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TEACHING AT BAUHAUS: IMPROVING DESIGN CAPACITIES OF CREATIVE PEOPLE? FROM MODULAR TO GENERIC CREATIVITY IN DESIGN-DRIVEN INNOVATION

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Abstract

In this paper we analyse teaching at Bauhaus (1919-1933), through the courses of Itten and Klee. We show that these courses not only aimed at teaching the styles. They aimed at increasing students creative design capacities and at providing them techniques to create their own style, in the sense of being able to be *generically* creative – ie be creative on as many languages as possible.
The analyses of the two courses leads to identify two critical features to get a generic creative design capacity: 1- A knowledge structure that is characterized by *non-determinism* and *non-independence*; 2- A genesis process that helps to progressively "superimpose" languages on the object in a robust way. These features are strongly different from the knowledge structure and design process of Engineering Systematic Design.
We finally show that these features actually correspond to two sufficient conditions for a mathematical model of sets to be "forced" (Cohen 1964) ie to lead to the creation of a new, extended model of sets that is *generically different from the original one* and still based on the law of this original one. This underlines the deep similarity between the logic of artistic creation and the logic of mathematical creation.

Introduction

Managing design-driven innovation may require improving creative design capacities. This can of course be done by hiring talented, recognized people. This can also be based on increasing the capacity of industrial designers – but how does one increase creative capacities of creative people? One can think of creativity methods, but they are more oriented towards "non professional" people (since they were initially developed for children). One exception is brainstorming, which is a method invented for creative people: it was developed by Osborn at the advertisement company BBDO; but its aim was more to improve the circulation of ideas than increase the number of ideas. And the succeeding psychological studies have shown that it actually tends to decrease the total number of ideas produced by a group of people (Mullen et al. 1991). In this paper we would like to investigate another path to know more about methods to increase creative capacities: namely some of the teaching methods used in industrial design schools, and more particularly at Bauhaus; if, as it often said, creativity is at the heart of industrial design, then some methods to improve creative design capacity might be at the heart of industrial design teaching. This is our initial intuitive motivation.

Still this motivation is slightly paradoxical inasmuch as teaching industrial design does not necessarily consists in increasing creative design capacity – it can also consist in learning new styles and new processes (drawing, molding,…). This is particularly striking in the case of Bauhaus, since Bauhaus was from time to time assimilated to a new style (functionalist) and one can be tempted to think that the school actually taught this functionalist style. So a first research question: did Bauhaus teaching really consist in teaching creative design methods (and theories) or did it rather consist in teaching a new "style"? (Q1)

Our research immediately raises a deeper question: what is a creative design capacity? Psychologists have proposed some measures of its effect (see Guilford criteria to characterize a distribution of ideas– fluency, diversity, originality of a set of ideas) (Guilford 1950). But is it possible to identify the capacities leading to such distributions? More recently, several works have underlined new forms of "bias" in creative design reasoning, leading to "fixation effects" (Jansson and Smith 1991), ie too narrow distributions. A design capacity can then correspond to the capacity to overcome fixations. Is it with more knowledge? Or maybe *less* knowledge, ie by inhibiting the immediate reuse of the most available knowledge? Is it through an association or combinative capacity (see serendipity)? Or else? Hence studying industrial design teaching should help us to learn more on some of these design capacities. Our second research question is: if Bauhaus consisted in teaching creative design capacity, then which type of capacity was it? (Q2) We will show that Bauhaus method has actually led to invent an original, specific form of creativity, "generic creativity", that can be distinguished from the usual modular creativity.

We briefly review the literature on the two questions (part 1), before presenting our method (part 2), our analysis on Bauhaus teaching (part 3) and the research results it led to (part 4).

Part 1: meaning creation in industrial design teaching

The tension between teaching meaning and teaching meaning creation

When looking at some points in the history of industrial design education, there are recurring tensions on what should be taught.

At the end of the nineteenth century, countries like Germany or the US decided to deeply reform their fine art teaching, in particular as a pragmatic consequence of the World Fairs where German products as well as American one exhibited poor quality (see reception of German products described by Reuleaux (Reuleaux 1877) and the poor reception of American applied arts at the 1889 Paris Exposition (Jaffee 2005)). It corresponded also to a more utopian focus on "art as an arena of social improvement" (Jaffee 2005) (p.41) an applied art as a way to recreate culture and communities in an industrial era {Schwartz, 1996 #2718}.

Fine art teaching is then reorganized, as in the Art Institute of Chicago and its School (Jaffee 2005). Jaffee explains that the basis of the new teaching is twofold: on the one hand, a "vigorous technical component" (ornamental design, woodcarving, frescoing, mosaic and stained glass) is added to the traditional fine arts offering (drawing, anatomy,etc.), in a tendency to address "all types of works of house decoration and industrial arts, including the "modern arts" of illustration and advertising"; on the other hand the teaching tended to be based on scientific principles: "many American educators believed that abstract laws or principles of arts existed which, once stabilized, would not only facilitate the production of art but raise it to a higher level" (Jaffee 2005) (p. 44), these principles ranging from Ross's works (Ross 1907) to develop a rational, scientific theory of the aesthetic of perception to Dow's principles of composition (Dow 1920).

For some professors like Sargent, a leading figure of design teaching at the University of Chicago Department of Arts, such a program could support the creation of new styles: "after the war, said Sargent in 1918 (cited by Jaffee), the United States will have to depend upon its own resources more than in the past, not only for designers but also for styles of design". But these methods were rather principles for addressing a higher, well-established, scientifically grounded "quality". Hence an ambiguity: industrial design teaching was not really addressing the creation of new styles but intended much more to teach students existing styles to enable them to improve product quality. As Jaffee concludes: the kind of teaching finally led to an extended vision of styles, as characterized in the famous book of Gardner, a former student of Sargent at University of Chicago, "Art through the ages" (Gardner 1936): Gardner presented a world panorama of styles, guided by the idea that "it was the universal values in design that made it possible for art to have a history" and providing clear methods for their appreciation and understanding.

Some years later, the tension between teaching style and teaching style creation is also at the heart of the debate that occurred at Ulm Hochschule für Gestaltung (Institute for Design) between the first director Max Bill and his successor Tomas Maldonado (Betts 1998): for Maldonado "Bill's venerable 'good form' itself become just another design style among many". Here again the idea was to avoid relying on past styles; rejecting art-based heritage, Maldonado insisted on the capacity of the designer to "coordinate in close collaboration with a large number of specialists, the most varied requirements of product fabrication and usage" (Maldonado 1960). Teaching had to be based on system analysis and the new product management; relying on Peirce semiotics and Max Bense teaching, the curriculum intended to "replace cultural judgement (taste, beauty, morality) with more scientific evaluation criteria" (Betts 1998) (p.79). As says Betts in a nutshell: Bill and his colleagues tried to "develop a critical theory of modern consumer culture untainted by Madison Avenue machinations" (p. 80), they look for a more "ethically-based critical semiotics" to address the relationship between people and (consumable) things". For Bense the issue was to "follow the lead of the modern physicist who studies the 'objective world' not by analysing its objects but rather its interactive semiotics effects" ((Bense 1956) cited by (Betts 1998) p. 79). Still this could also be interpreted as an extension of the logic of style to the interaction between the object and its environment. In the end of the 1960s, "even the supposedly anti-aesthetic ethos of functionalism had become just another supermarket style, as the Braun design story attested" (Betts 1998). Here again the tension between style teaching and teaching style creation was a critical issue.

Interestingly enough the extension from style to meaning also directly leads to the famous proposition of Klaus Krippendorff, graduated as diplom-designer from Ulm, that "design is making sense of things" or is a creation of meaning (Krippendorff 1989). But the paper of Krippendorff precisely exhibits the same tension: in the first part Krippendorff insists on the design ambition to be a capacity to create meaning – but in the second part (from p. 16) meaning creation is reduced to a referential of contexts (operational context, sociolinguistic context, context of genesis, ecological context) that an engineer would be ready to consider as a good list of functional requirements.

These elements give us two insights on the issue of design teaching:

1- over time there was a progressive extension from the design of objects (domestic objects, applied arts) to multiple objects (trademarks, advertisements, shopwindows,…) and to styles and meaning (new icons, symbols, signs, new forms of interaction between objects and people,… and even today "semiotic ideologies" (Keane 2003)). A similar evolution is actually visible in the historiography of design (Riccini 1998)).

2- Teaching styles (or meaning) is a source of tension between two approaches: teaching past and new styles or teaching style creation.

We can now better characterized this tension: teaching past and new styles can be characterized as teaching the values (engineers would say: the functional requirements) of existing styles and the ways and means to get it (mastering drawing, composition laws, material techniques such as woodcarving, frescoing, mosaic, stained glass…); style creation (or even: meaning creation) consists in creating an original culture, that encompasses new "objects" as well as new interactive receptions by people; hence a clear challenge for the new style, that has to be "significantly" original and new (break from past styles) and still has to be "meaningful" to the (occasionally lay) "user(s)" who should be enabled to "make sense" of the new related to the known. The new meaning is both *original (unique) and generic*, new and deeply related to all what is already known.

Which methods to teach meaning creation?

To get original genericity or generic originality requires some form of design creativity. It is today largely admitted that creative design is at the root of industrial design (Wang and Ilhan 2009; Dorst and Cross 2001). Still some authors wonder whether there might exist methods to learn this creative design (Dorst and Cross 2001). But recent studies have underlined that such methods were far from rare: for instance the very classical and largely diffused engineering design methods could be considered as a creative design process (Howard et al. 2008); and historical investigations have enlightened that the invention of new design theories and methods coincided with the new creativity challenges of their time (Le Masson and Weil 2012).

Recent works have provided advances in two different perspectives:

1- on the one hand, psychological approaches of creativity have helped to characterize creativity as the capacity to overcome fixations (Jansson and Smith 1991; Hatchuel et al. 2011), ie a tendancy to reuse the "most available" knowledge when designing. Interestingly enough, existing styles and meanings (icons, symbols, culture,…) can be considered as a very powerful source of fixation, be it for the designer himself or for the receiver(s) of an original designed object, who might be unable to design themselves (in a reflexive way) the object meaning (Gentes 2012).

2- on the other hand, design theories today help to better understand this creative design processes. In the perspective of General Design Theory (Yoshikawa 1981), creative design is a second-order concept generation that mixes two "base concepts" on the basis of the non-alignment, the *dissimilarity* between both ("powdered ketchup"). The creative concept resulting from that mix "inherits partial properties from both the two base concepts but is different from the two base concepts" (Taura and Nagai 2012). The authors define the concept generation based on this process as concept blending, echoing Fauconnier's works (Fauconnier and Turner 1998). In C-K theory (Hatchuel and Weil 2009) design creativity results from a knowledge expansion and the capacity to add to a concept (ie a proposition on a future thing that does not exist yet but is partially known) an attribute that is not immediately related to what is already known on this concept (eg "a cheaper and light camping chair [concept] without legs [unexpected, so called expanding, attribute]"); this attribute breaks the design rules that are usually used (namely "the chairs we know have legs").

In these perspectives, a creative design method should help to overcome some fixations created by the most available knowledge, and should be characterized by *specific knowledge structures* (eg two dissimilar ontologies in the case of GDT) and *specific processes* to create a new entity that break design rules.

In the case of meaning creation the tension between known and original is strongly increased since the new meaning should be different from previous ones – and hence break from highly complex and sophisticated ontologies (including all levels of semiotics)- but at the same time should also be related to these complex ontologies. In a nutshell: creative design consists in thinking out of the box (of design rules), while making use of these rules, creative design consists in *thinking out of the box from inside*; in the case of meaning, the box of rules is very large and generic, calling for *generic creativity*.

This provides us with a good analytical framework to study the methods used at Bauhaus to improve the designers capacities to create new meaning: What are the *knowledge structures* that help to be both *generically meaningful and generically original* and what are the *processes* that help to *improve the genericity of creativity*?

Part 2: The relevance of Bauhaus teaching for the study of generic creativity capacities

To study generic creativity and its method, we focus on Bauhaus courses. There are two reasons for that. As we will now explain: 1) style creation is at the root of the Bauhaus. 2) Bauhaus is famous for its formal, scientific teaching, which provides us with an impressive corpus to study the knowledge structure and design processes invented by some famous professors as Itten and Klee to meet the challenge of style creation.

Teaching style creation, a challenge at the roots of Bauhaus

The tension between teaching style (or teaching meaning) and teaching style creation (or meaning creation) was at the root of Bauhaus. This is shown by (Schwartz 1996) in his study of the German Werkbund, the melting pot of the debates that would later drive to Bauhaus. From 1890s onwards, the members of the Kunstgewerbe Bewegung and later the Werkbund (500 people at the Werbund creation in 1907, 2000 in 1914; among them Hermann Muthesius, Peter Behrens, Henry Van de Velde, Richard Riemerschmid, Werner Sombart,…) launched wide discussions and initiatives on German applied arts[1]. They reject the use of "historical styles" (as used in Fachverbände, professional associations) and promoted direct involvement of artists in production of objects of everydaylife, taking into account the industrial conditions of production and trade. The works of Peter Behrens at AEG clearly illustrate the contrast between the "historical style" approach and Werkbund one (see Figure 1 below). It also shows that designers like Behrens not only coped with objects but with the complete environment (AEG trademarks, retail shop windows, product catalogs,… and even the factory itself).

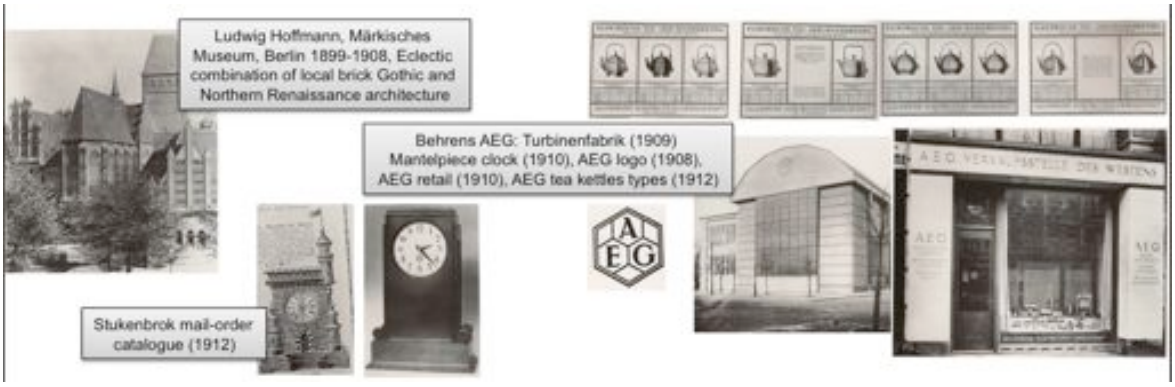

Figure 1: "historical styles" (Märkisches Museum and Stukenbrock clock) vs Behrens works at AEG in 1900s-1910s

As shown by Schwartz (Schwartz 1996), one of the great issue of Werkbund was to create "the style of our age", so-called "Sachlichkeit": "Sachlichkeit is NOT the aesthetic payoff of the functional form (and functionalism as such was widely discussed and rejected in the Werkbund); it is rather the avoidance of form as Fashion » (see Muthesius, 1902, Loos, the ornament as crime, 1910; and Gropius 1923). The expérience that many of the Werkbund members lived with Jugendstil was in all memories : Van de Velde, Riemerschmid and others had proposed a new style that was finally transformed into inconsistent fashionable ornaments (see Figure 2 below). In the social tensions created by the industrial revolutions in Germany, and following Tönnies works on the new Gemeinschaft (community) to counterbalance the complexity of contemporary Gesellschaft (society) or Sombart on Kunstgewerbe and Kultur, they wanted to organize to create a new style, ie a new culture and new communities through designed objects.

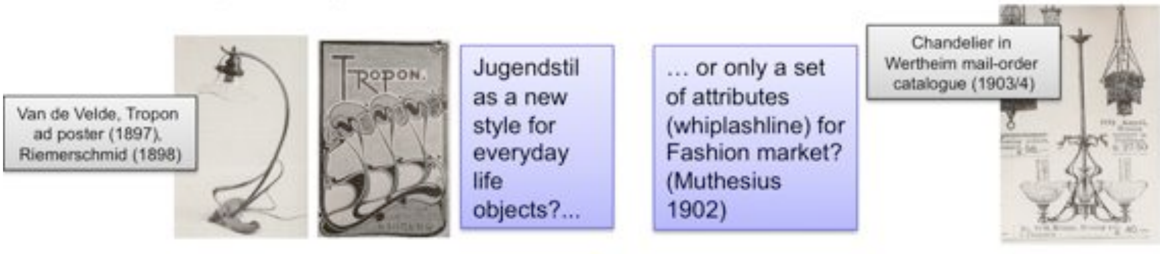

Figure 2: Jugendstil - inventing a new style… or just a fashionable ornament?

[1] They sponsored lectures, exhibitions (Köln 1914), publications (Werbund Jahrbücher), help to found a museum of applied arts, involved in Dürerbund-Werkbund Genossenschaft (publish a catalogue of exemplary mass-produced goods 1915), linked to Werkstättenbewegung (Riemerschmid, Naumann). In parallel they made strong effort on theoretical basis: Werkbund was a forum for discussion, with a wide cultural, economic, social and political audience

But once again this ambition was trapped in the debate between style and style creation. In 1914, the Werkbund was tired apart between Muthesius party of Typisiering, ie standardization of production and distribution of objects (protected by copyright) that would embody the new style, and Van de Velde (supported among others by Gropius and Osthaus), who advocated a free capacity for designers to create their own "style".

Werbund and the 1914 crisis laid the intellectual foundations of the Bauhaus: 1- the designer should not subordinate himself to the law of any style, nor should he just make use of motifs (like the Jugendstil ones) for designing fashionable products. 2- what has to be designed? Not a product, but a whole range of commodity products including trademarks, advertisement, shopwindows, catalogues… to create the "style of the age"; 3- this style creation is not reserved to happy few designers protected by copyrights or standardized but should be made accessible to many designers through teaching.

Itten and Klee courses

In this paper we won't address all aspects of Bauhaus teaching but will focus on the courses given by Klee and Itten. This quite formal corpus, often criticized to be too formal and "scientific" to meet the creativity challenges- will nevertheless provide strong elements for our research questions: improving the creative design capacities of the designers by improving his/her knowledge base (and learning capacities) and his/her design reasoning process.

Itten (1888 – 1967) was invited by Walter Gropius to teach at Bauhaus the introductory course, which he gave from 1919 to 1922 (hence the very first years of Bauhaus). He considered that "imagination and creative ability must first of all be liberated and strengthened" (hence a clear logic to overcome fixation effects) and he proposed to to this by providing specific knowledge on the "objective laws of form and color", with the idea that it would "help to strengthen a person's powers and to expand his creative gift" (Itten 1975). His theory of contrast had to "open a new world to students". His very famous theory of colors intended to « liberate the study of colors harmony from associations with forms », and to help discover « expressive quality of the colors contrasts" (Itten 1961). Hence this course will be particularly helpful for us to study the kind of knowledge structure that can improve generic creativity.

We can even go one step further to sharpen our analysis: it is interesting to note that the idea to provide knowledge to improve design capacity is absolutely not new – Vitruvius already (at the first century) insisted on the necessity for architects to master a large corpus of knowledge. When Itten taught his courses, engineers in Germany learnt engineering design by learning machine elements and engineering sciences (Heymann 2005; Le Masson and Weil 2012). Still machine elements or engineering sciences are not necessarily seen as sources of creativity – they rather tend to strengthen a so-called rule-based design, tending to re-use rules rather than breaking them. Hence our sharpened research question: what is the difference between the kind of knowledge and learning capacities as taught by Itten and the machine elements and engineering sciences as taught by German Machine construction courses at the same moment?

Klee was (1879 - 1940) was invited in 1921 by Itten and Gropius to teach at Bauhaus, where he staid professor for ten years. His course "Contribution to a pictural theory of form" is called by Herbert Read "the most complete presentation of the principles of design ever made by a modern artist". As he explains in the retrospective of his course (lesson 10) "any work is never a work that is, it is first of all a genesis, a work that becomes. Any work begins somewhere close to the motive et grow beyond the organs to become an organism. Construction, our goal here, is not beforehand but is developed from internal or external motives to become a whole" [our translation]. His intention is hence to teach a process to create an organism, a whole, that unfolds step by step. That's why it is particularly relevant to study design processes leading to generic creativity.

Here again one can go one step further and sharpen our research question: we know of such design processes that ensure that a coherent whole will emerged step by step. For instance systematic engineering (Pahl and Beitz 2006) prescribes to develop a product through four main steps (functional requirements, then conceptual design, embodiment design and detailed design). And again: such a process is not particularly famous for its creative aspects, or more precisely its capacity to break design rules. Hence what is the difference between Klee design process and such a classical engineering design process?

Part 3: results: knowledge structure and design process for generic creativity

Itten: a "contrast" based knowledge structure to better open holes

To illustrate Itten's method, we can analyze the series of exercises proposed by Itten to learn about textures (Itten 1975). In a first phase, students were told to draw a lemon. Beginning by the representation of an object, Itten wanted the students to go from "the geometrical problems of form" to the "essence of the lemon in the drawing." It was an "unfixing" exercise, helping the students to avoid assimilating the object with a geometrical form.

In a second phase, the students were asked to touch several types of textures, to "improve their tactile assessment, their sense of touch." This was a learning phase in which students "sharpened observation and enhanced perception."

In a third phase, students built "texture montages in contrasting materials" (see picture below). During this exercise, students began to use textures as a means of design. The constraint (design only by contrasting textures) helped them to learn about textures (to explore the contrasting dimensions of different textures and improve their ability to distinguish between them). It also meant that they were able to explore the intrinsic generative power of textures, ie the superimposition of textures that should create something new: "roughly smooth", "gaseous fibrous", "dull shiny", "transparent opaque", etc. Moreover they began to learn the relationship between texture and a complete work, a composition: against the idea that texture could be secondary and "optional", chosen independently of the rest of the piece, the exercise made textures as the critical part determining the whole.

Figure 3: Texture montage exercise (Itten 1975)

The fourth phase could be qualified as "research". As the students were by then more sensitive to the variety of attributes of a texture, they could "go out" to find "rare textures in plants." It is interesting to underline that Itten did NOT begin with this phase, as he was conscious of the need to begin by strengthening their capacity to recognize new things, just as a botanical researcher has first to learn the plant classification system and discriminating features before being able to identify a new specimen. In particular, students were told to find new textures for a given material (see figure below in which all the textures are made from the same wood). Once again, this was an exercise to disentangle texture from other fixing facets, ie materials, in the case in point. Note that in this step, Itten didn't teach a pre-formatted catalogue of textures but teach student how to learn on textures, here by building their personal "palette".

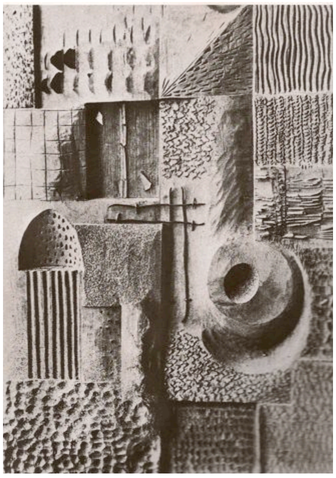

Figure 4: Several textures with the same material

The fifth phase consisted in representing textures. Itten stipulated that students had to represent "by heart", "from their personal sensation", to go from "imitation" to "interpretation". Instead of being an objective "representation", this exercise was intended as a design one, as students had to combine textures with their own personality. Just as phase 4 aimed at creating something new from the superimposition of contrasting textures, the idea in this phase was that the new should emerge from the superimposition of texture and the individual "heart". It was also designed to help improve sensitivity.

The sixth and last phase consisted in characterizing environmental phenomena as textures. For instance, the figure below shows a marketplace painted as a patchwork blanket. Itten urged students to use texture as an autonomous means of expression and not just a "constrained" ornament. By combining their enriched algebra of textures and the algebra of scenes, they could create new "textured scenes" that were more than the scenes and more than the textures. As Itten explained: "It stimulates the students to detach themselves from the natural subject, and search for and reproduce new formal relations".

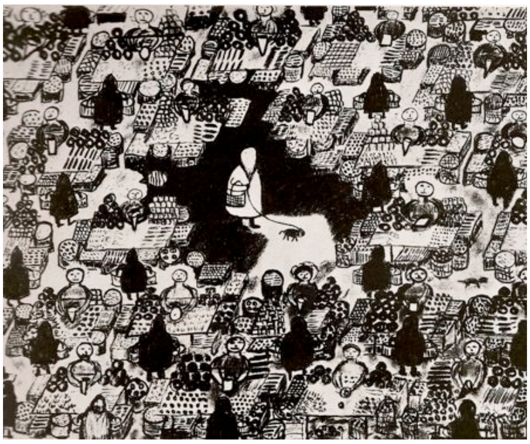

Figure 5: characterize environmental phenomena as textures

We could repeat this analysis on the other aspects of Itten teaching (lines and points, form, color…). In all cases one finds that Itten improved actually three facets of his students' design capacities:

a- Self-evidently students extend their knowledge base on the notion of interest (eg texture), knowing more on (texture) materials, (texture) descriptive languages, (texture) perception, (texture) building techniques. On color, Itten teaches to increase the capacity to perceive "distinct differences between two compared effects" and to "intensify or weaken (color) effects by contrast". In that sense this is not really different from an engineer learning machine elements, their production processes, their functionalities,… ie learning what design theorists would call design parameters and functional requirements. In both cases, seen from this perspective, the knowledge structure appears as a well-ordered catalog of recipes. Still a highly complex one, in which only few combinations have been explored.

b- Students are also ready to learn on the notion of interest. They know also parts of what they don't know: the contrasts, the materials, the process, the perception and sensation they tried and the one they couldn't try – unavailable material, new combinations, sharper sensations,… As Itten writes: " a theory of harmony does not tend to fetter the imagination but on the contrary provides a guide to discovery of new and different means of color expression" (Itten 1961). The industrial design students know the limit of what they know and the way to learn beyond – they not only the state of the (their) art but also the state of the non (yet) art. The knowledge structure is closer to that of a very smart scientist-engineer, who not only knows the engineering sciences but also know their limits and is ready to follow the advances they make.

   At this point we can already underline that this knowledge structure enables a designer to extend his own design rules. It is closer to style creation (even if the genericity is self-evident yet) than teaching the design parameters and functional requirements of pre-given styles.

c- Let's look now at a third aspect of the knowledge structure that will lead us to the genericity issue: beyond rules and the learning of rules, students are also able to deal originally with briefs or to give themselves original briefs. This is the key logic of contrasts: Itten doesn't teach colors, forms, textures, etc… but teach the contrast between colors, textures,… The juxtaposition provokes surprises, it creates "holes" in the knowledge base, that has to be explored by the designer. A contrast doesn't correspond to a unqiue meaning in a one to one correspondence; it paves the way to multiple elaborations. Itten's theory of colors actually a method to learn how to create contrasts and build on them. More generally, such briefs can be oriented to explore new textures, new texture montages, new texture contrasts,… These briefs can also be oriented towards creating original works using textures (or colors, forms,…) in a unique way. In that sense, Itten teaching is much closer to educating a senior scientist, who has not only to answer exogenous research questions but has also to be able to build his own, original, research program.

Let's come now to the "genericity" issue. It should first be noticed that – despite apparent knowledge expansion- the knowledge base actually relies on quite classical motives. So if there is creativity, it is based on a known set of means (textures, colors,…). This is more the combination of these elements that will provoke the movement out-of-the-box. As we will show now the logic of Itten enables to realize a work that uses traditional attributes but that is systematically different from all existing works because it differs from each of them through at least one feature. This is based on two critical properties of the knowledge structure built through Itten teaching:

- *Non determinism:* when confronted to a "hole", the student can not use a deterministic law. Because of the variety of contrasts, there is no law that link one color to one material to one texture to one effect. At each step the designer can always explore multiple paths! Itten fights against "laws of harmony" or "clichés" that tend to impose some relations (a warm fibrous wood, a cold smooth shiny metal,…). He wrote his book on colors to "liberate the study of colours' harmony from associations with forms." These deterministic laws would make that the new object is necessarily equal to all its predecessors on the (infinite) list of parameters defined by the laws. These parameters would then be neutralized for creative design. Without such laws, at any moment over time, the designer can add one attribute that will lead to a refined differentiation from existing pieces. For instance the "cliché" deterministically associated wood to fibrous; Itten's teaching opens the way to smooth wood, that will differentiate the designer's work from all previous work using wood as fibrous.
- *Non-independence:* on the other hand, not all attributes, not all combinations are equivalent. Itten does not advocate relativism. On the contrary. "subjective taste can not suffice to all color problems". Relativism deletes the valued differences: if texture is only a "secondary", "modular" property, then all works with wood are similar – a work with smooth wood is undistinguishable from a work with fibrous wood. Against "relativism" Itten teaches that one does not add a texture *independently* of the other aspects; if a scene or a montage can be made of texture, then a scene or a sculpture are not "insensitive" to the choice of texture. For Itten, each attribute (texture, color, matter,…) influences the whole work, propagates to all other aspects; here again the notion of contrast is

critical: each juxtaposition is a source of meaningful contrast that has to be amplified, tamed, or counterbalanced by another one.

To conclude on Itten's teaching: *non-determinism* and *non-independence* are two critical properties of the knowledge structure provided by Itten. Let's underline that these two properties are strongly different from the logic of machine elements (that is modular) and the logic of engineering science (that is deterministic). It leads the designer to be always confronted to a "valued unknown": at each step of the design process, the next one is neither determined (non-determinism) nor indifferent or independent (non-modular). The next attribute is at the same time undetermined and critical.

This leads to generic creativity: generic because it uses and discusses generic parameters of industrial design; and generically creative because it leads to design a piece that is different from all previous pieces through at least one attribute.

Last but not least, as we have shown above, Itten does not teach a stabilized knowledge base but rather teach the students how to build there own knowledge base with the two critical properties: non-determinism and non-independence.

Klee: composition as a genesis process, leading out-of-the-box

Let's first illustrate three facets of Klee teaching.

1- Even more than Itten, Klee provides an extended language of the design object. Beginning with "lines", Klee introduces the notions of active (vs passive) line, free line, line "with a delay" (befristet in german),… After lines, Klee addresses notions like rhythm of piece, the spine of the piece, the piece as a weighing scale, the form as movement, the cinetic equilibrium, the organs and the organism,… in particular Klee proposes new languages for perception, considered as a "moved form" with a specific cinetic, ranging from pasturage to predation (see illustrations below).

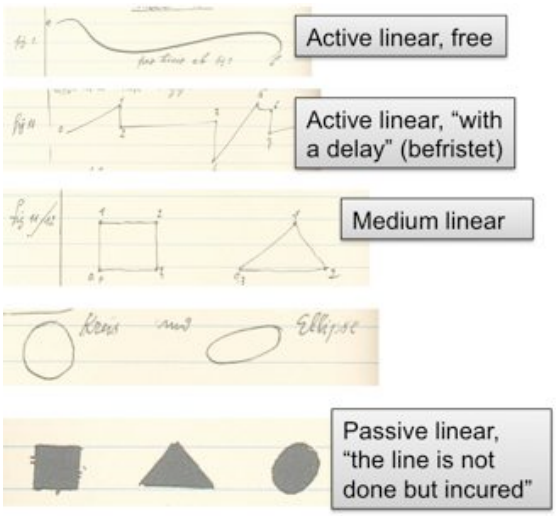

Figure 6: a new language on lines

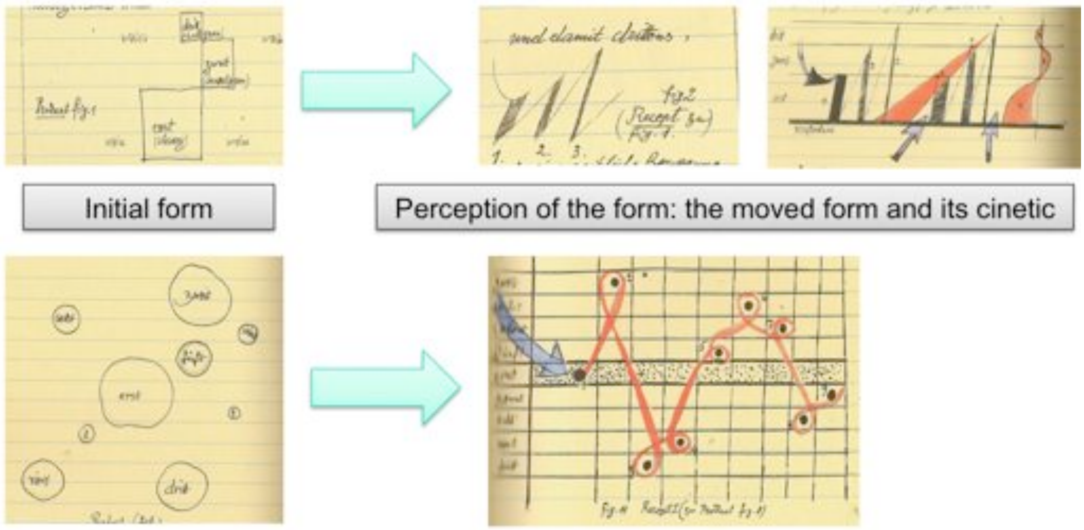

Figure 7: a language of perception: pasturage and predation; the cinetic of the moved form

2- Second aspect of the Klee's treaching: each chapter studies not only one dimension of the work (as did Itten: lines, surfaces, color, textures,…) but always discusses how one "part" relates to the "whole". For instance the line is related to the perspective of the whole piece, the "weight" of each element is related to the balance of the whole piece, the elemental structural rhythms of the piece are related to the individual that integrate all these rhythms, the joints between elements are related to the whole organism, the moved forms are related to the cinetic equilibrium of the received piece,…. This part-whole logic actually leads to a renewed logic of composition. In several exercises, Klee teaches composition. For instance see illustration below.

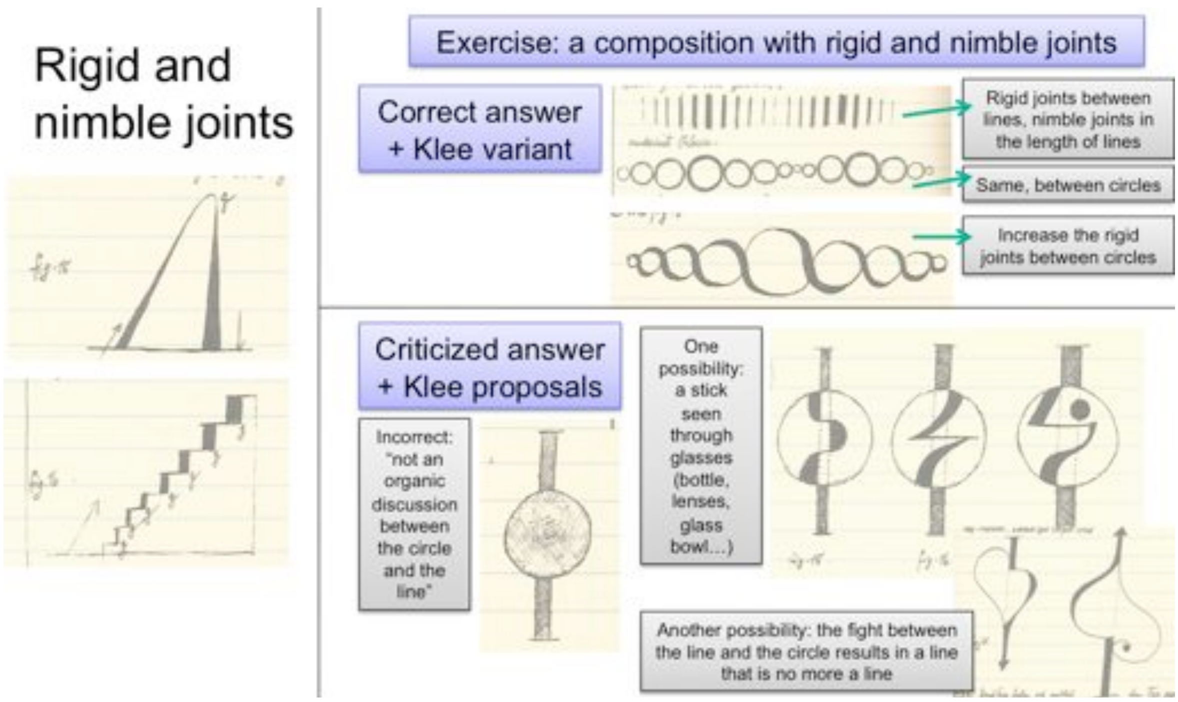

Figure 8: Composition with rigid and nimble joints
The incorrect answer is criticized for the absence of "organic discussion" between the circle and the line – Klee correction proposes ways to reconcile the line and the circle.

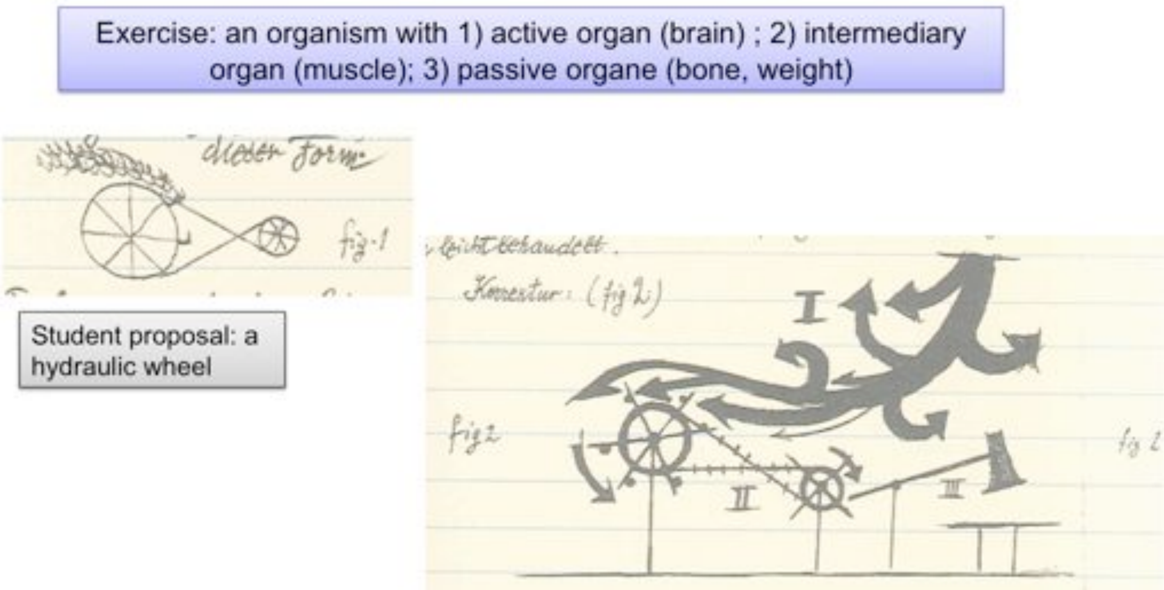

Figure 9: composition of piece with three organs – discussion of an hydraulic wheel schema proposed by one student. Klee supports the idea that an hydraulic wheel can be represented by these three organs and his drawing insists on the composition of these three organs.

3- Finally, third aspect, Klee also teaches how to shift from one aspect to the following one. One example is given at the second chapter. Teaching "weight" and balance in a piece, Klee shows that the imbalance of surfaces (see figure below) calls for a new "weight" to be balanced (for instance the imbalance of surfaces is balanced by a color). But the introduction of colored surfaces leads to a new imbalance. So that there the scale "oscillates" and creates rhythms in the whole. This is the shift from weight and balance to scales and rhythm, which creates the "spine" of the piece (see figure below). This transition is actually mediated through music, in which "weights" and "balances" correspond to rhythms, tempi and bars.

Klee teaching is the presentation of all the transitions: from perspective to weight (via gravity), from balance to rhythm (via scales, space and music), from individual to joints (via physiology), from joined individuals to organisms and organs, from organism to "moved form" (via eye's perception).

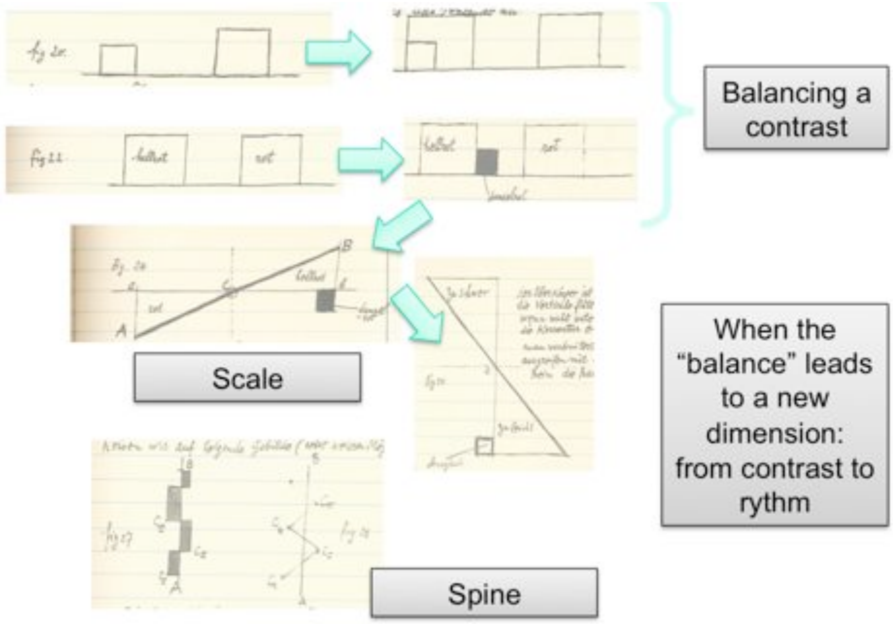

Figure 10: Shifting from one aspect to the following one – the case of balance and rhythms

How does Klee improve the design capacities of the students? It is interesting to note that Klee proposes a design or construction process; hence our sharpened question: is the Klee process "comparable" to a systematic engineering process?

To begin, let's underline that, just like Itten, Klee also teaches new means for design action (new types of lines, of shapes, of compositions,…) and new values (eg "have an organic discussion" in a work, beyond the pure juxtaposition of forms). In that sense Klee teaching is also teaching the elements of a new style. And it can be noted that this new style is already strongly different form the previous one: for instance it doesn't follow the classical catefories (landscape, mythological scene, still life…). Moreover, always like Itten, Klee rather insists on the capacity to *expand these languages* (new types of lines, new organic compositions of joints,…), ie to create new style. It does not really provide solutions, but rather helps to open questions: how to organize an "organic discussion" between a line and a circle? How to build an organism that integrates together given organs? (see the waterwheel exercise above). How to provoke predefined "cinetic equilibrium" ie not the work "as such" but the work as seen from the viewer ("moved forms"), ie how to integrate this "moved form" into the composition of the fixed form? In all these exercises (and particularly the last example), the notion of style creation or meaning creation is at the heart of the teaching.

To get this "generic creativity", Klee relies on a very original *process*. With Itten we saw that the attributes of the piece are mutually interdependent (the scene is created by the texture and vice-versa). With Klee, we have *a means to be sure to get a result in the end, and a result that is still generically creative!* Let's analyse this:

1- First, Klee focuses always on the genesis of the whole, in a constantly refined part-whole relationship. Even if each step of teaching seems to address only one partial aspect of the final piece (perspective, balance,…), each of these aspects has to be consistent in itself at the level of the piece taken as a whole. *At each step Klee teaching tends to validates a consistent part-whole relationship*. Klee lessons show that certain types of elements (lines, “weights”, rhythm, joints, organs,…) are in deep correspondance with one aspect of the final piece (respectively perspective, balance, individual, organism,…). Each lesson consists in working the relationship between one type of language (lines, “weight”…) and the aspect of the whole related to that language (perspective, balance,…). This is the generalization of the exercises where Itten proposed to work on a whole montage only based on textures: Klee always teaches the whole, even if it is the whole related to its parts. At each step, Klee teaches the whole piece as seen from one type of language (the work seen as a perspective / the lines; the work seen as a balance / the “weights”; the work seen as an organism / the organs and the joints,…). One can consider it as a logic of *robustness*: by working at each step on the part-whole relationship, Klee ensures that each of the languages (perspective, balance,…) expressed by some specific means (lines, “weights”,…) is “present” on the final piece. The languages are applicable to all known pieces, they form a form a “generic” frame of references. And Klee ensures that the new piece in emergence will be understandable in all these languages, in this frame of reference.

Coming back to systematic design, we can only be struck by the fact that the languages of the systematic design process (functional, conceptual, embodiment, detailed) can precisely appear as *languages of the part-whole relationship*. Validating a list of requirements finally consists in checking the consistency of the emerging object on the functional dimensions. The parts are functions, the whole is the functionality of the final object – the part-whole relationship is acceptable when the list of functions designs a functional object. And the same holds at the conceptual level (where the consistent combination of technical principals is supposed to address the conceptual design of the product), at the embodiment design level (where the consistent arrangement of organs is supposed to build a coherent organism) and at the detailed design level (where the fine adaptation of industrial component builds an industrially feasible product).

2- Still there is one strong difference between both processes: in the logic of systematic design, the designers work with a knowledge base that is structured by determinism (engineering science laws) and independences (modules). In this case, the interaction between the levels are simplified and purely driven by the deterministic laws (since the relationship between the languages is either a pure determinism or an independence: either a function determines a technical principle; or, on the contrary, whatever the function, one technical principle can be used -modularity). If the knowledge base is non-deterministic and non-independent, then the transition from one language to another one is nomore defined by the deterministic rules. And Klee, just like Itten, builds a knowledge base that is non-deterministic and non-independent. We find by Klee the same effort to propose always multiple paths (no deterministic rules, there is never one solution to an exercise given by Klee!) and to always show that the attributes and the effects created at any moment in the genesis will have an effect for all the rest of the design process.

If there are no deterministic rules to structure the design process, then how to shift from one type of language to the next one, what is the order of the process steps? The magic of Klee might be precisely here: Klee proposes a logic of transitions and this logic of transition is based on a language that might sound very far from the genesis of design objects. Let’s analyse some of these transitions: the first language is the language of lines (part) and perspective (whole); Klee suggests that these lines and perspective define horizontal and vertical and relate that to the ohysical notion of gravity; having introduced that notion of gravity, lines and perspective lead to a second language, based on weights (parts) and balance. In this new language the emerging object inherits the dimensions designed with line to build perspective (hopefully original ways to treat lines and perspective) and the heritage will be expanded in the new language (the original lines and perspective will give birth to original treatments of weights and balance). Then Klee shifts from this language of weights and balance to the language of structural rhythms and the paced individual by showing that a series of weights and imbalances and balances creates some forms of music. After phyics and music, the third transition is based on physiology (the rhythms and the paced individuals are animated by joints that build an organism),… these transitions sound arbitrary and they are certainly. But they ensure the designer to shift from one language to the following one so that the genesis process leads to accumulate on the object a growing number of languages. *These transitions contribute to increase the genericity of the final piece.* Certainly a master designer wouldn't need such codified transitions and could invent his own ones. But he should forget to invent such transitions otherwise the genesis of his pieces would be limited to a (too) small number of languages, hence losing in genericity.

To conclude on Klee teaching: Klee teaches a process that ensures the apprentice designer to accumulate many general languages on his piece, hence improving its genericity. This accumulation is based on two principles: 1- a constant concern with the "whole": even if each step of the genesis addresses "parts", each step also addresses an aspect that is valid at the level of the whole (perspective, balance,…). Hence each steps leads to "validate" one dimension of the "whole" piece. 2- a process of accumulation that is neither based on deterministic laws or independence principles (as in the case of systematic engineering) but is based on *transitions* between languages that keep the possibility of originality at each level (multiple paths open) and propagate the originality won at one level to the following one (no modularity). These transitions make sure that the genesis will accumulate as many contrasted (and still coherent) languages on the emerging piece, while keeping and increasing the creativity. This explains why this is a *generic creative design process*.

Part 4: towards a mathematical characterization of design capacities?

Main result: Bauhaus as a way to teach generic creativity, for style (meaning) creation.

We can now conclude and answer to our research questions:

1- the courses of Itten and Klee not only aimed at teaching the past style and a new style. They aimed at increasing students creative design capacities and even, more precisely, at providing them techniques to create their own style, in the sense of being able to be generically creative – ie be creative on as many languages as possible.

2- The analyses of the two courses leads to identify two critical features to get a generic creative design capacity:
    a. A knowledge structure that is characterized by non-determinism and non-independence
    b. A genesis process that helps to progressively "accumulate" languages on the object in a robust way. This accumulation is based on a step-by-step work on part-wholes relationships and a series of transitions from one language to another one.

A mathematical characterization of the knowledge structure and design process of Bauhaus teaching

These two features of the design capacities for generic creativity can be compared with some mathematical structures that are favorable to the "creative" generation of new mathematical objects. We will now show that these features correspond actually to two trivial properties that a mathematical structure is supposed to meet to be "forced" in the sense given by Cohen.

(Hatchuel and Weil 2007) have shown that forcing, a method invented by Paul Cohen to create new models of sets (Cohen 1966; Cohen 2002), can be interpreted as a very generic design method to create new models of sets while preserving some basis rules of sets (basically Zermello Fraenkel axioms). The logic of forcing is as follows:

- The first element of Forcing is a ground model M: a well formed collection of sets, a model of ZF. This is the basic "knowledge base" of the designer.

- The second element is the set of forcing conditions that will act on M. To build new sets from M, we have to extract elements according to some conditions that can be defined in M. Let us call (Q, <) a set of candidate conditions Q and a partial order relation < on Q. This partially ordered set (Q, <) is completely defined in M. From Q, we can extract conditions that can form series of compatible and increasingly refined conditions (q0, q1, q2 ... qi) with for any i: qi < qi-1; this means that each condition refines its preceding one. The result of each condition is a subset of M. Hence the series (qi) builds series of nested sets, each one being included in its preceding set of the series. Such series of conditions generates a filter F on Q. And a filter can be interpreted as a step-by-step definition of some object or some set of objects where each step refines the preceding definition by adding new conditions. Q is the knowledge structure used by the designer. In the world of industrial design, this could be color, texture, matters, lines, points, joints,… (referring to the words used by Klee or Itten).

- The third element of Forcing is the dense subsets of (Q, <): a dense subset D of Q is a set of conditions so that any condition in Q can be refined by at least one condition belonging to this dense subset. One property of dense subsets is that they contain very long (almost "complete") definitions of things (or sets) on M, since every condition in Q, whatever its "length", can always be refined by a condition in D. But a dense subset contains only constraints so that it is a way to speak of all elements without "having" one element and speaking of them only from their "properties". Interestingly enough the notions of perspective, balance, organism… could be interpreted as dense subset defined by constraints such as line (for perspective), weight (for balance), organ (for organism)… The set of constraints (lines) leading to a perspective is dense in the set of all constraints since whatever a sequence of constraints (a partially defined piece) it is always possible to identify some additional constraints that lead to speak of the "perspective" of this partially defined object.

- The fourth element of Forcing (its core idea!) is the formation of a *generic* filter G which step by step completely defines a new set not in M ! Now how is it possible to jump out the box M? Forcing uses a very general technique: it creates an object that has a property that no other object of M can have! Technically, a generic filter is defined as a filter that intersects all dense subsets. In general (see condition 1 below) this generic filter defines a new set that is not in M but is still defined by conditions from Q, defined on M. Thus, G builds a new object that is necessarily different from all objects defined in M. We can interpret G as a collector of all information available in M in order to create something new not in M. In the case of industrial design a new piece is only a filter (a series of constraints: lines, colors, matter,…). There is no warranty that this series of constraints builds a generic filter, ie intersects all dense subset. So there is no warranty that the new piece goes "out-of-the-box" as long as one can't warranty the intersection with design filters.

- The fifth element of Forcing is the construction method of the extended model N. The new set G is used as the foundation stone for the generation of new sets combining systematically G with other sets of M (usually called M(G)). The union of M and M(G) is the extension model N.

These elements enable to create a new set G that is built on M, is "generically" different from all elements of M and still is coherent with the rules of M. Our question is then: what are the conditions for a filter to be a generic filter that goes out of M? There are actually two sufficient conditions to create a "generic filter":

Condition 1 : the splitting condition. A generic filter doesn't necessarily go out of M. It has actually been showed that G is not in M as soon as Q follows the splitting condition: for every condition p, there are two conditions q and q' that refine p but are incompatible (there is no constraint that refine q and q'). [2] (see figure below).

[2] Demonstration (see (Jech 2002), exercise 14.6, p. 223): Suppose that G is in M and consider D = Q \ G. For any p in Q, the splitting condition implies that there q and q' that refine p and are incompatible; so one of the two is not in G hence is in D. Hence any condition of Q is refined by an element of D. Hence D is dense. So G is not generic.

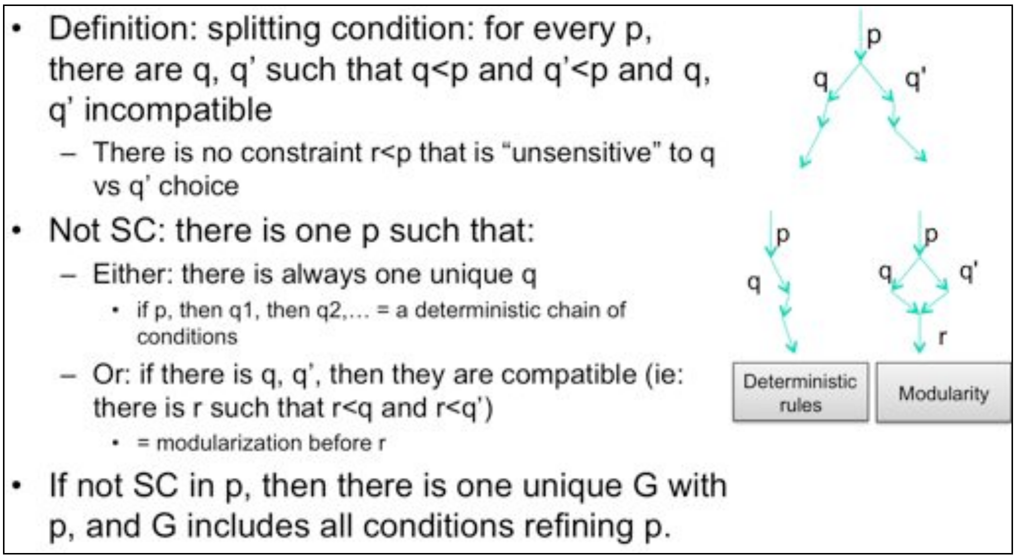

Figure 11: The splitting condition

Condition 2: the countable condition: if M is countable, then the collection of desnse subsets of M is countable and there exists a generic filter on Q.

We can now analyse Klee and Itten courses related to these two conditions.

1- as shown on figure 11 above, the splitting condition excludes two cases: there are deterministic chains of conditions (laws) or there is a modular structure such that there is finally a constraint r that refine q as well as q' (q and q' are modularized and r is unsensitive to the choice or q vs q'). So it appears that Itten, providing a knowledge structure that characterized by non-determinism and non-independence finally enabled students to build a knowledge base *that meets the splitting condition*.
   Conversely there appears that knowledge structures which favor laws and modularization (like classical engineering design) actually prevent splitting condition. Itten builds a knowledge structure that enable the designer to "go-out-of-the-box" whereas engineering design tends to build a knowledge structure that avoid to go-out-of-the-box.
2- Regarding the second condition, if one analyses the part-whole relationships introduced by Klee as dense subsets (see above), then the genesis process proposed by Klee corresponds to a form of countability of the dense subsets. Mathematically, it warranties to go-out-of-the box.
   Note that in systematic engineering, one can consider that the design process also warranties a form of countability of the dense subsets and hence enableto create a generic filter. But since the knowledge base doesn't meet the splitting condition, the generic filter is in M, "inside-the-box" and not "out-of-the-box".

We have finally shown that Itten and Klee courses provided students with a knowledge base (or a method to build such a knowledge base) that meets the splitting condition (Itten) and with a method to systematically build a generic filter (Klee).

Conclusion

This mathematical analysis helps us to generalize the results obtained in the Bauhaus context. We have proposed to analyse style (or meaning) creation as a form of *generic creativity* (part 1), ie a creativity that will address the generic languages of a culture. The Bauhaus texts (and the formal models of forcing in mathematics) helped to analyse some critical features that make design capacities adapted to generic creativity (parts 2 to 4):

1- the designer(s) relies on (or is able to create) a knowledge structure that is characterized by non-determinism and non-independence. Technically speaking, this knowledge structure meets the splitting condition. Metaphorically, this knowledge structure is "open", it contains many "holes", ie many open concepts that will require investigations, learning and knowledge creation.
2- the designer(s) is (are) able to identify (or build) a structure of dense subsets and to follow a design process that leads him (them) through all dense subsets of the knowledge base.

This comparison helps also to show that systematic engineering is precisely characterized by knowledge structures that prevent the splitting condition, that are characterized by independence (modularity) and determinism (engineering science).

But our results also suggest an analytical framework for contemporary design. In a period of strong technical, social and scientific challenges, some engineering design situations are precisely characterized by forms of non-independence (eg propagation of constraints, values,…) and non-determinism (multiple paths to be explored). Conversely this analytical framework could also be a source of critical studies in design, to differentiate between forms of industrial design aiming at generic creativity (today inventing new knowledge bases meeting splitting condition) and more modular industrial design that does not necessarily aims at going-out-of-the-box.

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