Material Tinkering. An inspirational approach for experiential learning and envisioning in product design education.

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Abstract: Knowledge about materials is a fundamental element in product design education. It involves learning engineering concept about the technical properties and selection tools. More important, this concerns developing a sensitivity to the sensorial and experiential qualities of materials. We propose Material Tinkering as a practical and creative approach to develop this sensitivity through experiential learning. Integrated with envisioning and abstract conceptualization, it leads to richer and more complete projects. The paper uses a case study. This case is an experimental educational activity applying the tinkering approach to self-produced materials, i.e. DIY materials. This method fosters students’ creativity and educates them to understand, evaluate, and design the experiential, expressive, and sensorial characteristics of materials, i.e. the concept of Materials Experience, Tactual Experience, and the Expressive-sensorial dimension of materials. In conclusions, we suggest strategies to facilitate Material Tinkering.

Keywords: Material tinkering, Tactual experience, DIY materials, Materials experience, Experiential learning.

Introduction

Knowledge about materials is a fundamental element that product design students should gain during their educational journey. By knowing materials, their technical properties, sensorial qualities, their manufacturing processes, and treatments designers can select the proper materials for their projects. They can also design their appearance and feel, or even start from a particular material and develop meaningful applications for it. In this paper, we address an approach for design education regarding materials for design. It is based on a creative and direct experimentation on materials, namely Material Tinkering, which grounds on experiential learning. We argue that this approach may be helpful to foster students’ creativity and to educate them in understanding, evaluating, and designing the experiential, expressive, and sensorial characteristics of materials. Through this paper, we describe the main features of Material Tinkering and its role and contribution in the whole design
process. In particular, we highlight its relationship with envisioning and abstract conceptualization, which are promoted by Design thinking and the predominant design education approaches.

After having addressed the most relevant theoretical foundations of Material Tinkering in the scope of Experiential Learning and having considered other methods of direct experimentation in education (1), we describe the main features that characterize this approach in terms of procedures, techniques, tools, and resources (2). Next, we introduce the importance of sensoriality in tinkering. In particular, the role of the tactual experience is described (3). As a case study, we describe an experimental educational activity applying Material Tinkering on Do It Yourself (DIY) materials. Then, we present its results and the insights from this experience (4). Concluding, we discuss them, by conducting a reflection upon this experience and proposing some suggestions and strategies to facilitate the Material Tinkering process (5).

1. Material Tinkering as educational practice

In the scope of design education, the relevance of the role of the sensorial and experiential qualities of materials has remarkably increased. In the last 30 years, scholars interested in materials and design moved their attention from the technical properties of materials to the sensorial, expressive, and experiential qualities of them (Manzini, 1986; Cornish, 1987; Ashby & Johnson, 2002; Rognoli, 2010; Karana, Pedgley, and Rognoli, 2014). Also, their educational approach moves from a theoretical one to a more explorative and practical one.

Supporting this change, new tools and methodologies for materials exploration started to be developed and used in design education, by drawing inspiration from Bauhaus didactic notion of Learning by doing (Wick, 2000). All these tools and methods grounds on the acknowledgment of the importance of sensoriality of materials and of direct engagement between the designer and physical samples of materials (Pedgley, 2014). More and more courses and workshops are set on these premises and encourage students to experience materials through a hands-on approach (Rognoli, Ayala, and Parisi, 2016 a; Groth and Mäkelä, 2016; Mäkelä and Löytönen, 2015; Ayala, 2014; Sonneveld and Schifferstein, 2009). Also, designers who are focusing on material-driven innovation likely use an experimental approach to design and embody novel materials or reinterpret the conventional one.

We refer to this practice of direct, creative, and iterative experimentation on materials as tinkering with materials or with the expression “Material Tinkering.” Tinkering (Wilson and Petrich, 2014) is a term borrowed from Human-Computer Interaction (HCI) that points to hacking and manipulating physical interaction materials in a naive, playful, and creative way (Cermak-Sassenrath and Møllenbach, 2014; Sundström and Höök, 2010; Buxton, 2007; Zimmerman, Forlizzi, and Evenson, 2007). Both the HCI community and the materials community show interest in studying this approach concerning its implications for the designer’s experiential learning and engagement with the material (Falin, 2014; Niedderer, 2007; Nimkulrat, 2012; Seitamaa-Hakkarainen et al., 2013; Vallgårda and Farneaus, 2015; Parisi and Rognoli, 2017).

Material Tinkering is a practice that may drive innovation and uniqueness in design. As David Pye (2007) stated “the range of qualities which mass production is capable of just now is so disarmingly restricted.” This is because "each is so uniform and [...] nearly all lack depth, subtlety, overtones, variegation, diversity, or whatever you choose to call that which distinguishes the workmanship of a Stradivarius violin” (Pye, 2007). Indeed, we can observe a relation between tinkering and the practice of crafting, with the meaning of “making with own hands.” This relationship is consistent with an increasing trend in design, namely the Craft 2.0 (Micelli, 2011; Cavalli, 2014; Sennet, 2008), in which
designers draw inspiration from traditional craftsmanship’s techniques, skills, and knowledge, and use a self-made, hands-on, and experimental approach. This is not a nostalgic return to traditional practices but, on the contrary, is directed to future and innovation by using crafting as an inspirational and creative driver to enhance and qualify design.

The process of Material Tinkering is encouraged in a particular step of the Material-Driven Design (MDD) method (Karana et al., 2015). This step is named ”Tinkering with the material” and aims to understand the material through its direct manipulation. The MDD method is a new methodology for materials exploration and design focusing on the notion of Materials Experience and combining practical experimentation, user studies and envisioning. Since materiality highly contributes to the definition of Product Experience (Desmet and Hekkert, 2007) the concept of Materials Experience arises as “the experience that people have through and with materials” (Karana, 2009; Karana, Pedgley, and Rognoli 2015), considering senses, meanings, emotions, and ways of doing (Giaccardi and Karana, 2015). A hands-on approach appears to be crucial in the MDD method to understand materials and develop them further.

Tinkering may be observed through the lens of Experiential Learning (Smith, 2001, 2010). This term is used to describe the kind of learning undertaken by students able to gain and apply knowledge, skills, and feelings by being involved in a “direct encounter with the phenomena being studied rather than merely thinking about the encounter” (Borzak, 1981). The main contribution on the topic is the work of David Kolb (1984) and Roger Fry (Kolb and Fry, 1975) who developed the model of “Experiential learning cycle” out of four elements:

1. **Applying**, i.e. testing a particular action in a specific situation through active experimentation;
2. **Experiencing**, i.e. having a concrete experience of it and its effects in a specific situation;
3. **Reflecting**, i.e. understanding the effects in the particular instance through reflective observation in order to anticipate it if it happens again with the same conditions;
4. **Generalizing**, i.e. the formation of abstract concepts in order to gain an experience of the action beyond the particular instance and suggest the general principle.

Kolb and Fry (1975) state that the experiential learning cycle should be approached as an iterative process in the form of a continuous spiral and that after the Generalizing step the process restarts with a new Applying step in which the action is tested in new situations within the range of generalization. The starting point of the process can be set at any one of the four stages.

Observing the model of Experiential Learning we can assert that Tinkering may cover the steps of Appplying (Active Experimentation) and Experiencing (Concrete Experience). On the contrary, a more conceptual and Design thinking approach may cover the Reflecting (Reflective Observation) and Generalizing (Abstract Conceptualization). Currently, the latter approach is predominant in design courses. Indeed, for many of the students, the concept of Practice-Led Research (Mäkelä, 2007; Pedgley, Rognoli, and Karana, 2015) is almost unknown probably due to the abundance of digital sources for design and theoretical and conceptual approaches in design education. Most of the time, for students the idea of a hands-on project is related to the development of mock-ups or prototypes during the final stage of a design project (Rognoli, Ayala, and Parisi, 2016 a).

We do not state that tinkering, combining active experimentation and concrete experience, is meant as an alternative to a conventional design approach oriented to reflective observation and abstract conceptualization, i.e. envisioning. Instead, as the model of Experiential Learning suggest, we state that the integration of the two could be helpful to obtain a richer and more complete development
of the projects, involving both tinkering and envisioning. On the one hand, the risk of adopting just envisioning is the generation of insights lacking any test, practical results, and physical and intuitive outputs. On the other hand, tinkering without envisioning means mere making and crafting without any designerly intention.

2. Characteristics of Material Tinkering

Material Tinkering is a design practice characterized by specific features, procedures, supportive activities, and goals. Material Tinkering aims to extract data, understand material properties, understand constraints, and recognize its potentialities. Material Tinkering helps to gain knowledge about materials and to develop procedural knowledge through experiential learning. Tinkering fosters sensorial awareness of material qualities. It may reveal unpredictable and unique results as a bricolage practice (Louridas, 1999). Tinkering allows generating unique and meaningful visions by making and manipulating materials. The Material Tinkering process encourages continuous development and perpetual prototyping.

By tinkering with materials without a project in mind, the designer uses exploratory research to create a vision for a meaningful Material Experience to lead further development. One can say that the results of tinkering are just experimental and incomplete materials. In fact, usually, they are samples of semi-developed material proposals ready to further developments or be used as inspiration.

We can easily apply this direct and creative experiments and engagement with materials to self-produced and low-tech materials. Do It Yourself (DIY) materials (Rognoli et al., 2015; Rognoli, Ayala, and Parisi 2016 a; 2016 b; Parisi, Rognoli, and Ayala, 2016) are a case in point. The diffusion of workshops, fab labs, maker spaces, and the access to knowledge and sharing online platforms facilitate this kind of experimentation. Thanks to this democratization of knowledge and technologies, even unskilled people can tinker. As a new way of crafting, the self-production of materials allows designers to control the whole process independently. It allows them to use the resources they want or find inspiring. It allows them to invent their tools. Also, it permits designers to make a technical and sensorial material characterization, according to their visions and creativity. In few words, these features define the notion of Material Activism (Ribul, 2014). This practice reveals an unconventional design paradigm. In standard industrial practice, engineers develop new materials first. Only then they ask designers to make these materials meaningful for users. Designers do this by developing the sensorial and expressive characteristics of the materials and finding an application for them. With the emergence of an explorative approach to DIY materials, designers ideate meaningful material experiences first. Then engineers make them feasible and fully functional.

Tinkerers use pictures, videos, drawing, notes, and diaries to document the process. Documentation records the process and makes the process visible, communicating it and allowing tinkerers to return to any part of the process. Tinkering is a process of trial and error. Successes and failures both contribute to understanding the material. Through tinkering, we become aware of rules to master and break them.

In this process, materials have an active role by suggesting ways of interaction and manipulation. Metcalf (1994) argues that “the material speaks” and the designer has to be ready and open to listening to it. In tinkering, we open to material vitality from the aesthetic, affective (Bennett, 2010), and performative point of view. The material engages tinkerers on a very deep level, establishing intimacy with them. Through iteration and tinkering students establish an emotional bonding with the material, enriching the experience that they have with and through it and developing a pleasure
of making. One can state that an emotional value of tinkering is evident and visible in the iterative process (Rognoli, Ayala, and Parisi, 2016 a). Through tinkering, the agency extends to the materials. The material becomes an active participant in tinkering. It co-participates in the process and co-performs (Robbins, Giaccardi, and Karana, 2016) with the tinkerer. As Rosner (2012) states “Materials are collaborators in the craft process.”

Another issue related to tinkering is the aesthetic of its results. It emphasizes imperfect, organic, and rough surfaces, activating a process of humanization of materials, making them honest, expressive, and vulnerable (Parisi and Rognoli, 2016). This is mainly due to the use of a non-technological approach and the use of waste and local resources, characterized by high disposal and low pricing.

3. The role of Tactual Experience in Material Tinkering

Tinkering involves all senses. It is through tinkering that one discovers the possibilities of how materials may look, feel, sound, and smell. Also, this multi-sensorial aspect is one of the strongest aspects of tinkering, as all senses are contributing to the overall experience of the material, each sense in its own right. However, we live in a world where the visual often seems to be dominant. Moreover, the tactual at times may even be neglected. As Arnheim (1954) stated, we live in a crippled world, where the sense of touch is not addressed as it could be, leading to impoverished experiences. Also, our experience with multisensory design (Sonneveld and Schifferstein, 2009) made clear that to involve all senses, they should be addressed explicitly, to avoid that they are neglected. Therefore, in this paragraph, we want to emphasize the importance of the tactual senses - e.g. skin sensations, proprioception, temperature, and pain - in the tinkering process: why should they be addressed and how can we encourage the awareness and sensitivity for touch? This question can be addressed from two interrelated perspectives: the meaning of touch and the aesthetics of touch.

Touch has a meaning in its own right. First, it is through touch that we learn about the materiality of the world: its texture (smoothness, roughness), flexibility (stiff, flexible), hardness (hard, soft), temperature (warm, cold), shape (organic, geometric) weight (light, heavy), and so on. In a few words, all the Expressive-sensorial characteristics of materials (Rognoli, 2010) that are related to touch. Through touch we learn how materials behave: how they warm in our hands, melt, how they react to swinging, to pressure, to stretching, and so on. Also, it is through touch that we understand what we can do with a particular material: touch is not only the foundation of understanding but also of making. It is through touch that we can manipulate, shape and create our material world. This understanding through touch is, therefore, an important aspect of tinkering that should be addressed in its own right. In tinkering, students should be encouraged to explicitly experience the tactual dimension of the materials they are exploring. To allow this to happen, one of the methods could be to explore with one’s eyes closed, to avoid the dominance of the visual senses (Sonneveld, 2007).

Next, it is through touch that we experience the affective behavior of the material world: how materials may be tender, adaptable and love us, or cold and harsh and reject us, or elastic and bouncy and energize us. Again, this aspect of touch is not easy to become aware of, and should be addressed explicitly during tinkering to allow students to address this affective aspect in the exploration and development of the materials they are designing: what kind of affective messages does the material express? To allow students to address this question, a possible exercise could be to ask: if the material were a living creature, what kind of personality would it have?

To design for pleasant and coherent tactual experiences, designers need to develop their tactual sensitivity, much like a perfumer, a wine expert or a chef develop their sensitivity and become super
smellers and super tasters. Developing tactual sensitivity has been addressed by several educators, and is always addressed through touching and making. This can be observed in the “Laboratorio Tattile” developed by Bruno Munari (1985), where primary school children develop their sensitivity to touch by touching and creating material objects. Sonneveld translated these insights in an approach to develop the sensitivity of design students for touch (Sonneveld, 2007). The approach consists of a process in which students alternatively explore and create material objects, using a specific language to describe what they are experiencing. This language, the body language of material objects, is developed into a tool that is used along the way: the Tactual Experience Guide (Sonneveld, 2007). The guide integrates the knowledge about materiality and its affective meaning, that are both gained through touch.

Tinkering offers a powerful platform for students to develop their sensitivity to touch when these tactual experiences are addressed explicitly. Students develop their own lexicon of experiences, and develop their own aesthetic preferences, thereby allowing them to understand how other people developed their own subjective preferences. It is through this sensitivity, developed in tinkering, that design students will be able to design materials and material objects that offer rich and coherent tactual experiences. Moreover, by understanding one’s own preferences through hands-on experiences, design students will be able to become empathic for preferences of others, thereby being able to develop rich tactual experiences that are appropriate for and appreciated by the people they are designing for.

4. A course on Material Tinkering. A case study.

Tinkering with self-produced materials is an activity that could be proposed to students to develop innovative and creative material proposals, and to improve pragmatic skills and a particular sensitivity about experiential and sensorial qualities of materials. A course based on Materials Tinkering was organized in two editions, in 2015 and 2016.

In 2015, a pilot course was organized1 on the topic of Tinkering with Do It Yourself (DIY) Materials. 34 product design master students from 8 nationalities, divided in teams of 3 members, were involved for five weeks in an experimental process of ideation of DIY materials. The students were encouraged to share results, findings, and insights to create an open and virtuous collaborative environment. They were invited to produce some novel DIY materials by starting experimenting with basic and cheap ingredients easy to collect in a high amount, such as waste, food ingredients as starch, plants, local resources, and to use low-technological techniques that they could perform in their kitchen or the school laboratories. They were also suggested to find some open source recipes or instructions of materials available online, such as the ones for home-made biopolymers, to use as a starting point, and to draw inspiration from other disciplines, such as culinary science and synthetic biology, activating a trans-disciplinary cross-pollination2.

Since these materials were open source, do it yourself and low tech, it was possible to interact with them easily and directly through a tinkering process. Through the whole development process of these materials, students were facilitated by following the MDD method that helped them to

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1 At Politecnico di Milano, School of Design, as a didactic module of the Concept Design Studio in the Product Design for Innovation Master of Science, Academic Year 2015/16. The teaching staff was composed by: Valentina Rognoli, as course leader; Giulia Ardenghi, as teaching assistant; Camilo Ayala Garcia, as course advisor; Stefano Parisi, Giada Martinelli, and Vanessa Monna, as tutors.

2 This approach was encouraged in a lecture by an invited guest of the course, Laurence Humier, designer and author of the book Cooking Materials.
understand and develop their materials and to create meaningful materials experience. Specifically, as a guideline for the tinkering phase, they adopted the “Tinkering with the material” step, described in the first phase “Understanding the material” of MDD method. Through this step, characterized by a hands-on approach, it was possible to obtain information about the materials’ properties and how they could be processed and shaped. Furthermore, it was possible for the students to have experience of the materials in the first person. This step is crucial when technical data sheets are not available or are not completed, e.g. for experimental or semi-developed materials.

Students tested the materials through tinkering both operating during the process and after the process (Fig 1). The first practice aims to develop the final formulation for the materials, to identify possible manufacturing processes and to understand the material behavior through the relationship between the variables of the process and the results (Fig. 2). The second practice aims to determine the possible surface treatments and resistance of the material. Students performed different interventions on the treated samples: texturization, dyeing, test for fire, water, weather and UV resistance, water resistance, tensile strength, scratch resistance. They also changed variables to the process and recipes: molds shapes, size, and materials, molding techniques, kind and ratio of the ingredients, time, and temperature of the process, etc.

Fig 1. Some examples of Material Tinkering operations in the project “I Leek you a lot”, experimentation on leek’s fibers. By Esra Erdogan, Claudia Fumagalli, Clémence Paillieux, and Yui Hasegawa. 2016.
Material tinkering revealed to be a constant activity from the beginning to the end of the process, i.e. from the first attempts to the final samples. After the first direct experimentations and tinkering with different ingredients, compositions and processes, the students started to understand the potentialities and limits of the materials they were creating and to select the most potential material recipes and push them to the next level through iteration and repetition of tinkering, obtaining feasible and replicable samples.

Together with the understanding of the technical properties and of the processes that helped in gaining a know-how of the materials, the assessment of the Expressive-sensorial qualities was necessary to understand the potentiality of the materials regarding evoked meanings, elicited emotions, and aesthetic, both visual and related to the other senses. In particular, since the materials were novel, the tactual experience of them was unknown. Often these materials showed visual qualities that were not consistent with the actual tactual qualities, e.g. some materials appeared hard, but they were soft and flexible. Others looked heavy and robust, but actually they were lightweight and vacuum. By practicing in examining the samples and focusing each time on a single sense, they improved their sensitivity and developed their own lexicon, i.e. a more unique, subjective, and detailed way to express materials qualities. For instance, the feeling provoked by a textured material surface, after few examinations, was identified as “a comfortable and accommodating feeling of a soft roughness.” In few words, tactual exploration helped to discredit visual expectations, to improve students’ sensitivity, and to understand the material in a deeper and more unique way.

Taking annotations and recording the process with pictures and videos was fundamental for learning. Students were asked to collect their documentation in a diary of their experience (Fig. 3). Furthermore, all the students found the necessity to accompany the samples with descriptive labels containing information about the samples, such as the ingredients and their quantities and the instruction for the process.
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According to the MDD method, parallelly with Material Tinkering, the students conducted user studies, by obtaining information about how people perceive the material, and material benchmarking, by comparing the samples with other alternatives. The results of these studies helped the students to proceed with tinkering. Then, through mapping all the insights and envisioning, the students developed a statement of a vision of materials experience which helped them to identify further design and experimentation direction, i.e. the technical and Expressive-sensorial characteristics to transfer and to emphasize in the following materials development. As a final step, by continuing with tinkering, they explored and identified techniques and processes to shape the materials into concepts of products.

As a result, 11 projects were presented through sets of materials samples in different variations of colors, textures, compositions, accompanied by concepts of products, diaries, brochures, videos and communication materials (Fig. 4, 5). Most of the materials were based on waste and local resources creating sustainable and virtuous solutions. Emphasizing imperfect, organic and rough surfaces, the students wanted to enable a process of humanization of materials, making them honest, expressive and vulnerable. Furthermore, they discovered that materials are not aseptic substances but living and reactive, and they understood that they should have started to “establish a dialogue with them” and to be inspired by them. Serendipity factor, unexpected results, and mistakes played a significant role in material understanding and in fostering creativity. Through tinkering and iteration, a sort of intimacy was established between the DIY material and the student. This peculiar intimacy facilitated the establishing of the pleasure of making and of an emotional bonding with the material that led to unique and meaningful results, which have their strength in their subjectivity and originality.
Figure 4. “Frangile” is a set of edible materials based on basic ingredients, like starch and sugar, enriched with flavors obtained by adding spices or food. Because of its fragility and edibility, it can be used as a temporary object in the food industry. By Patrizia Calcagno, Martina Carraro, and Francesca Pucciarini, 2015.

Figure 5. “Rosae” is a set of natural materials produced with different techniques coming from different cultures, as the Persian sugar crystallization, to obtain a precious and timeless aesthetic. Their appearance and surfaces are similar to stone, diamonds, and crystal. By Mona Khajavi, Alessandro Pampuri, Giulio Tedeschi, and Rui Zhang, 2015.
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Based on this pilot experience, in 2016, the teaching staff organized a course of the length of a full semester. The second edition of the course was named “Designing Materials Experiences” and involved 98 students from the Master’s level, from 32 nationalities, divided in groups of 4 members. The course had a structure similar to the one before, but in a larger timespan. This allowed to focus on the Material Tinkering phase, which lasted around two months. The insights from the previous course allowed to optimize the process and to develop useful tools to facilitate Material Tinkering. These are described in the discussion. Some guests from other universities and from the professional field were invited to take lectures and seminars, consolidating a network of experts on materials design. A dedicated theoretical and practical contribution on sensorial and tactual experience was integrated in the course and projects workflow, through a lecture and practical exercises. This was fundamental in the scope of the projects and contributed in the practice of tinkering for experiential learning and in the development of the vision. As a result, 25 experimental materials were developed and presented through a set of samples, an application into a concept of product, a poster, a video, a diary describing the experimentation process and the material’s journey, and communication materials, like booklets, brochures, and postcards. Some of the most promising materials from the two editions were undertaken in the procedures to obtain patents and caught the interest of some companies to make further development and to reach technical feasibility. Other were showcased in some exhibitions or were developed further by the students themselves.

Figure 6. “Fluff” is a material based on bioplastic and waste fibers. By Eileen Kruger, Valeria Mundo, Setareh Salehi, and Juuso Koski, 2016.

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3 The teaching staff was composed by: Valentina Rognoli, as course leader; Stefano Parisi and Camilo Ayala Garcia, as teaching assistants.
4 At Politecnico di Milano, School of Design, elective course at a Master’s level, Academic Year 2016/2017.
5 Carlo Santulli, professor and expert on bio-plastics and biomimesis from the School of Architecture and Design of the University of Camerino; Valérie Bergeron, materials library manager of Materfad, Materials centre in Barcelona; Gabriele Carbone from the IMMAGINE Lab of the School of Design of Politecnico di Milano.
6 Marieke Sonneveld, professor from the Department of Industrial Design Engineering of TU Delft, held this didactic activity.
7 “Design X Designers 2016”, at Politecnico di Milano, School of Design, Milano, 6th April 2016 – 27th April 2016; “BB Construmat 2017” fair in partnership with Materfad, FAD, in Barcelona, 23rd May 2017 – 26th May 2017.
Figure 7. “Midas” is a material made from used cigarettes. By Quentin Fedrizzi, Tahmineh Setoodeh, Tina Jochens, and Media Hosseini, 2016.

Figure 8. “Marbile” is a material based on waste textile fibers. By Ioanna Oikonomou, Marina Psimikaki, Yang Yudan, Marta Siminska, 2016.
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Figure 9. “It’s never too Lat(t)e” is a bioplastic based on rotten milk. By Dicle Aslan, Dinullah Ibrahim, Shao Yizhuo, and Unal Betul, 2016.

5. Discussion

This educational experience was fundamental to test tinkering in the scope of materials understanding, exploration and design, and to understand its relationship with envisioning and its contribution to the whole design process. Furthermore, according to the results and the insights from the course we had the possibility to learn how to improve the management of the tinkering process for further didactic activities. In particular, three main goals emerged:

- make the tinkering process more intuitive and approachable for students;
- foster creativity and provide inspirations for materials understanding and experimentation;
- uniform the research tools and the results for facilitating students and for disseminations.

All these goals should be satisfied considering the issue of not losing flexibility, personalization and students’ personal initiative that characterize tinkering.

Thus, the necessity of creating a set of guidelines in the form or rules, toolkits or methodologies for tinkering arises. These could help students to find inspiration when they lack in creativity, e.g. proposing ingredients or source of inspiration such as trans-disciplinary techniques. They could also explain how to deal with mistakes and with serendipity as a strategy for creativity. They may establish rules related to safety issues and suggest ways of recording and documenting advancements.
A set of molds for samples’ production could be developed to assist students and to provide a format for the creation of a materials library or the installation of an exhibition. These molds could be thought as versatile tools to easily personalized operating with 3D modeling software and rapid prototyping. Plus, they could offer the possibility to reproduce different sensorial qualities on the material’s surface, e.g. touch qualities like texture and roughness.

From the first edition of the course, the teaching staff designed a template to facilitate students in communicating their materials and used it for the second edition of the course. Students had to fill the template with texts and images, providing a name for the material, its description, its properties, its sensorial qualities, its ingredients, its process, a slogan for storytelling, and the students contacts (Fig. 10).

Furthermore, tools for a correct material assessment through tinkering may be developed taking as inspiration the Expressive-sensorial characteristics Atlas by Valentina Rognoli (2004; 2010) and the Sensorial evaluation scales by Elvin Karana (2009). The latter has been already adapted in a template for the second edition of the course (Fig. 11). This template was a useful tool for students to assess their materials through the whole process of tinkering and development of the material, from the first experimentation to the final samples. The assessment regards the sensorial, affective, and interpretive levels of Materials Experience. In addition to a sensorial scale of qualities and properties, e.g. rough/smooth, matte/glossy, fragile/resistant, two open questions are asked to arise reflections on the emotions, feelings, memories, and meanings evoked by the materials.

Figure 10. Template designed by the teaching staff, 2016. Filled template’s examples: by Elena Sophia Di Giacinto, Gaetana Marzocchi, Lilach Pomerantz, and Xiao Ya, for “ReFruit”, a leather-like material based on fruit, 2016; and by Mikaella Chrysostomou, Ayasu Sani, Panayiota Vasileiadou, and Yang Xiaodan for “Veggie Pla”, a bioplastic material, 2016.
Conclusion

Concluding, through this paper, we introduced the practice of Material Tinkering in the scope of education. This approach is based on creative, direct, and iterative experimentations on materials. Next, we described its role in understanding materials and experimenting with them, its contribution in the whole design process and its relationship with envisioning and abstract conceptualization of Design thinking and with predominant design education approaches. After having considered its main theoretical foundations that are grounded in experiential learning, we argued that by integrating Material Tinkering with envisioning and abstract conceptualization it is possible to obtain richer and more complete projects. Sensoriality and tactual experience appear to be relevant to understand materials and to develop meaningful material experiences. As a case study, an educational course focused on Tinkering with DIY materials is addressed, describing the processes undertaken by students, the outcomes, and the insights. Through tinkering students appear to gain knowledge on their own materials, to acquire a sensitivity about sensorial, expressive, and experiential qualities of materials, and to establish an emotional relation with them. Learning from an iterative trials and errors process and unexpected results, students improved their materials and developed meaningful materials experience visions. Finally, the students’ material proposals emerged and were characterized by unique and subjective values and aesthetics. Observing and discussing the results, the need for defining a set of guidelines, templates, and tools to facilitate the materials tinkering process, to foster creativity, to enhance a profound and complete understanding and to promote disseminations of results has emerged. All these tools need to be further studied, developed, applied, and tested for the next edition of the course and generally for supporting the process of tinkering. Some of the tools and strategies were already tested in a second edition of the course.
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