develop a robust study. The methodologies applied in this second part include Creative Toolkits (Sanders and Colin, 2003), Prototyping (Martin and Hannington, 2012, p. 138), and Storytelling (Beckman and Barry, 2009; Salomon, 2010; Giovagnoli, 2013).

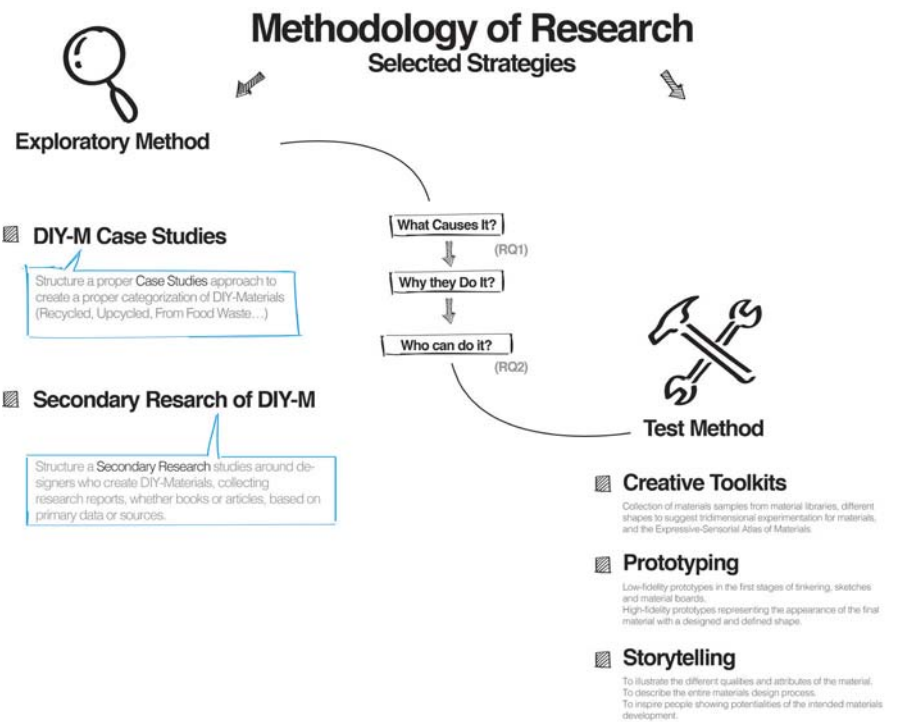

Fig. 5 – Methodology of research and the strategies performed during the studies

[3] Elective course at master level held at Politecnico di Milano academic year 2017-2018.

Exploratory method

For the exploratory studies, the two selected strategies are:

Cases studies

Case studies are one of the most common ways to carry out qualitative research. According to Robert Stake (2000, p. 437), there are three types of case studies: intrinsic, instrumental and collective. For this investigation, the collective case study strategy was more suitable, as it is a way to understand individual cases and recognise how some common characteristics manifest. Studying a collection of cases is believed to provide a better understanding of a phenomenon, population or general condition. It led to a better theorization of the research.

Secondary Research

Secondary research allowed for the analysis of the different cases inside each kingdom grasping qualitative data of each material. Different from primary research which implies a closer contact with the study subjects, secondary research allows for the collection of information from a variety of sources (Booth *et al.*, 2008, p. 76). This strategy, together with the instruments for gathering information, also helps to suggest research directions to follow during the study.

Test method

For the test studies, the three chosen strategies are:

Creative toolkits

Understood as collections of physical elements conveniently organized to inform and inspire design and business teams (Sanders and Colin, 2001), this method allowed participants to gain familiarity with materials, understanding them by physical interaction instead of face-to-face lectures, typical in materials science. To this aim, different elements were introduced during the third and fourth study, as a collection of material samples from the "Materioteca" the material library of the Politecnico di Milano, shapes to suggest tridimensional experimentation for materials, and the Expressive-Sensorial Atlas of Materials (Rognoli, 2005) – an educational tool aimed at helping designers study the sensorial qualities of materials as a translation of engineering properties.

Prototyping

Prototyping is the physical creation of artefacts at various levels of resolution, for development and testing of ideas within design teams and users (Martin and Hanington, 2012, p. 138). A prototype allows testing physically different attributes of the designed element, in this case, the material. Transforming the material sample into a prototype means that some shapes, textures, finishes, and volumes become subject of study. This type of samples is critical not only to the designer but also for users to understand the intentions and features of a material.

Design prototypes are defined by their level of fidelity or resolved finish. Low-fidelity prototypes appear in the first stages of tinkering accompanied by sketches and material boards. High-fidelity prototypes are more refined, often representing the appearance of the final material with a designed and defined shape. The participants are encouraged to move away from the standard flat, two-dimensional form of a material sample and test the material through prototyping in three-dimensional shapes with multiple textures and colours. Contrary to what scientists usually do, trying to minimize variables, here designers test any possible skill acquired in their career, achieving unique results in every single prototype. The portfolio of material samples becomes incremental, and the tools for storytelling and envisioning become more productive and more stimulating.

Storytelling

Storytelling is at the very heart of human cognition, of the interactions of individuals with one another and of the development of cultures in which humans thrive (Beckman and Barry, 2009). The field of design uses storytelling as a tool to describe the entire design process. It is used to inform the current stage of the project, or it is used to tell a new story, inspiring people by showing the potential of the intended proposal. When it comes to materials development, both types of stories can become handy in illustrating the different qualities and attributes. Through the dissertation, it is possible to see different case studies with the designers telling the story of how they achieve a particular material and the whole meaning of this achievement. Others focus on how this material can open doors to new possibilities for parallel applications to contrast the current state of product development and mass consumption.

During the study, the participants received training in the different possibilities of what a story behind material development can do. This method allowed all teams to collect various data from the very beginning and organize it according to what the material vision proposed.

Research plan

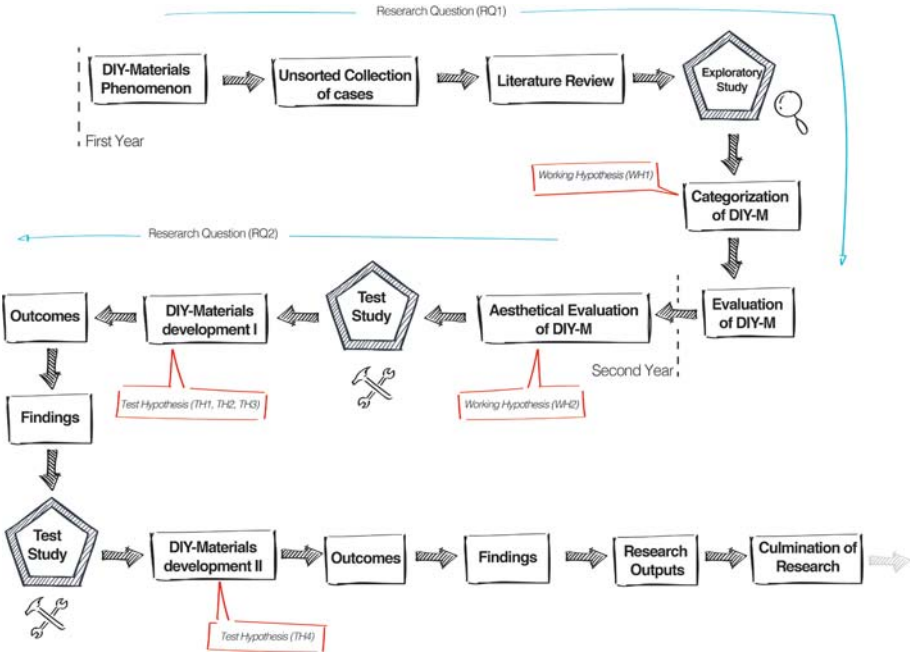

Fig. 6 – Graphical visualization of the research path.

Structure

The investigation was conducted first by understanding the theoretical background which was divided into the three macro areas of research. The analysis of the different elements of this theoretical background and the points of convergence resulted in the formulation of the first research question (RQ1). To answer this question an extensive collection of cases and an in-depth analysis of them began to give the research a sense of order.

Different classifications and evaluations of the various cases studies collected became these exploratory studies:

- ***Pre-Study.*** Collection and analysis of 150 cases of DIY-Materials. This study resulted in the classification of cases by kingdoms and is published under (www.diymaterials.it). The cases studies are continuously updated in the open source database and analyzed to extract qualitative data. By researching case studies in journals, blogs, websites, articles

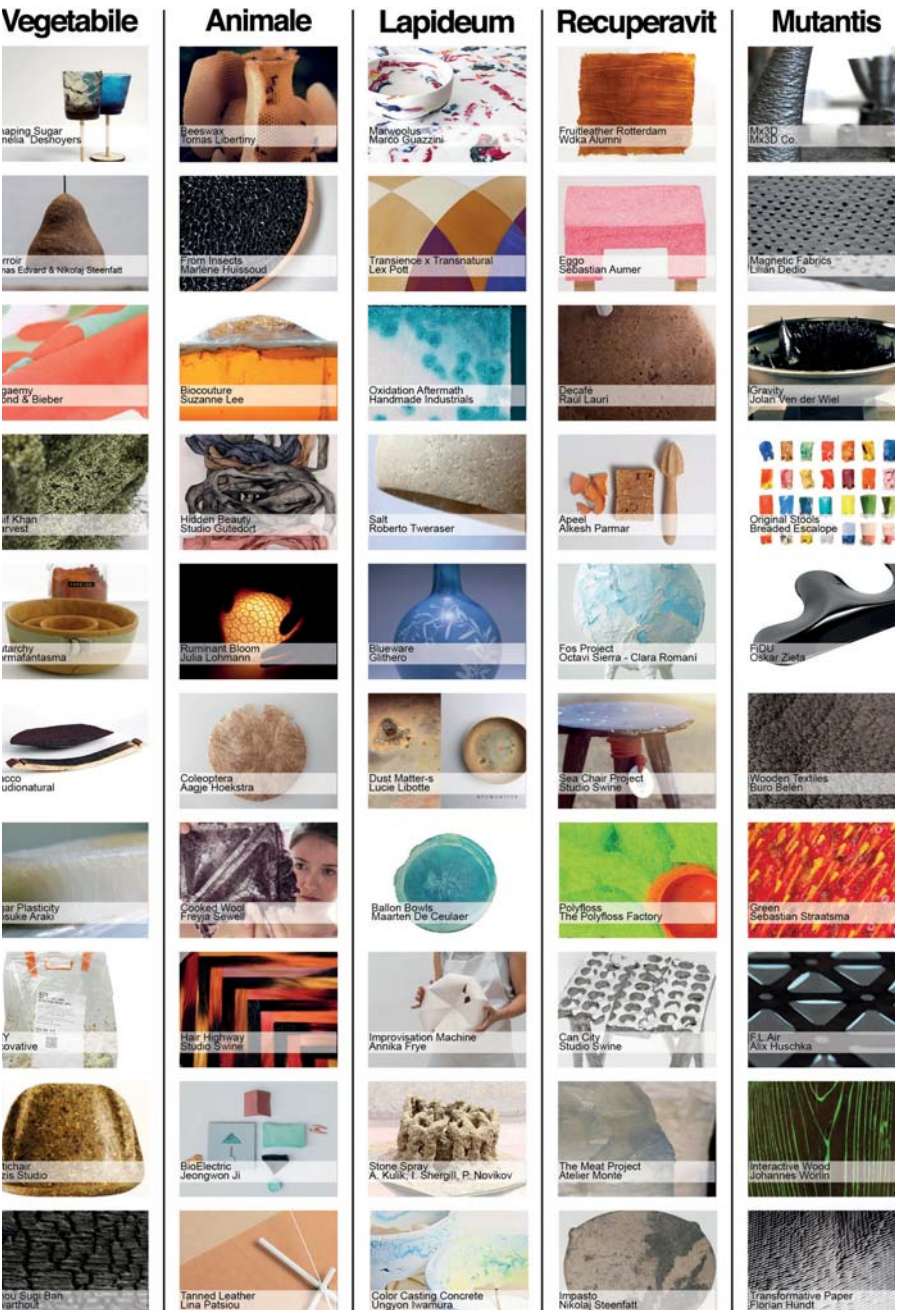

Fig. 7 – Categorization of DIY-Materials into Kingdoms.

and exhibitions, we began to think of these examples and their unique qualities. We started to create groups of similar items. Since the classification of objects means to combine them into categories based on common elements, we drove the focus on a possible categorization for the DIY-Materials. We look for inspiration in the first biological classifications of the XVII century (e.g. the work of the Swedish botanist, zoologist and physician Carolus Linnaeus called Systema Naturae (Linnaeus, 1740). Linnaeus published what became for many years the standard biological classification of elements of earth, known as the Linnaean taxonomy. This landmark publication established a hierarchical classification of the natural world, dividing it into three main kingdoms: plant, animal and mineral. However, the original taxonomy provided by Linnaeus inspired us also in naming the DIY-Materials categories (fig. 7).

1. ***Kingdom Vegetabile*:** When the primary source for a DIY-Material derives from plants and fungi, we categorize the material under the Kingdom Vegetabile.

2. ***Kingdom Animale:*** It refers to all material sources derived from animals and bacteria. Those materials can be developed either by collaborating with living organisms or by using parts of the animals, like hair or bones.

3. ***Kingdom Lapideum:*** It contains all DIY-Materials, which come from minerals: stones, sand, ceramics, clay, etc. Some current cases combine sources from other kingdoms, such as wool or cotton fabrics, but in a lower percentage compared with the main constituent.

4. ***Kingdom Recuperavit:*** comprise all sources society consider as waste but have the possibility to transform into a valuable resource. They often come from plastic, metal or organic waste, sometimes as side products of industrial production.

5. ***Kingdom Mutantis:*** includes the DIY-Materials created from different technological mixes and hybridization of industrial, interactive or smart sources.

- ***Study One.*** Evaluation of the different cases studied with specific instruments allowed information to be gathered regarding the various motivations behind the creation of such types of materials.

- ***Study Two.*** Basic research on aesthetic qualities of the DIY-Materials classified by kingdoms. By gathering different qualitative tools and theories from various scholars, it was possible to establish an initial evaluation of the aesthetic and sensorial characteristics of these materials. This evaluation allowed for a better understanding of possible similarities and general characteristics of a kingdom.

With the exploratory studies concluded, the formulation of a second research question (RQ2) guided the second group of studies. Two courses at the M.Sc. level and five master thesis projects developed under strict guidelines provided the necessary data to move forward in the proposition of a DIY-Material theory. An additional research question (RQ3) emerged between studies aiming to find additional insights and organize the findings into what could be the primary outcome of the research. This second group of studies became the following test studies:

- ***Study Three.*** A course developed specifically to test the theories and methods gathered to create a material under guidance. Two editions of the proposed study happened during the research plan and provided insights to validate hypotheses.

- ***Study Four.*** Added another layer into the development process creating a series of incremental steps for advanced DIY-Materials development. Five participants from the previous study with the potential to develop an M.Sc. thesis on DIY-Materials were selected. Their topics for thesis work and their investigation were guided to prove hypotheses and provide additional information for the DIY-materials theory.

The different research questions, hypotheses and the related studies in correspondence with the chapters of this dissertation are visible in fig. 8.

Context

The overall research was conducted in an academic context first by analyzing the phenomenon of DIY-Materials within the design field and with empirical research tools known in the design domain. Subsequently, the test studies took place within the design department of the Politecnico di Milano, and all participants were Master students. They accepted to be subjects of research and agreed to share their findings and contribute to the theory's for-

Study	Research Question		Hypothesis	
Pre-Study	(RQ1)	What causes the DIY-Materials Phenomenon?	(WH1)	- The DIY-Materials phenomenon tends to grow. There should be a way to organize it to allow a better understanding.
1st Study	(RQ1)		(WH1)	
2nd Study	(RQ1)		(WH2)	- If DIY-Materials emerged from the creative fields of humanities, then there is a gap that traditional material related sciences are unable to fill.
3rd Study	(RQ2)	Who can generate a DIY-Material?	(TH1)(TH2)(TH3)(TH4)	- If somebody who knows how to craft things get additional knowledge and guidance about how to perform a materials development, then he or/she can produce a material sample of any kind. - Starting material development from a particular source has an effect on the final material developed.
4th Study				- DIY-Materials were the result of motivations other than what STEM materials commonly have. - If DIY-Materials achieve a mature level of qualitative development, it is possible to analyze them with standard methods to reveal qualitative data and with the combination of data propose possible paths towards an application.

Fig. 8 – Overview of studies with focus on research questions and hypothesis.

mulation as presented in this dissertation. Although the whole investigation was conducted and analyzed within academia, the different outcomes of this dissertation have the potential to be explored outside an academic environment through the various streams proposed.

Intended Outcomes

The dissertation presents the different achievements of the doctoral study, aiming to better understand the phenomenon known as DIY-Materials. A theoretical background based on a taxonomy of the different materials collected allows for the interpretation of the motivations behind the designers who create those materials and will seek to establish directions for this type of developments.

A practical method composed of a series of steps which allows for the development of DIY-Materials with a high level of quality is considered as an outcome of this investigation. The second part of this dissertation which is called the test phase shows an in-depth explanation of how the different subjects of the study experienced a DIY-Materials development process. During this process, participants produced a series of samples following different directions and methods.

An open source database with the results of both explorative and test phases is available to anyone who decides to replicate a material, propose a new alternative or continue the development of material given a specific application. The PhD started by collecting cases and moved towards the creation of new ones. By building a database organizing previous cases and newly developed ones together and in a visible manner, the investigation will open the doors for more designers to perform and develop these new emerging materials experiences.

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