From ANT to Material agency: a design and science research workshop

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Abstract

This paper studies a design workshop that investigates complex collaboration between fundamental physics and design. Our research focuses on how students create original artefacts that bridge the gap between disciplines that have very little in common. Our goal is to study the micro-evolutions of their projects. Elaborating first on Actor Network Theory (Latour, 1996; 2005) we study how students' projects evolved over time and through a diversity of inputs and media. Throughout this longitudinal study, we use then a semiotic and pragmatic approach to observe three "aesthetical formations": translation, composition, and stabilization. These formations suggest that the question of material agency developed in the field of archeology and cognitive science (Knappett & Malafouris, 2008) need to be considered in the design field (Renon, 2016) to explain metamorphoses from the brief to the final realizations.

Keywords: Design Theory, Design Education, Pluridisciplinarity, Material Agency, Aesthetic Formation

Literature Review

The literature on sciences and design shows numerous collaborative programs (Cross, 1993, 2001 ; Bruffee, 1999; Stahl, 2006; Renon, 2015b, 2016). While interdisciplinarity is advocated by educational institutions and sustained by the analysis of professional design practices (Gentes, 2015) many students who are introduced to design multidisciplinarity are afraid of the vast array of disciplines that they should know and use. The question is how to train for an almost infinite set of knowledges? Is it even possible to do so or is it a myth? And how are students prepared to raise up to the challenge of not understanding the depth of other disciplines that they must work with? Some programs actually engage the students into scientific literacy with the usual argumentation as reported by Feinstein (2011): sciences are helpful even for students who do not intend to engage into a scientific career because they are part of a general education (Donnelly, 2006). Sciences are therefore part of a cultural heritage considered the literacy of contemporary humanists. Science literacy is also supposed to help people make better reasoning and therefore helps them better manage their lives. As far as design education is concerned, Findeli (2001) points out that design has been considered as an applied science. However, he remarks the impossibility of listing the infinite number of sciences that could be applied by design. Yet design also builds a relation to other sciences. In a first fieldwork (2016),

we studied a case of education where disciplines, that at first sight have nothing in common, were brought together. We wanted to better understand how design uses interdisciplinarity in a designerly way to produce new objects (Gentes, 2015, Tovey, 2015). The analysis showed that interdisciplinarity in design can be better understood if one looks at the properties of these situations and how they actively support invention. Five properties that framed the interdisciplinarity of design were discovered and analyzed: affective, cognitive, reflexive learning, economics, and political (Gentes, Renon & Bobroff, 2016). Elaborating on this research, we wanted to further understand interdisciplinarity in practice through the observation of material transformations during the design work. To do so, we used some of the methods and concepts of the Actor Network Theory (ANT) so as to pay special attention to the non-human actors that structure the designers' work. After presenting how we used the ANT and its methods, we describe the transformations at play through two use cases in detail. The analysis shows three operations that seem to be key to understanding the design practice: translation, composition, and stabilization. We suggest to call these operations: "aesthetic formations" so as to emphasize the aesthetics at play in the design work. In the discussion, we suggest that these "formations" are supported by a theory of material agency (Knappett & Malafouris, 2008; Renon, 2016) that we will try to develop after so and so.

Research Methods

Chain of transformations and Collaborative programs in Design & Science

The Actor-network Theory studies societies as collectives or networks (Latour, 1996; 2005) constituted by human and non-human actors in interaction. This theory takes into account objects and discourses, and the set of relationships and mediations that connects them. These relations are based on a series of translations or chains of transformations, which eventually constitute "the social". In the same way, the scientific fact is the result of a chain of transformations (instruments, articles, laboratory materials, subsidies, etc.) ANT tends to construe translation as a collaborative performance. Translation, by this account, is a communicative process in which actors inhabiting different social worlds enter into relations with each other, and begin to recast or reconstruct themselves, their interests and their worlds. The sociology of translation "takes the semiotic insight, that of the relationality of entities, the notion that they are produced in relations,and applies this ruthlessly to all materials – and not simply to those that are linguistic" (Law, 1999). Such relationships are not essential or given: they have to be made and maintained, or 'performed'. Law (2009) emphasized the openness, uncertainty and revisability of ANT-inspired Studies. He suggests that we talk of « materiel semiotics » rather than ANT. Elaborating on Law, Yaneva (2015) illustrated the potentials of an Actor-Network Theory (ANT) perspective to design, arguing that design triggers specific ways of enacting the social, understanding design's investigation as a type of connector, not as a separate cold domain of material relations. Rather than mobilizing the ANT as a strict theoretical framework, we propose, following Law (2009), Fenwick & Edwards (2010), and Fenwick (2011), to take ANT into account both as a tool for reflecting the interactions between humans and nonhumans, understood as spaces of transformation, and to analyze these transformation spaces by re-situating the materiality inherent in any production of design (Danholt, 2012).

Case study: an education program between design and physics

Since 2011, François Azambourg and Julien Bobroff have been organizing workshops called "Design and Research" for students of a school of design in Paris, ENSCI les Ateliers. The workshops investigate forms and materials in a design project. Fifteen to twenty design students at different stages of the design curriculum but with no specific qualification in science have attended these workshops. The workshop lasts four months. In addition to informal interactions, there are generally six formal presentations. The students also have a permanent co-working space to develop their projects. During the workshops, students are given outreach seminars by the physicist together with physics lab visits and open discussions about physics. Students are then asked to conceive a design project inspired by the scientific material. The challenge of the workshop is to work on tangible productions while starting from intangible concepts and notions from fundamental physics. Each year, the designers and the physicist choose a new theme: "Supraconductivity" in 2011, "Quantum physics" in 2013, and "Light and optics" in 2014. Productions are evaluated at the end of the workshop during a collective presentation and exhibition. They are also displayed on websites and further used in various outreach activities: exhibits in science museums, outreach talks, science fairs… In the spring of 2016, the workshop "Design and Research" was sub-titled: "Voir l' invisible" ("Catching the invisible"). Anne-Lyse Renon made an ethnographic observation during the four month of the workshop (March to June 2016), collecting 12 hours of video, 562 pictures and interviews and informal discussions. Out of the 13 projects done by the students in this session, we selected mainly two (A and B) for this paper so as to give a detailed analysis of productions and discourses. A proposed a game for children and B a pastry cosmology. C is also mentioned who designed a book for children. We chose to focus mainly on students A and B because they presented interesting differences in terms of production (A a tool, B a tangible typology), and were positively evaluated in terms of originality and seriousness of the design work by the designer and the scientist.

Workshops: description of inputs and transformations

Asking design students to work with fundamental physics seems like a particularly tough pedagogical and design challenge. This section looks at how tangible objects were produced while addressing fundamental physics, intangible by essence.

The physicist was the first to suggest a way to solve the paradox. While the subject title could very well be interpreted in mystical terms, the introductory lesson delimited the scope of the project by using a vocabulary coming from physics: "What does « see » mean at the atomic scale? How do we capture and manipulate phenomena at the Nano scale?" He emphasized the scientific standpoint by mentioning:

- human sight as well as the definition of "invisibility": the definitions were taken from biology and physics;
- tools: microscopes including the history of the instruments;
- recent scientific questions: the limitation of traditional microscopy (Richard Feynman) as well as the technical specificities of contemporary quantum microscopes.

Mostly, his presentation resolved the paradox of "Seeing the Invisible" through a history of

science. However, this resolution was not presented as the only way to address the paradox. The physicist and designers insisted that students would not be evaluated on their expertise in physics, yet they had to produce their own interpretation of what was at stake in the "invisible" within "the specificities of their own materials" (Designer François Azambourg).

The first lesson was followed by a session where students could manipulate scientific tools: magnifying glasses, lenses, mirrors, two or three traditional microscopes, small USB microscopes (which were connected to the computer), polarizers, flashlight, UV lamp and laser (e.g. Figure 1 & 2).

Figure 1. The physicist manipulating an optic refraction artefact and doing a demonstration to the student with the designer teacher on his left.

Figure 2. Students experimenting the different instruments and optical lenses and microscopes brought by the physicist

In this propaedeutic stage, students tackled the complexity of the paradox using different

strategies and heterogeneous materials. At first sight, it seems that none of the students were interested by the same things. However, at this stage of "exploration", we could observe two main postures: either, they isolated and circumscribed an artefact or a theme from the scientific world. Or, an artefact or a theme was the pretext to reach out to other worlds. For instance, student A used the session of manipulation as a stepping stone for her research since it was an occasion to identify tools and functions of microscopy, while student B chose the table of Mendeleev: "guided by the physician, I discovered the Mendeleev periodic table of the elements". For him, the starting point was more about building a taxonomy of matters than working about an optical phenomenon.

> B: "It was from there, on the confusion of the reigns, that I wanted to work, that is to say finally that in the aspect of the table of Mendeleev there is this confusion there since all the atoms create the infinite bodies of materials that are known "

Questioned about their choices, the two students evoked (A) childhood memories of playing with tools and exploring, or (B) their personal attraction for the sensuality and plasticity of matters. The starting point of their design work already put together science and personal experience: A chose a scenario of use where people would manipulate microscopes, and B focused on blending the elements of the classification table.

> A: "(...) I went (with a pedagogical association) (...) to *La Cité des Sciences* (The City of Sciences in Paris), and there I said "yeah, there you really have to do something for children, to play, etc."

Students also tried to find other connections and sources of inspiration through "auto-brainstorming" (student A). For instance, very early on, student B compared the table of Mendeleev to Indian ritualistic objects and this comparison later led him to introduce the notion of "activation". The first version of his project therefore changed in contact with another network of references. Student A remembered treasure hunts, "hiding things" that she loved doing as a kid. She compared it to more recent experiences with kids at *La Cité des Sciences* (a place devoted to sciences) and this helped her do her auto-brainstorming. Another student, C, mentioned science-fiction literature that she had read. She also questioned students doing their PhD in Sci-Fi to get more visual and narrative references. This literary design space conforted her into doing a book for children.

This practice of associations is completed by another type of activities that starts from materials and gestures. Student B expressed a pronounced taste for the manipulation of materials. He mentioned that he had a habit of collecting things with which he experimented. Materials were for him at the basis of design experimentations: "To start with, I wanted to invent an elementary paste. So, really from a design point of view, how we could actually recreate an assembly of materials that would be in the form of micro elements ... type of powder, etc. So things one can combine with a more or less equivalent granulometry and which together, depending on the mixtures used, can constitute a number of very different properties ". He investigates even further the principles of combination, by imagining a moving plasticity of materials: "I think my idea was to make something that could be in constant evolution, hence alive. "

A found not only a tool but a good material to investigate: the project "Foldscope". Designed

by Manu Prakash & Jim Cybulski in 2012, it is an open source microscope made of paper, downloadable in pdf, and hand-assembled with the addition of an optical lens). ” I just wanted to see how it works, and understand how to build it.” From there, she began an inquiry about optics and printed images, going successively from digital to analogical production of images in order to find a good way to change the scales of the details she wanted to show (e.g. Figure 3).

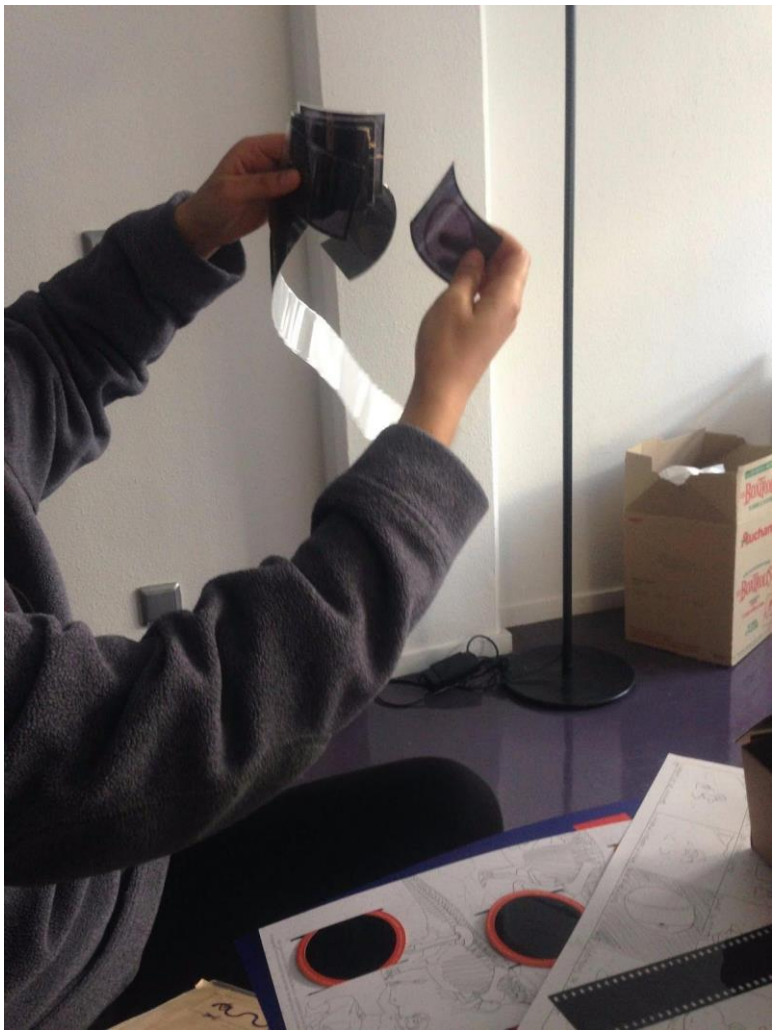

Figure 3. Student A handling different type of photographic films, comparing the transparency, the sharpness and the possibility to change the scale.

B wanted to embody complex notions in a device as simple and obvious as possible. But more importantly, he wanted to design for the senses so as to share his interest for physical experience with matter. He finally decided to explore taste because of the subjective and intimate as well as intensely physical experience. He chose food as a fieldwork to investigate: "This was the trigger: I told myself that in fact the food world was very interesting because there is all this faculty of mixing, food, ingredients to create different types of food with different ... tastes, textures. It was hyper global and at the same time hyper simple of apprehension since it was enough to eat it to understand. So it was from there that I said to

myself I will explain chemical links by making people eat them".

The tangible qualities were essential to build new “versions” (Béjean, Gentes, 2013) to answer the initial paradox. The design work consisted in finding material configurations by comparing properties, testing physical limits, and matching gestures with materials. Materials fought back and stopped the experimentations because of their own properties, their “requiredness” (Rosenthal & Visetti, 1999; Potter, 1980). The designers were surprised by the results that could be different from what they planned.

For example, through his use of materials B wished to change both the relation to a cooking recipe and the symbolic representation of the periodic classification (e.g. Figure 4). However, the implementation of the project was not without certain pitfalls, especially in the assembly of the elements, conditioned by their chemical composition and the properties adjoining their materiality. Hence, B selected 5 substances, which he tried to combine according to an experimental protocol. Since this assembly was not possible from one material to another, the productions finally presented were dictated by the possibilities and the resistances of the material. In the interview, B pointed out the “surprising combinations” of all natural elements and at the same time stressed that the “ chemical compositions [of these elements] are much closer than what first appears”.

Figure 4. the student B “pasty cosmology” as it was displayed at the final presentation, the cakes were tasted arranged in the Mendeleev table used as a tray.

For student B, the analogy with cooking goes beyond the mere pretext of production. From a chemical composition at the very beginning, he changes to an aesthetic composition.
The potentially infinite process of associations and configurations taking place at different moments was brought to a halt by the necessity of communication of the projects in formal presentations. We observe three stages of successive stabilization in the formation of composition: a first stabilization which is made by the choice of materials and their manipulation. Then from the relation between material properties and manipulation emerges an aesthetic stabilization, linked with the objective of a project rendering and the necessity of doing selections. And finally, the need for circulation leads to a final phase of stabilization which is a communication stabilization.

These presentations forced the students to choose a particular version of their project and to justify their choices. A went straight to a game and emphasized her scenario of use: to provide a microscope that would be a game for kids. The sobriety of manufacture she shaped found its origin in the will of student A to lead the project to an economy of means. The implementation of this playful microscope has thus taken a turn of popularization in the perspective of its concreteness, and the simplicity of its manufacture (e.g. Figure 5).

Figure 5. Display of the evolution from the original paper microscope (on the left) to the A first prototype including a new shape and a game .

Conversely, student B proposed to develop a "culinary nomenclature", in order to explore the complexity of variations and assemblages of edible matter in the manner of atomic transformations (e.g. Figure 6). His quote from Carl Sagan "*If you want to make an apple pie from scratch, you must first create the universe."* in some way contributed to the network of associations that creates the "Pastry Cosmology".

Figure 6. Detail of one of the combination for H2O, using biscuit for Hydrogen, and chocolate for Oxygen

Discussion

From the outset of the workshop, the students took (i) the lack knowledge and (ii) the notion of invisible, as a constraint of production. Two strategies emerged to tackle the paradox of "seeing the invisible".

Student A wanted to produce a popularization environment. Her idea was to take the scientific technical instrument (the microscope) and to explore the dimension of simulation, hence the tangible tool and the focus on its manipulation. This manipulation is made possible by the DIY construction process, which in turn simulates an appropriation of scientific and technical knowledge.

In the case of student B, the intuitively sought-for analogy between concepts in physics and their modalities of material transcription, proceeds from a symbolization. His work of transfer reveals a relation with the analogy of science to systems (Renon, 2015a; 2016). This "aesthetics of systems" (Burnham & Haacke, 1968), which is dear to conceptual art and to the processes of the "artificial sciences" (Simon, 1969), consists in finding a grammatical or even syntactic relationship between materials in order to construct a universal language close to the periodic table. For student B, understanding the periodic table of Mendeleev relies on an iconic transposition, term by term, or rather terms to materials. And these translation and composition take place through the constraints of the materials themselves, and their specificities, from abstract physics notions to design material production.

However, as we looked at the dynamics of the design workshop, we observed "composites" (Le Marec & Babou, 2003) that included living and non-living actors, symbolic and tangible material, personal memories and inputs from other designers and physicist but also operations of transformation. Elaborating on the concept of composites as heterogeneous semiotic

combinations, we observed how these combinations evolved all along the project but also changed initial meanings by cutting and relating elements in different ways.

The first "aesthetical formation" consisted of **translating and networking operations**. Students mixed elements of physics presented at the beginning of the project with personal memories, associating different worlds of references. This propaedeutic moment activated a network of knowledge pre-configuring how they were going to orient themselves. The presentation of the subject was already tacitly a way of setting up chains of transformations towards a project space. However, the translation in this case is not retro-active as in the case of a scientific activity studied in STS. Each "translation" produces a new version and also, as Gentes and Bejean showed in the case of a theater production (Gentes & Bejean, 2012), produces a new definition of the initial paradox. This aesthetical formation is therefore a chain of dynamic configurations where every element influences each other.

The second type of aesthetical formation consists in **composing** the "initial paradox" with tangible materials, as well as by gestures and the "manner" of each designer. While these were often chosen brought by the "translating" and "networking" formation, they also had their own logic and resisted the network, surprising their creator. These compositions were evolving because each material resisted, surprised not only by itself but new resistance and new material "behaviours" that appeared when they were brought together. The final video of student C is an illustration of this process of metamorphosis through composition (Figure. 7).

Figure 7. Screenshots of the process described by Student C,
from the first approach of the project till the final realisation.

This composing process which can be described as a field of tensions (Gentes 2017) sometimes reached a balance: what we suggest to call a **stabilizing formation**. Things seem to fall into place according to their authors. While most of the literature on design activity focuses on the fixation / defixation issue, we suggest that the design process can also be described as a quest for balance between heterogeneous elements. This balance between elements in tension fixes one version of the design work. Such states of stabilisation are obvious when students need to communicate about their projects during formal presentations. In that particular case, the stabilising formation is directly related to the necessity of social circulation of the project. However, it would be insufficient to attribute this stabilisation formation to the social circulation only. Students, and their supervisors, feel that a certain authenticity is achieved. The videos that give a view of the work process are often a dramaturgy of this goal. The denouement is presented as a refined process of choice, an elimination of useless elements, and an equilibrium reached by the designed artifact.

Conclusion

In the framework that we analyzed, designers tapped into their personal history and experience of other projects - in effect introducing even more facts into the project - to create new representations at the crossroads of disciplines but also letting matter speaks for itself in

compositions and eventually stabilized forms ready for circulation. The radicality of the experiment that we presented here lies in the fact that fundamental physics is intangible in essence and the starting point of the design project is therefore abstract. However, the designers took into account and invested the scientific material, which became both a tool and a function for exploration. The word “material” here does not simply point to what is tangible in the productions, nor is defined by a subject / object dichotomy. It is made of iconic, technical and semiotic dimensions, which constitute the “material agency” inherent in any design process. For Malafouris, “while agency and intentionality may not be properties of things, they are not properties of humans either: they are the properties of material engagement, that is, of the grey zone where brain, body and culture conflate” (Knappett & Malafouris, 2008). For us material agency in design is a combination of material engagement as developed by Knappett & Malafouris and the continuous aesthetical dynamic formation process between abstraction, symbolization and shaping process (Renon, 2016). To address the abstraction, it is particularly obvious that the design students constructed their projects between gesture and materiality. By focusing on the students experience, the concept of material agency therefore emerged not only as a grey zone where people and matters are engaged together but also as a "zone" where aesthetic formations take place that are at the heart of the design activity.

Here we can extend the ANT perspective so as to explain the combination of non-knowledge and experience. Even if ANT has been used to explain the design process in recent years, we think that the chains of transformations in the design process cannot be compared strictly to the scientific process. In the ANT perspective, the chains of transformations, from the experiment to the results, are described as fundamentally reversible and reproducible. One can go from the results back to the first observations et redo the experiments under the same conditions of reproducibility. But in a design process, the material agency includes the personal expression that is based in the networking practice of the designer and the resistance of materials while they are composed: shapes and matters talk back. The whole process is eventually not reversible because each “stage” transforms the meaning of the previous “composite” made of operations and matters. We therefore suggested to use the expression “aesthetical formations” so that we could represent the different qualities of these situated practices. First, we could see that they were part of a learning and appropriation process. Formation is here understood as “expansive learning”. The active form of the word “formation” also points to the fact that the design process is potentially an infinite semiotic process. In their evocation of the design process, students deployed an encyclopaedic network of associations. The situations eventually stabilized into certain combinations where they could finally circulate, triggering special emotions and experiences. We also qualified these formation as “aesthetical”. By that we wanted to reassert not only a personal, subjective experience but also as a cultural and historical situation, as well as a social space of communication.

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