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The Material Affinity of Design and Science for a Circular Economy

Miriam Ribul (University of the Arts London, UK),
Hanna de la Motte (Research Institutes of Sweden, SE)

Abstract

This paper presents a design and material science collaboration in a science laboratory for regenerated cellulose. The material affinity outlines how both disciplines are connected through a materials practice in communication and production of cellulose films. The outcome presents new transdisciplinary approaches for design and science towards circularity of materials.

Introduction

This paper presents a design science collaboration at RISE Research Institutes of Sweden where a design researcher was a participant observer in a material science laboratory for regenerated cellulose. Design and science are connected through a materials practice, and by collaborations at the raw material stages of the lifecycle, a shared understanding of properties and behaviours may facilitate resourceful material circularity. The brief for the design residency was to explore how design and science can inform each other when working with regeneration of cellulose for a circular economy. To explore these questions, the design researcher was embedded in the laboratory work at RISE, documenting the scientific processes and introducing design tools into the scientific environment. The collaboration has lead to identifying that the exploration of a comparable material process in design and science can develop connected approaches in both disciplines. This was explored through making regenerated cellulose films in the science laboratory and bio-plastic films in a design studio lab. This paper proposes how material processes for design and science can evolve to establish a transdisciplinary practice for a circular economy.

A definition of the material affinity will outline how both disciplines explore materials with their hands. Key approaches to materials experimentation in both disciplines emerged from the lab work and studio practice. The outline of these approaches for each discipline will link to processes and tools for material experiments. The use of different language will demonstrate how this can create barriers and innovation in this context. A final map will field two new areas for design and science in a materials context.

Design and Material Science

The connection of design and technical science in a circular economy is that both develop their work through working with materials with their hands. According to Sawyer, both are connected through experimentation and creativity, and a will to create beautiful outcomes (2002). While scientists explore materials from the molecular level, designers work with the material properties that are perceived through the senses (Karana *et al*., 2014). The Encyclopaedia Britannica (Chisholm, 1911) definition of a chemical affinity is 'the property or relation in virtue of which dissimilar substances are capable of entering into chemical combination with each other.' As analogy, a material affinity defines how design and science can collaborate in a circular economy as they are connected through a materials practice. This was explored during a residency at RISE Research Institutes of Sweden, where the design researcher collaborated with the technical scientist to explore the scientific processes involved in the regeneration of cellulose. This paper maps how both disciplines work with materials, and proposes a model for a material affinity of the disciplines for a circular economy.

In a take-make-dispose linear system for textiles, recycling occurs at the end of the lifecycle and is disconnected from the material selection in the design stage. In Vezzoli's Life Cycle Design approach (2014), design considers the impacts of material selection for a product at the beginning of the lifecycle. In the Ellen MacArthur Foundation definition of a circular economy, materials at the end of their life are reinvested in a new loop (2014). This provides the need for material science and design to collaborate. There are other relevant stages for design-science to interact in a material lifecycle such as retail, distribution and use which connect to services, business models and consumer behaviour, however material science and design are linked through what is described by the Science Community Representing Education (SCOR) as practical work with materials (2008). The technical scientist who develops methods for closed loop material recycling at the end of life and the designer who selects a material at the beginning of the lifecycle are both connected through working with the same material, however with different aims.

This can be related to a question of scale, as described by Oxman (2016), '*The way we view our environment, and interact within it, is ultimately dependent on the lens through which we choose to see it. Choosing is no innocent act. A material scientist will generally explore the physical composition of matter through the lens of properties. A biologist, however, looks at the world not through the lens of properties, but rather through the lens of function. Both live in the same reality, but experience it altogether differently, and therefore act upon it in a singular way. If they could see both views simultaneously, they would link properties and behaviors*.' Ito (2016) argues for *'antidisciplinary'* approaches that '*move beyond "many sciences"–a complex mosaic of so many different disciplines that often we don't recognize when we are looking at the same problem because our language is so different and our microscopes are set so differently*."

According to Ito (2016) and Oxman (2016), design and science are located opposite each other in a coordinate plate. In these, design and science connect through art or engineering. Brown *et al.* (nd) explain how the exploration of a design science practice goes back to Buckminster Fuller's work in 1927 and Cross (2011) argues how efforts to bring design closer to the scientific method were unsuccessful.

Karana *et al.* have listed a range of projects that support collaboration between these disciplines, however designers are still evaluating how to move in the scientific domain (2015). Collaboration is a key word of our time to approach complexity where systemic change is what Rittel and Webber defined a wicked problem (1973). Increased funding pressure, large scale projects and competitiveness require efficient communication between disciplines for an immediate impact on environmental concerns. As both design and material science work with materials, we need to develop a connected practice for both disciplines in what Drazin calls 'material transformations' (2015) at each stage along the material lifecycle.

Material Approaches

Film-making

The residency at RISE Research Institutes of Sweden was split into two parts: one for observation and one for action within the science laboratory. However, the design role in this context varied from observation to action, and no linear separation of stages can be made. According to Reason and Bradbury, the methodology of cooperative inquiry in participatory design outlines that inquiries can be linear, Apollonian, or Dionysian, taking a ‘more imaginal, expressive, spiralling, diffuse, impromptu and tacit approach to the interplay between making sense and action’ (2006). Due to the context of the research where the outcomes were not defined and the approach was open (Muratovski, 2016), a Dionysian approach was chosen. According to Ito (2016), a participatory observer is part of a wider complex system and cannot describe the process in a linear way. The residency provided many potential outcomes for design and science collaboration. However, two main categories crystalised: the first is communication of materials, comprising language and presentation, the second is production or making of materials.

For the development of a practice that considers both design and science, regenerated cellulosic film materials were chosen for the analysis of processes in each discipline for the following reasons: both require similar processes for making in the science lab and design lab, as opposed to regeneration by dissolution and spinning processes that can not be replicated in a design studio due to technical requirements; the science collaborator noted how regenerated cellulose films and bio-plastic films have similar properties and can be achieved in both the design and science lab; the film material does not need a context for a specific product at this stage, and invites an experimental approach in both disciplines. Scientific research in cellulose films has been completed (Sundberg *et al.* 2013, Hameed 2009) and film making is also explored as a material process in design projects (Ribul, 2013; Lee no date; Nijkamp 2012). An initial exploration of cellulose films in the science lab supported a ‘quick prototyping’ approach where the scientist and colleagues were involved in exploring a new ‘recipe’ while the designer introduced design techniques into the laboratory.

The work in the science laboratory evidenced how design and science follow similar approaches of communication and production when working with materials, however at a different scale of materials and with different aims. This connects to Ingold’s two fields of anthropological enquiry of visual and material culture (2013): The former is apprehended through the senses, while the latter through making with materials. Table 1 and 2 compare general approaches of design and science in the practical exploration of cellulose films. The simplified structure is not to be considered in a linear way, as communication and production happen at several stages throughout the cellulose film making process. An equivalent to the scientific method for design does not exist, however the widely accepted design methodology of the double diamond developed by the Design Council can act as a useful framework for the design process (2005).

	Communication	
	Science	**Design**
Documentation	Lab book, excel, pictures, film clips, graphs and spectra, computing softwares	Sketch book, drawing, photography, visualisations, film, material samples, prototypes, descriptions, computing softwares
Communication and presentation	Conference presentations, scientific publications including data and method sharing for replication (retesting by others), internal and external reports	Visual format for presentations, press, web platforms, social media, exhibitions, films, animation, events and publications

Table 1: Communication approaches of design and science with cellulose films

	Production	
	Science	**Design**
Preparations	From observations, questions and problems to hypotheses, predictions and experimental plans	Sketch book, drawing, photography, visualisations, film, material samples, prototypes, descriptions, computing softwares
Techniques	Practical laboratory methods/settings and scientific instruments, computing and calculating methods	Practical design work through planning and making with design tools, textiles-specific techniques or development of new ones
Experimentation	Collection of data using the techniques, replication (iterations and recursions)	Sampling and prototyping using the techniques, iterations
Outcome	Correlations and regressions, conclusions (theories), products (such as different materials)	Process for design, visual outcome and product for use
Analysis and characterization	Data and product analysis, statistical analysis, external reviews	Analysis of experience of information and product by users

Table 2: Production approaches of design and science with cellulose films

The tables demonstrate how both disciplines follow parallel approaches in the development of practical work with materials in communication and production. According to Sawyer, the scientist aims to create outcomes that are clear, well communicated and presented (2002) and the collaboration evidenced how tools and language differ to design. Peralta and Moultrie have analysed how science explores a hypothesis of reality in the properties of materials, while design follows a vision for what could be (2010). To achieve results, both require what the Wikipedia definition of the scientific method outlines as intelligence, imagination and creativity (no date).

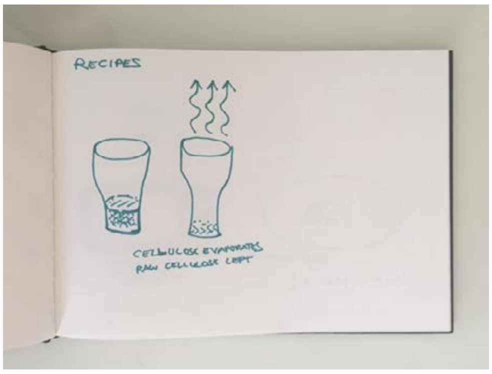
Cellulose films can be produced with shortened cellulosic fibres that are obtained from used cellulosic fibres, therefore link to the circular economy through providing a system for recycling at a later stage in the material lifecycle. Current research by Ma *et al.* (2015) and Östlund *et al.* (2015) into creating high value textiles by regeneration of cellulose fibres are reliant on a production model based on fibres, yarns, textiles and products, and a process where science has to go through engineered yarn technologies to design. This corresponds to Oxman's argument (2016) that science goes to design through engineering. To explore practice-based research that connects design and science without going through engineering, films provided a material process that connects both disciplines. Cross states that design knowledge is acquired through reflective practice, however in order for disciplines to collaborate it is beneficial to find a way to communicate this practice to the scientific method (2001). When working with cellulose films, what we explore is transdisciplinary, or as per Antonelli's definition 'knotty' (2015) as we require knowledge from different disciplines. This implies the complexity of a designer working in a lab and of a scientist exploring design tools.

The residency lead to a low-tech approach to making bio-plastic films in an improvised design lab (Anonymous 2013) that is comparable to processes for making cellulose films in the science laboratory. This ensured making was concerned with a similar material scale.

The inversion of design and science roles

The collaboration between design and science in the science laboratory lead to an inversion of roles. The designer observed processes of regeneration of cellulose in the science laboratory, finally producing a dissolution of regenerated cellulose. The designer introduced design tools into the scientific context of the laboratory: Sketchbooks, work sheets, prototypes and exhibition of samples. The scientist took lead when using the design tools provided for the collaboration. In a cooperative inquiry, where both the designer's and the scientist's questions were explored, the designer does not have the role of the facilitator.

A sketchbook was used to document the collaboration and communicate concepts between the designer and scientist. Both used this to write or draw during conversations. Differences in language can define scientific processes that can also be found in design, however the same words can have a different meaning in each discipline, leading to barriers in communication or innovation: For example, the discussion of an exploration of ‘films’ was introduced by the designer as a tool for communication, while the scientist described it as a material to explore production models. This lead to the collaborative exploration of regenerated cellulose films. For future design-science collaboration, selecting between communication or production can lead to a better understanding of the shared aims for the collaboration.



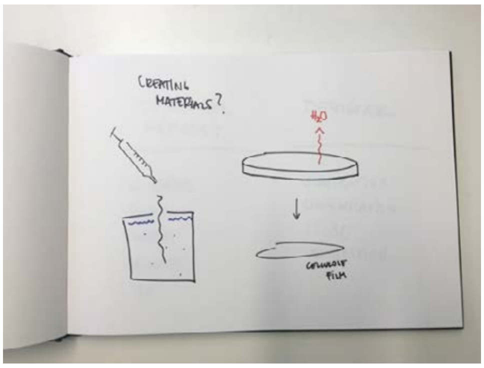


Figure 1 (left): Design sketch for communication of cellulose processes through film.
Figure 2 (right): Scientific sketch for production of cellulose films

Both disciplines encounter barriers to introducing new roles into a daily practice. The introduction of a sketchbook as used to visualise and present possibilities is an exception provided through the collaboration. A designer’s conventional practice is not linked to a science laboratory. Incremental changes to the practice were possible through the collaboration in the adaptation of tools from the other discipline: the scientist increased the use of images in scientific presentation slides, not to communicate results, however to engage a wider audience with a 3D representation of materials; the designer considered the scientific method in the production of material samples in the studio practice. This lead to expanded areas for communication and production for both design and science.

Figure 3 (left): Visual communication of cellulose dissolution in edited scientific microscope picture. Figure 4 (right): Cellulose film experiments in design studio

New Approaches for Design and Science

The residency evolved over a short period of time, and demonstrated initial results for how a collaboration of design and science can impact practical work with materials towards a material affinity. While design and science is often connected to the development of methodologies (Cross 2001, Brown *et al*. nd), according to Karana *et al.* there is no model for how these can inform each other through collaboration (2015). The practice described as 'antidisciplinary' (Ito 2014) or 'transdisciplinarity' (Lawrence and Deprés 2004), is one where individuals move fluently between disciplines such as design and science.

Figure 5 outlines the residency results in how design and science have informed each other's practice to lead to new approaches when working with regenerated cellulose films. While design follows a vision through its practice with the perceived qualities of materials at the macro scale of products in the first quadrant, science develops the scientific method through repeatable and tested processes starting at the material's micro scale in the third quadrant. For a closer connection of design and science in a circular economy, both designers and scientists have developed a transdisciplinary practice at a different scale of materials.

The design researcher has evolved an increased understanding of the scientific processes with regenerated cellulose, particularly through the scientific framework of materials and methods to create valid experiments that are repeatable and shareable. The understanding of the material at the micro scale provides a new input for design in a circular economy context: Design considers the scientific method through the development of valid material experiments in the fourth quadrant that are repeatable and tested to create material samples that can be up scaled and shared for a circular economy (Figure 5).

The scientist increased the understanding of the design processes for visualisation and communication of the material in a 3D format. Adopting a visual format in science will benefit a collaborative process, as it will provide designers with an increased understanding of the processes involved for recycling and end of life in a circular economy. Through images in presentations or through collaborations with designers to produce compelling prototypes, the new third quadrant for visual scientific communication can engage a wider audience (Figure 5).

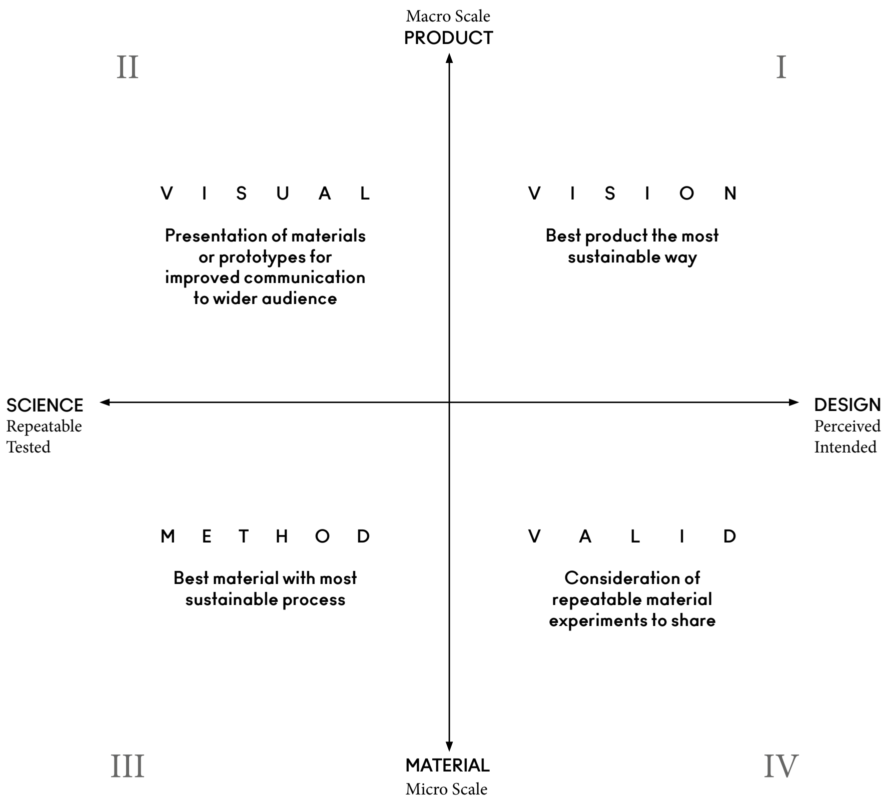


Figure 5: Design – Science Material Affinity diagram. Source: Ribul, 2016

The residency also highlighted a need for better communication informed by language. Both researchers have been working in cross-discipline collaboration before, and this supported the collaboration. Design and science differ in their development of methodology, and questions of explaining the design process for this context have emerged. Like in science, different materials and contexts require different approaches in design. How design and science can work together with materials will be further explored in future residencies, however the starting point is to develop an affinity of practice for a circular economy.

Conclusion

In this paper, we have outlined how design and science can develop new approaches for practical enquiry with materials for a circular economy. The collaboration has led to valid material experiments for the designer and visual approaches for the scientist for practical work with materials. While the designer in this collaboration has a keen interest in working with scientific processes of materials and the scientist is interested in exploring design processes, more work needs to be done to explore how both disciplines can effectively collaborate through the practice of materials to achieve a circular economy. It requires openness towards the development of new skills. Collaboration does not involve eliminating working in separate fields, as professional expertise in practical work in science as well as design are needed to achieve a circular economy. Time efficiency, distances between locations and funding are other barriers for collaboration. The luxury of exploration is to be balanced with results, however the freedom of un-linear approaches to collaboration can bring beneficial outcomes.

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