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New Silk: Studying Experimental Touchpoints between Material Science, Synthetic Biology, Design and Art

This article presents a study in which new materials are developed through experimental knowledge construction and knowledge exchange between different disciplines. The New Silk research project (2017-2020) is the building block for the research. New Silk aims to produce new types of silk-like materials in the context of synthetic biology. In this article we discuss the initial experimental touchpoints between material science, synthetic biology, design and art encountered during the project's first year. Firstly, the study shows that shared material experiences in the setting of workshops build foundational understanding of perceived material agency leading to discussion on material activity and research ethics. Secondly, our research identified that all of these disciplines, material science, synthetic biology, design and art, approach materials research through experimental methods, even if the goal of the research differs in each discipline.

1 INTRODUCTION

Most new materials for designers' use are developed through a science-driven approach, meaning that scientific (mostly technical) innovation is commercialised (Ashby and Johnson 2002). In contrast, designers can bring in their design knowledge into a dialogue on material development by proposing material attributes needed in a certain product or production (e.g. Niinimäki et al. 2017). Moreover, designers can contribute their understanding of aesthetic or sensorial material qualities (Ashby and Johnson 2002). Karana (2009), in particular, has studied material experiences and how designers may include experiential aspects of materials in the product design phase. Designers can even play with and apply different production techniques to enhance material properties and characteristics, achieved through new production techniques in combination with new materials (e.g. Härkäsalmi et al. 2017). This more creative and even experimental knowledge adds to the technical qualities of new materials.

Materials research is attracting new attention from many corners, especially from a design point of view. Recently, artists and designers have increasingly started to explore and experiment with creating their own materials. These materials are either new combinations of existing materials or attempts to *grow* new materials that in one way or another create themselves (e.g. Thompson and Ling 2014, 203). The Eksig 2017 'Alive, Active and Adaptive' conference featured many such endeavours (Karana, Giaccardi, Nimmkulrat, Niedderer and Camere 2017). Materials that have a biological existence are alive and behave in unexpected ways. They can be controlled by the creator to a certain extent,

but the material displays an agency of its own. With these materials, the explorative approach is the only possible route until the creator gains enough experience to be able to start controlling the material and to design a use for it.

As part of recent general developments within materials research, multidisciplinary, or even interdisciplinary, collaboration is becoming more common. In multidisciplinary collaboration, partners stay in their own disciplinary knowledge areas. In interdisciplinary collaboration, real knowledge sharing or even knowledge co-producing is happening (Grix 2010). Designers and design researchers are invited to help materials researchers to develop attributes for materials or to find suitable application sectors for new materials. Through these endeavours, more experimental collaboration between disciplines is emerging. The biological production of materials is expected to be one of the key enablers of the future bio-economy, and designers have the possibility of playing a key role with this. Protein materials relying on recombinant DNA technology offer distinct advantages: when *designing molecular structures* for protein polymeric materials, the *properties can be tailored* according to the final applications. Even fibre requirements 'can be established in advance, and fibre created specifically to fulfil them. Thus, a fibre can be created to respond to changes in heat or light, to carry electronic information, to resist or retain moisture, to destroy odour-causing bacteria or exude a perfumed aroma, or to change surface colour and patterns under different conditions (O'Connor 2005, 46). Therefore, O'Connor (2005) argues that these new, active and powerful textile materials 'have contributed to new ways of thinking and being' (ibid., 54), which can be interpreted as meaning agency.

The interdisciplinary New Silk research project (2017-2020) aims to produce new types of silk-like materials

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CASE STUDY

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in the context of synthetic biology. The project is inspired by how spiders produce their silk – a material with properties that surpass existing synthetic materials. The New Silk project combines the knowledge of silk protein production with skills in polymer processing and the creative perspective of designers. The project’s aim is to open this new research path and to lay a foundation for this type of materials design, materials which are possible to produce in the distant future. Therefore this research is not yet even in the fuzzy-front end stage of the innovation process (Lee and Markham 2013) but in the very early stage of fundamental science.

The design research component in New Silk aims to construct new knowledge through an experimental approach, studying touchpoints between early-stage fundamental materials research, synthetic biology, design and even art. In this article we will first present key theoretical perspectives and then describe the case study and discuss topics that emerged in the interdisciplinary collaboration and material experimentations. We will then discuss the findings on a more general level, such as what these initial encounters could mean and where these initial touchpoints could take interdisciplinary materials research in the future.

1.1. Human-material interaction

The emerging interest in materials research and new ways of designing with materials have raised philosophical discussions on materials and their use. We are used to thinking of materials as resources that we master and utilise for our own purposes. We can control our material environment since we have the intelligence, power, skill and intentionality to do so. However, this hierarchy has been questioned recently with the advent of post-humanistic thought. New Materialism proposes a non-anthropocentric view of the human-material relationship that is more symmetrical and that suggests a more democratic proposition (Coole and Frost 2010, 10).

New Materialism theory puts forth the idea that even non-biological material has agency (Bolt 2007, 2013; Malafouris 2008). Through her concept of *vital materiality*, Jane Bennett (2010) proposes that materials are vibrant actants. According to Bennett (2011, viii) materials are capable of motility and change, to act on their own terms, not only through the activating force of a living agent such as human or animal will or intentionality. Thus, we must abandon our hierarchical attitude towards materials (Coole and Frost 2010; Bennett 2010) and accept materials as an equal force in creative action (Bolt 2007). Both Bennett (2010) and Malafouris (2008) describe human-material interaction as a collaboration rather than a utilisation, and Bennett (2010, 31) describes it as a ‘complicated dance that humanity and non-humanity perform with each other’. Having said that, it is understood that materials do not have intentionality or will in themselves, and that this agentic force of the material is our (human) perceived impression of the materials agentic activities. However, this perspective on materials as actants opens broader and more diverse discussions on our relationships, dependencies and responsibilities with and towards materiality in general. It also connects with specific discourses and ways of making sense in creative practises and the poetic language used in describing felt experiences. In particular, in cases where the material is

in fact ‘alive’ and active, these materials can produce effects and alter the course of events. Bennett (2010) argues that this grounding in positive ontology stretches our understanding of agency, action and freedom of matters and material. She furthers her argument by saying, ‘what issues would surround stem cell research in the absence of the assumption that the only source of vitality in matter is a soul or spirit’ (ibid., viii).

In designers’ experimentation with materials, previous material experiences and embodied knowing (Johnson, 2007) of material properties provide a basis for our understanding of new material experiences (Fredriksen 2014; Groth 2016, 2017). Experiential knowledge building with materials happens through bodily interactions with it, through sensorial, visual, haptic, auditive and olfactory experiences (Karana, Pedgley and Rognoli 2015; Ojala 2013; Shifferstein and Wastiels 2014; Zuo, Hope, Castle and Jones 2001). This is a sense-making process (Harrison 2000) that can be difficult to put into words, but it is to be taken as a knowledge-building process equal to the more explicit process of the scientist (Tin 2013).

In this material sense-making process, the artefact embodies part of the knowledge and displays this in concrete form (Mäkelä 2007; Niedderer 2012, 2013; Niedderer and Roworth-Stokes 2007). Art and design researchers typically work with and through material, exploring the material through its physical properties, its affordances and limitations (Gibson 1983, 1986). These are bodily, felt experiences that lead to new questions and propose new pathways for further experiments (Groth and Mäkelä 2016).

1.2. Experimental interdisciplinary approach

Designerly processes are experimental in nature, as the main goal is usually to create something new, something that did not exist previously. Designers’ processes are constructive, as knowledge is literally created through a *building* of concepts and material experimentation (Koskinen et al. 2011). Designers as well as artists are thus used to uncertainty and tie the solution or answer to a research problem, as this often aids in developing concepts and building further knowledge, reaching more developed and sophisticated results.

Although scientists have another epistemology and other traditions for their research processes on *what* something is or *how* something comes about, in the development of new materials they too are confronted with the unknown, with unexpected behaviour from the materials. We can only make predictions about new materials through our past experiences with them or with similar materials and experiences. Therefore, intensive material interaction and material exploration is the route by which we can construct knowledge in this context. In our interaction with materials, our understanding of the processes may be analysed based on the background knowledge of material research in other similar materials and chemistry, biology or even physics. Such a position forces the intersection of disciplines that have the potential to construct knowledge together, knowledge that would not be possible to achieve within the separate disciplines alone (Hennessy and Murphy 1999).

In this study, we explore how an experimental approach to collaboration can create touchpoints between disciplines. In the studied case, the focus is on these interdis-



ciplinary moments where different disciplines work together and share their own disciplinary practice and knowledge (constructed beforehand in a multidisciplinary manner) in an experimental workshop setting. In this way, dialogue between disciplines can take place. As Grix (2010, 99) points out, “the aim is not the knitting together of disciplines in a seamless mass of interpretations and explanations, but rather the sharing of insights, best practice and methods with other disciplines”. Grix argues that the need for an open mind is essential in interdisciplinarity, and that collaboration can even lead to cross-fertilisation in which a real overlapping of different perspectives can happen. In our study, participants from material science, synthetic biology, design and art collaborated and shared their experiences of the properties of a new material, a material yet to exist.

In our case, the phenomenon under study is the dialogue between disciplines. To set up the framework for the research of these interdisciplinary touchpoints, we organised two creative and exploratory workshops during the project’s first year. These two workshops provided the empirical evidence for this study. The data consists of field notes, video recordings and photographs from the workshops and feedback from the participants. Data were interpreted by descriptive analysis. A qualitative approach guided our inquiry in locating themes on our phenomena of interest. The following research questions guided our analysis of the data:

- What are the interdisciplinary touchpoints in this context?*
- What is the experienced material agency in this context?*

2.2. Workshop 1

The first workshop with material researchers and design students took place in June 2017. There were 23 participants: twelve design students, two chemistry students, eight researchers from material sciences and one design researcher. The main aims of the workshop were to familiarise the scientists with the designers’ mindset, and vice versa, and to observe how designers embrace synthetic biology without previous knowledge. The secondary aim was to gain understanding of what kind of collaborative activities would make sense in this context.

The one-day workshop was divided into two sessions: in the morning four material scientists gave 20-minute presentations on their field of expertise (*Biomimetics, Short introduction to polymers, Spider silk as a polymer, Recombinant protein production*). The afternoon consisted of two one-hour

2.1. Research design

This exploratory case study is based on two interdisciplinary design interventions, during which participatory observation took place, that have been analysed through descriptive data analysis. Yin (1994, 18) defines a case study as an empirical inquiry that focuses on a contemporary phenomenon in its real context. We expand this definition and bring the case into a design research context where a design intervention is made through an interdisciplinary

assignments. To get started, the project leader (researcher in synthetic biology) presented the New Silk project. The presentation included micro-scale images of real spider silk and the artificial material with which the team is working. The artificial material seems to have a special characteristic: filaments formed by pulling can fuse to each other permanently. We asked: How do these molecules work, and how does this behaviour happen? What could future applications be, e.g. adhesives, fibres? To conclude, the project leader pointed out the need for a new dimension of communicating between programmes and disciplines to get inspiration, stating that research is all about inspiration and how to look at things from new angles.

In the first task, introduced by the workshop facilitator (designer), participants were asked to explore the new material by playing with modelling clay (see Figure 1), which in its properties behaved similar to the original material. Participants were encouraged to start working hands-on and use bodily exploration with the material. After a 15-minute hands-on session, participants wrote down their personal observations and reflections regarding the material, its properties and general insights. The most popular ways of working with the modelling clay were rolling bars, stretching thin filaments, pulling and flattening the material, twisting, ripping, braiding, layering and testing the stickiness of the material. The participants were active and attentive and continued discussing what they felt when touching, testing and playing with the material. While playing with the materials, they especially noted the effects of pulling, fusing, and stretching behaviour and how the material breaks.

For the second task, the participants were re-grouped into six teams. Each team consisted of 1 or 2 material scientists or chemistry students and several design students. Each team was handed an empty notebook containing one question. Three notebooks included question 1: *What kind of shared actions would support the New Silk Collaboration? (or find another question)* and the three other notebooks included question 2: *Where could New Silk concepts be applied? (or find another question)*. The teams were asked by the facilitator (designer) to discuss and reflect on the proposed questions freely. They were also encouraged to make other comments and propose other questions based on their conversations. Finally, the teams were asked to document their discussion results and reflections in the notebooks, and to present their ideas to the other teams. Playing with different scales (nano-micro-human scale) and creating conceptual design ideas arose in these reflections. Furthermore, the challenge of sharing knowledge between disciplines was identified as one important aspect in the collaboration. Some of the participants from the workshop are quoted as follows:

“Differences in fields – different form of knowledge.”

“Sharing knowledge from silk needs more simplifying, more to share and make understandable - also makes it interesting – the challenge!”

“How to overcome the abstract?”

Question 2 – Where could New Silk concepts be applied? – was given to three teams and resulted in a long list of potential applications. Due to biocompatibility, the material was seen to have great potential in medicine and health care, for example as bone replacements, replacements

for connective tissues or ligaments, or as plasters or stitches. As the material is expected to be light and durable, it could have applications in transportation or even in space travel. It could be sprayable and used as a glue or for adhering products. Textiles, garments, different kinds of flexible connectors, replacements for plastics and rubber, filters, films, thin optical fibres and construction applications were also mentioned. One team noted that the question of reusing and recycling the new material should also be taken into consideration.

At the end of the day, all participants were asked to anonymously write down one positive and one critical comment about the workshop on separate post-its. The most positive issue seemed to be the inspiring encounter with new people from different disciplines. Several participants mentioned that they had gleaned completely new information and learned a lot about the materials and materials research in general.

“It has been really interesting to hear and talk to people doing something completely different.”

“I think that the biggest positive message for myself was to consider more collaborations outside the science field.”

“I got to know a new material, some of its properties. It also inspires me a lot and brings back my creativity.”

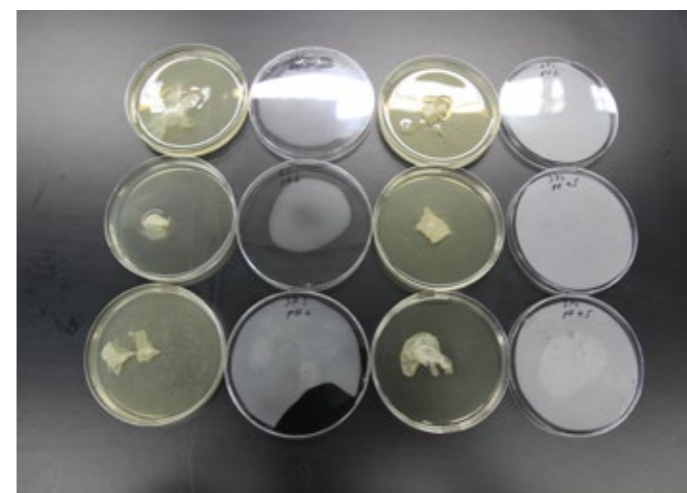
“Interesting new ideas to develop.”

Critical feedback was mainly related to the lack of time and the difficulty of absorbing and understanding so much new information in a very short time. The fact that the real, tangible material samples were missing, as these were still under development, and the experiment with modelling clay were found to be both inspiring and confusing. One participant said, ‘The modelling clay experimenting made me more confused... I understand the material as sticky threads...’ Another said, ‘It would have been nice to see a new silk material sample.’

2.3. Workshop 2

The second experimental workshop was organised internally for the research consortium in collaboration with a bio-artist in November 2017. The two-day workshop took place in Biofilia, a special lab for bio-art at Aalto University. The participating team consisted of two designers and seven material scientists. The topic was to explore the growing of microbial cellulose in the context of art, outside the scientific environment. The workshop programme was planned by the bio-artist. The main aims were to familiarise scientists with artists’ working methods and to explore potential touchpoints between art and material science, especially in the New Silk project.

The workshop began with a short introduction of all participants and continued with three lectures: a general project presentation by the project leader (professor in synthetic biology), a presentation on the molecular visualisation of silk proteins (scientist) and a presentation by the workshop leader (artist). The next step was to familiarise the participants with the material itself through the hands-on, bodily experience of touching and feeling microbial cellulose (see Figure 2). Participants were blindfolded when touching the



←← Figure 1: One result from participants playing with modelling clay and exploring the material’s behaviour. Photo by the researchers.

↑ Figure 2: How does microbial cellulose feel? Blindfolded familiarisation with microbial cellulose. Photo by the researchers.

→ Figure 3: Preparing microbial cellulose sheets for drying tests. Photo by the researchers.

← Figure 4: Second day results: the miracle of growth. Photo by the researchers.

Participants	Roles	Activities	Results
12 Design students	Workshop participants	Presentations	Imagining how future materials could behave
2 Chemistry students	Workshop participants	Playing with modelling clay	Possible application sectors for this new material yet to exist
8 Material researchers	Presenters Workshop participants	Written individual reflection	
1 Designer	Facilitator	Group brainstorming	

Table 1. Participants in workshop 1, their roles and activities, workshop results.

Participants	Role	Activities	Results
1 Bio-artist	Presenter Facilitator	Presentations	Discussions on:
7 Material researchers	Presenters Participants	Exploring living organisms	1) research ethics while working with "living" materials
2 Designers	Participants	Microbial cellulose growing experiment	2) disciplinary practices
		Discussions	3) interdisciplinary touchpoints

Table 2. Participants in workshop 2, their roles and activities, workshop results.

Experimental approach with new, active materials			
Discipline	Design	Material science Synthetic biology	Art
Focus	Material properties	Material activity (and technical qualities)	Artistic expression
Interest	What the application areas are	What it can do	What it expresses or what it is
Perceived material agency	Design ethics	Assembly options	Representations or How it grows

Table 3. Experimental approach in materials research.

material for the first time, and the team agreed afterwards that the physical experience was strong.

“It was not as slimy as I thought.” (Material science)

“I know this material and when it is white in colour, it is no problem to touch it. This was off-white and the colour is very skin-like, and the colour changes the experience.” (Design)

“It had the same texture as the human body, skin or flesh.” (Design)

“I had a strong feeling of leather, like touching a horse.” (Material science)

“It was disgusting, I had a very strong association of the material being alive.” (Design)

“I expected it to be softer, but it was so hard, you had an association with skin.” (Material science)

“When it was folded I didn’t know where it started and where it ended.” (Design)

The afternoon session focused on preparing the cultures and discussing lab versus DIY protocols, mould protection and culture inoculation. The first day ended with a feedback session during which experiences were discussed. The material being alive and active was an interesting topic and raised intense discussion on research ethics, artificial food, mimicking flesh and taking care of the material.

“I felt that I have to take care of it and warm it.” (Design)

The artist who usually works with this material explained:

“Yes, I feel that I have a relationship with something that is alive. I have to take care of it and, for example, when I am travelling, I have to make preparations, not like with a dog, but anyway, I have to take care of it.” (Art)

The second day also started with a discussion, this time with a specific question: What is the biggest challenge in your research? Each participant wrote a sentence, each of which were discussed individually, to give space for everyone’s personal thoughts. Time and resource limitations and management, communication, accuracy, uncertainty of what went wrong, and how to formulate the right questions were mentioned as the general challenges. One of the participants said, “The most challenging [thing] in my research is to formulate good questions to be able to address significant problems in an approachable way” (Material science). Another participant said, “Uncertainty of what went wrong, if something went wrong” (Material science).

Philosophical discussions about research ethics continued. Is the material alive? What is alive, what is dead? Do microbes have gender? If the material is alive, does it have a will? Does it have agency? Are we allowed to study this material? Is the New Silk method the most sustainable way to produce new materials? Are we doing the right thing? There were no clear answers, but the opportunity to discuss these topics in an interdisciplinary team was eye-opening. After agreeing upon the importance of mistakes in research and life, it was time to go back to the laboratory to observe and analyse how the growing of the material proceeded and if it was succeeding (see Figure 4).

The day ended in an artistic way: instead of written feedback, the participants were asked to visualise their experiences on paper. Other feedback was collected afterwards through a digital survey. Discussions between people from

different disciplines, learning about bio-art and bacterial cellulose, and art + science interaction were mentioned as the most interesting experiences. One of the participants said, “The most interesting and probably most valuable [thing] was the glimpse into a completely different perspective of materials and science in general” (Material science).

Material experimentations through imagination are challenging if the actual material does not yet exist. This could be seen in the reflections from the first workshop. This is especially challenging for designers, who need physical experience and embodied knowledge to deeply understand the material’s properties, affordances and perceived agency. On the other hand, it was interesting to note that by playing with substitute material, it was possible to understand the actions of this new material, the material to exist. Experiences with materials were led by bodily actions, as our documentation shows pulling, flattening, twisting, ripping and layering the modelling clay. An understanding of material properties and especially material agency was sought in order to move from an abstract to a concrete level, from material theory to design practice. By physically playing with and replicating the material actions, the participants could create a mental image of New Silk (the material yet to exist) and transfer this understanding to other scales (from nano to the human scale). This was an important knowledge transformation process through which participants could understand the future material through embodied experiences with substitute material and transform this embodied experience into ideas about possible application sectors (design expertise). The perceived material agency was the event here in which activities that the material performs under a microscope and on a nano level were ‘imagined’ through embodied encounters with the substitute material. Through bodily interactions, through playing with material, experiential knowledge was constructed: how the future material can act on a nano scale and what the modelling clay can ‘tell’ us about this future material. As Norman (1993, 49) argues, “representations are important because they allow us to work with events and things absent in space and time, or for that matter, events and things that never existed - imaginary objects and concepts”. He further argues that representations can ground an ‘idea’ through which we can think (we think through representations). Through this knowledge-making action we can ‘discover higher-order relationships, structures, and consistencies’, and we can better understand a particular phenomenon (ibid.).

In the second workshop, the strong tactile experiences created emotional associations of the material being alive. This led to discussions on research ethics and a strong association of the material possessing agency. Does this material have a will of its own, and what are we allowed to do with it? Can we modify it and do we have a right to design it? These associations take the designer closer to generic engineering. The question of material agency in

these experimentations provided no answers. Instead, the experiments pointed towards future research paths to follow. One important question is how we can produce and design material if it is alive, if it has a “will” or goals of its own. Moreover, what are the ethical issues regarding synthetic biology, and how should designers deal with them?

In the second workshop, the scientists were curious about the artist’s work, and the team had several discussions comparing the approach and procedures in art and in science. Disciplinary practices were compared in this manner and the discussions reflected interdisciplinary sharing. In this knowledge-sharing process, physical experimentations with the material helped the discussion to evolve. All participants agreed there are some touchpoints between these disciplines. Interestingly, the experimental approach, a trial and error type of research strategy, was obvious in all disciplines. The importance of learning from mistakes while creating something new, and even when doing science, was recognised. In design research, experimentation and design interventions are conducted to push boundaries and to explore alternatives, which leads to integration of making/experimenting and theorising (Redström 2017).

We argue that two topics emerged as the most interesting ones from these collaborations: perceived material agency and an experimental research strategy (see Table 3). Based on our empirical data we argue that all areas, design, material science (synthetic biology) and art, use an experimental approach in materials research, yet the interest of the inquiry differs in each discipline. Firstly, in material science the foundational investment in how the materials function and, especially in the New Silk project, how two different materials (with different DNA) affect each other or even blend together, is the focus of the research. Moreover, materials researchers study how these materials’ activities can be ‘designed’.

As the leading material scientist pointed out after the workshop, genetic engineering is needed to create materials the way they are done in nature. He added, ‘Next we need to know a lot about how the actual materials are formed using the building blocks produced by the microbes. This “assembly process” is actually very demanding, as it requires combining a lot of different fields such as polymer physics, material science and biochemistry.’

Secondly, in the discipline of design, material properties and the application sectors are central. Even if the material does not yet exist (it is still a material scientist’s dream), designers imagine the material properties and ‘envision’ their possible (sometimes even utopian) application areas. In the context of design, the core question will be: what are the ethical implications of designing with live materials, do we design for or *with* the materials, and who is in control of the process? Through the recognition of perceived material agency, aspects of design ethics enter the discussion. This requires further study.

Thirdly, artists explore materials as expressive media which they can use to support their own artistic intention and they select materials according to what the materials can represent. ‘Relationships’ are created with materials, especially when the material is alive and active or has human connotations or attributes. The motility and

growing of these materials further strengthens the association of material agency or anthropological and animate features of materials. Bodily interaction with the material helps in reflecting on it more concretely, on a more fundamental level rather than only visual or conceptual explorations. These intuitive reflections support the connection to the new materiality theory in the initial stage of ideation or in the creative processes, and therefore a more pragmatic approach may be useful later at the actual product development stage.

4 CONCLUSIONS

This study aimed to find new perspectives and interdisciplinary touchpoints between materials research, synthetic biology, design and art. Interestingly all these areas use experimental approaches to knowledge building. This is especially so when the material research process is in the initial phase of development.

Ashby and Johnson (2002) point out that all materials have intrinsic qualities, but some are easier to identify than others. They argue that designers can demonstrate and exploit these qualities in the product design phase. Perhaps designing needed attributes and intrinsic qualities into new materials will be part of design work even more so in the future. In this development, it will also be important to engage more deeply in the understanding of perceived material agency, especially when designing in the context of synthetic biology. In this research context, we can advance our understanding of perceived material agency and explore this issue through imaginary materials. Moreover, in the future we might design not only material attributes but perhaps we must learn to ‘negotiate’ with these new engineered materials and their ‘will’ or behaviour.

During the coming years, we intend to monitor how these first interdisciplinary collaboration encounter advance while aiming to build new knowledge, knowledge that combines materials research with design knowledge, tactile with verbal knowledge and even ethics with practice. Through combining design-specific and scientific knowledge, it will be possible to create new materials that include not only technical attributes, but which also have strongly aesthetic and sensorial material qualities. These first workshops were mainly a starting point for a series of shared actions falling under the context of interdisciplinary material development. As one of the participants noted:

“Research is a process that takes a lot of time and the possible uses of the new materials in ‘real’ life can take many years” (Material science). Therefore, exploratory and experimental collaboration will continue.

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