A didactics of colour based on an innovative educational approach at the Hochschule für Gestaltung in Ulm

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Abstract

Tomás Maldonado held the posts of lecturer and rector at the famous Hochschule für Gestaltung in Ulm from 1954 until 1967-68. His foundational contribution to the field of education/training dates to his thirteen years at this school, where he concentrated his theoretical and practical inquiry on developing a new approach to the teaching of key design-related subjects.

While at Ulm, Maldonado became keenly interested in devising an innovative new teaching method based on the notion of “cooperation among disciplines”.

This principle guided him throughout his lengthy teaching career, as he enriched and refined his educational thinking and developed increasingly effective teaching methods for the disciplines he taught. There was something important and revolutionary about his teaching approach and his method also became well known in Italy. Even earlier, as a very young artist in Argentina, where he helped to found the Concrete Art movement, he had displayed and constantly shared with others an “almost obsessive preoccupation” as he himself defined it, with actively contributing to a total vision of culture. Towards the end of his life, he characterized this project as “over-ambitious". However, it showed that he was interested in cross-disciplinarity from the outset. Crossdisciplinarity, or the “third culture”, as he himself called it and understood as the attempt to overcome the dichotomy between “hard” and “soft” sciences. In light of this background, I set out here to examine Tomás Maldonado’s approach to developing new teaching methods for his classes, especially in relation to the theme of colour as an integral part of his course in Visual Methods.

KEYWORDS: didactics of colour, Tomás Maldonado, visual education, visual methods, scientific approach to visual culture, interdisciplinarity, transdisciplinarity, Hochschule für Gestaltung in Ulm,

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1. Introduction

Tomás Maldonado held positions as a lecturer, and later rector, at the famous Hochschule für Gestaltung in Ulm (Germany) between 1954 and 1967-68.

In this paper, I offer an analysis - based on my personal acquaintance with Tomás Maldonado and my knowledge of his studies and his works - of his teaching methods and especially the "didactics of colour" that he devised for his course in visual methods. I was stimulated to document his teaching of (and with) colour by our shared interest in certain themes. One interest that we had in common was a passion for colour and how it is perceived, topics that we often discussed, and which for Maldonado were the object of meticulous study, enriched by his wideranging inquiry into the culture and science of colour. Here, I document some extraordinary interdisciplinary and transdisciplinary exercises he designed and implemented with his students during his years on the academic staff of the foundation course in design at the Hochschule für Gestaltung in Ulm.

His interest in teaching and training, which he later continued to pursue in other universities around the world, first developed during his time in Ulm.

Over these thirteen years, Maldonado focused his theoretical and practical inquiry on developing a new perspective on teaching particular subjects, both to students of design and to those pursuing other branches of study.

2. Who was Tomás Maldonado?

"[...] Although I was not very young when I arrived in Ulm, I was thirty-two and [had previously enjoyed] a short but intense career as an artist in Argentina, I acknowledge that the [Ulm] experience played a decisive part in my formation.

It contributed to considerably broadening my intellectual horizons… I am especially alluding here to my theoretical (and practical) engagement with industrial design and communications.

At the same time, it was in this very setting that I developed an interest in semiotics, the philosophy of science and technology and, last but not least, the sociology of communications.

A crucial role in all of this was played by the educational challenge, the need to prove myself every day in my teaching.

Suddenly I discovered within myself a passion that would remain a constant throughout the rest of my life; a passion for making myself useful in the intellectual (and professional) training of young people. […]" (Maldonado 2010, p. 29)

Tomás Maldonado arrived in Ulm in 1954 at the invitation of Max Bill, a well-known exponent of the Concrete Art Movement in Switzerland. The academic staff at the German design school was composed of internationally recognized figures from all over the world.

During his years at the Ulm school, Maldonado was appointed Lethaby Lecturer at the Royal College of Arts in London in 1965, Fellow of the Council of Humanities at Princeton University in 1966 and lecturer at Princeton's School of Architecture from 1968 to 1970. In 1979, he was research fellow at the Graduate School of Design at Harvard University and gave numerous lectures at other universities in the United States and around the world. In the 1970s, he moved to Italy; first to the University of Bologna from 1971 to 1984, where he taught on the degree course in Music and the Performing Arts offered by the Arts and Philosophy Faculty, and subsequently at Milano Politecnico, where he was based at the Faculty of Architecture from 1985 to 1997 and taught on the degree course in Industrial Design he himself set up in 1993. He also taught at the Faculty of Architecture in Venice (IUAV).

His itinerant teaching work across Europe, the Americas, and beyond fuelled his constant and impactful passion for the formation of generations upon generations of students, who subsequently became expert professionals in multiple fields and who today are scattered all over the world (Chiapponi 2018).

3. The role of HfG in generating a new design culture

The Hochschule für Gestaltung in Ulm was founded to be an international experimental centre dedicated to theory, research, and development in the domain of industrial design (https://roericht.net/hfg-synopse/aufbau). Lindinger wrote in the catalogue of the *Ulm School* exhibition that the ideas that sprang up there were "a message destined to the whole world". A more than reasonable statement, given the international composition of the school's academic staff and its stated educational mission, that of teaching an innovative approach to design during the post-World War II reconstruction period (Lindinger 1988).

Although its existence was brief, the HfG in Ulm is still today viewed as one of the leading design schools of the twentieth century: it was founded in 1953 and closed down in 1968. Beginning in 1954, Tomás Maldonado

contributed to defining the school's curriculum and subsequently also to devising a new and robust method of training designers. Kenneth Frampton stated in an interview that: "HfG was undoubtedly the most important school of design founded after the Second World War, not because of what it accomplished in terms of actual production nor because of the large number of designers who actually qualified there, but ultimately on account of the extraordinary level of critical awareness that it managed to sustain in its everyday work [...]" (Frampton 1974; Lindinger 1988).

The curriculum was initially divided into four streams: product design, visual communication, construction, information, with the addition, at a later stage, of film. It offered a four-year course of studies, at the end of which students were awarded a diploma. The course was structured as follows: in the first year, all students were required to take the Foundation Course, before going on to specialize in one of the areas just listed for the remaining three years.

The HfG was officially inaugurated on 02 October 1955.

Max Bill was rector initially, from 1955 to 1956, while six months later, in March 1956, a council of rectors was set up to run the school, a group that initially comprised the following members of the academic staff: Otl Aicher, Max Bill, Gugelot, Tomás Maldonado, and Vordemberge-Gildewart (Escot 2002).

The HfG, like the Bauhaus, offered a preparatory year known as the Foundation Course (Grundlehre), designed by Max Bill, to introduce the students to the various career paths within design. Part of the first-year curriculum was devoted to the fundamental principles of design or *Basic Design*, a term coined by Josef Albers, based on the course that he had delivered at the Bauhaus, at Black Mountain College in Asheville in 1933, and finally at Yale University (Huff 2009).

In 2002, Günter Hörmann and Martin Krampen came to Milano, and interviewed Tomás Maldonado about his experience at Ulm. On that occasion, he spoke about the challenging historical period and the difficult decisions to be made when he first came to teach at the HfG, especially in relation to teaching methods, given the school's goal of developing an innovative didactic approach: "[…] the issue was whether to continue the tradition of the Bauhaus or to distance ourselves from it. We chose to distance ourselves from the Bauhaus. That meant that we wanted to revisit traditional Bauhaus themes in light of the newly emerging circumstances of that given historical period, it was the post-WWII era in a Germany in need of reconstruction". Maldonado laid particular emphasis on the HfG's revisiting of certain Bauhaus themes in the context of its Foundation Course. To cite his own words during the interview: "[…] The idea was to change approach, or rather, to identify a different approach, trying to permeate it with, to make it sensitive, receptive to scientific developments, and to mathematical and methodological studies with a bearing on what was actually needed to engage in design. So, it was a question of inheriting the ideas of the formal [Bauhaus] methodology, but adopting a highly mathematicized approach that was beginning to come to the fore at that time in the domains of problem solving and decision making - these were techniques that could be immediately applied to the field of design […]" (Hörmann and Krampen 2002).

Some years after this interview, in 2009 to be exact, Tomás Maldonado spoke, during a talk delivered in Weimar at the Festakt zum 90. Gründungsjubiläum des Bauhauses, about his "[…] lively exchange of letters with Walter Gropius […]" on some of his [Maldonado's] theories concerning "[…] the need to take on board the elements of continuity and discontinuity in the Ulm project with respect to the Bauhaus project […]". In this regard, he stated that: "I am personally more and more convinced that it is time to recognize without nostalgia, without any pretence of regret, that the Bauhaus, as an institutional model, has ceased to be relevant, for the simple reason that it is no longer equipped to provide appropriate responses to the pressing needs of our time […]" (Maldonado 2009).

On the other hand, in relation to how the legacy of the Bauhaus contributed to the Ulm school's approach to teaching design, we should note another memorable statement of Maldonado's concerning the merits of the Bauhaus school: "[…] The reason that I remain deeply attached to the Bauhaus, still today, is not the thousand small and big achievements that are usually attributed to it, but rather the great lesson that the leaders of the Bauhaus – the 'Bauhäusler' – passed on to us as their legacy. That is to say, the fundamental desire to seek out and to provide, by every possible means, socially and culturally innovative responses to the needs of the historical phase we have been destined to live in" (Maldonado 1963; 2009).

4. A new teaching methodology

Thus, Tomás Maldonado's keen interest in the field of education emerged at the time that the HfG was being founded in Ulm. He particularly focused his thinking on devising an innovate educational approach based on "cooperation among disciplines". A teaching method developed for the students at Ulm, the future designers of

the third industrial revolution, and for all those still keenly interested in revisiting aspects of the Bauhaus approach to teaching design, on which Max Bill had originally based the HfG's courses. In Maldonado's view, such aspects of the Bauhaus approach were no longer suited to the needs of the HfG in Ulm.

The first-year Foundation Course at the HfG had four stated objectives: "1. It introduced students to the activities of the different streams of the curriclum, and especially the methods in which these activities were grounded; 2. It familiarized the students with key issues in [contemporary] technological culture, thus informing them about the broader context framing specific design tasks; 3. It trained students in collaboration with other disciplines, thus preparing them to work on teams, or groups of specialists, in which it was crucial for each individual to understand the issues and perspectives of the other members; 4. It set out to rebalance differences in prior knowledge among students who not only had previously pursued different academic specializations but also came from different countries with different education systems." (Lindinger 1988, p. 45).

In 1955, when Maldonado took over responsibility for the Foundation Course at the HfG, he attempted to modify the didactic approach of the previous year, that of the Foundation Course directed by Max Bill which was in keeping with the Vorkurs developed by Albers at the Bauhaus.

Maldonado was a great admirer of Josef Albers, and especially of one part of his course. He wrote that Albers had taken on a very difficult challenge in devising the Bauhaus approach to teaching design and that he had risen brilliantly to meet this challenge by transforming a set of diverse, and partially conflicting, compoments - such as pedagogical activism, mystical expressionism, and an exasperated version of constructivism - into a functional and coherent teaching model (Maldonado 1963, p. 12).

Hence Maldonado took the latest didactic approach developed by Albers for the Vorkurs into account when formulating the HfG Foundation Course, but only maintained selected themes, namely those relating to the theories of Gestalt psychology, with a view to providing in-depth background to his exercises in visual perception (Huff 2009, p. 107). He set out to adapt the other themes to meet the new requirements for training students in design, with the goal of formulating a teaching approach that would be more consistent and in keeping with "technocratic-positivist ideology (the mathematization of the design process, and the shift towards "operational research" models"). Thus, Maldonado embarked on a structural and concepual reform of the Bauhaus didactic model which he essentially saw as obsolete (Wick 1993, p. 285-286).

His ultimate aim was to rethink the profile of the industrial designer in the post-war era and above all to design an educational trajectory for designers that would be more in line with the changes then underway in the industrial and production sectors. He believed that this could be achieved by improving the didactic approach and contents of courses for designers, chiefly by adopting a method that was scientific, exploited the benefits of technology, and was interdisciplinary.

His educational strategy was focused on progressively enhancing learning based on "cooperation among disciplines", a guiding principle that was to inform his entire academic career as a teacher and researcher in the field of education (Maldonado 1963, p. 12; Neves and Rocha, 2013).

In one of his last books, he stated that: "[…] Interdisciplinarity and transdiciplinarity not only respond to an increasingly urgent need for cooperation among disciplines, but are also (and always have been) the expression of an inescapable universal vocation to knowledge. […]" (Maldonado 2010, p. 11).

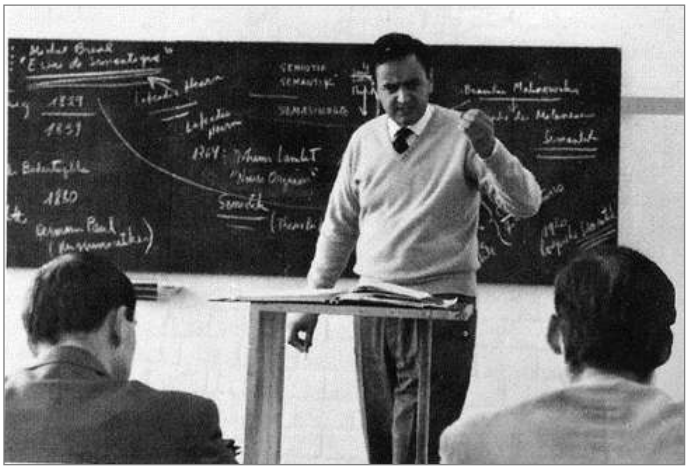

Fig. 1. – Tomás Maldonado, teaching at the HfG Ulm, 1958, source: photograph by Wolfgang Siol, © HfG-Archiv/Museum Ulm.

Tomás Maldonado was almost obsessively preoccupied by the desire to actively contribute to a total vision of culture, which he had counted among his intellectual goals since he was a young artist helping to found the Concrete Art movement in Argentina.

This was a project that towards the end of his life he characterized as "over-ambitious", but which was already present when he was a young artist, forshadowing his later keen interest in crossdisciplinarity - or, as he himself preferred to call it, the "third culture", which he

understood as an attempt to overcome the dichotomy between “hard” and “soft” sciences (Maldonado 2010, p. 9).

Therefore, coming back to the teaching of design in Ulm, from 1954/55 onwards, a new groundbreaking approach began to take shape, thanks to the crucial contributions of Tomás Maldonado and other lecturers invited to teach at the HfG. The change prompted by this novel approach, as mentioned earlier, not only impacted on schools of design and applied art around the world, but also on art academies, universities, and even other educational and training settings and institutions. The Ulm model, defined as a new approach to teaching design that combined formal, theoretical, and practical instruction with working for industrial partners on so-called ‘development teams’ directed by members of the HfG academic staff, would be introduced in various other schools around the world in the years spanning 1960 and 1962 (Lindinger 1988). In relation to the international spread of the HfG approach, Kenneth Frampton recounted in a 1974 interview that: “The questions that the Hoschschule für Gestaltung was asking itself ten years ago, are now consciously or unconsciously being posed by all schools of design and architecture, and the Hochschule’s crisis of identity has become a universal malaise” (Frampton 1974; Lindinger 1988).

In light of these developments and due to some disagreements with Max Bill, Tomás Maldonado, viewed as the theoretician behind the HfG’s founding principles, left the school and Germany in June 1967, heading initially for Princeton in the United States before moving to Italy in the 1970s.

When Maldonado began teaching in Italian universites, first at the DAMS in Bologna and later at Milano Politecnico, he was immediately popular with students. His extraordinary capacity for study and his deep and lively intellect both contributed to his charismatic style of communication in the classroom. He was also a talented storyteller. A particularly exceptional aspect of his teaching was how effectively he was able to convey his knowledge to his classes of students.

His intellectual generosity was amazing, and he was skilled at offering countless perspectives on any given topic. It came naturally to his listeners to allow themselves to be guided through a process of active cooperation and reciprocal exchange among the many disciplines that only Maldonado was able to draw together so masterfully. The outcome was generally a hugh enrichment and broadening of his students’ collective knowledge base, along with a continuous flow of intellectual stimuli that inevitably gave rise to a pleasant, creative, and fertile “contamination” of the thinking of each individual student. His teaching was encyclopaedic in nature, and his method was based on active learning strategies informed by constructivist theories, which entailed the cooperative co-construction of knowledge with his students, whom he would invite to give seminars in the classroom. In sum, his method was new, stimulating, important, and revolutionary in its time. It was Italy’s good fortune that he came here and formed many generations of students in this country also.

5. Tomás Maldonado’s influence on the teaching of design

Maldonado’s artistic experience as a student at the Escuela de Bellas Artes Manuel Belgrano in Buenos Aires up to 1941 and his involvement in the Concrete Art movement that he helped to found, shaped his artistic journey, which underwent a number of key changes. His classical figurative art training was reflected in his earliest paintings, which were dark and monotonous in character. Almost concurrently with this brief initial phase he began experimenting with abstract art. This shift is documented by works published inside and on the front cover of the first and only edition of the magazine “Arturo”, which Maldonado produced in 1944 with his first wife Lidy Prati and a group of other artists from the Argentinian concrete art milieu. After this, Maldonado entered a full-blown experimental phase as an exponent of concretism (Escot, 2007). In embracing this new dimension of art, he was influenced on the one hand by constructivism and the avant-garde and on the other by his encounter in 1948 with European members of the concrete art movement: Georges Vantongerloo in Paris and Max Bill in Zurich. His trip to Europe and these contacts helped him to reinforce and consolidate his thinking about the role of theoretical assumptions in Concrete Art. The themes he explored in depth at this time included the objectives of the process of generating a work of art, the deployment of techical and operational strategies, and the consumption of the final work of art (García 2010, pp. 105-109).

When he returned to Buenos Aires, his art began to display a different compositional syntax: within the space of his paintings, he now used “more delicate” lines and geometric patterns with “weighted” chromatic interactions, yielding sophisticated compositions underpinned by unconventional visual-perceptual equilibriums and novel aesthetic relationships. Beginning in the early 1950s, Maldonado’s art – and his underlying approach to the creative process and to constructing his compositions – began to display the sign of further change: some of his works were now clearly based on the application of scientific methods and mathematical calculations, the basic principles of concrete art.

Maldonado's keen interest in applying scientific theory and mathematical rigour to his art soon became his key focus.

This focus also played a key part in his subsequent choices: the contents he taught at Ulm were partly informed by new studies in the scientific domain which he systematically encountered in the course of his inquiry, as was his ongoing interest in concrete art (Neves and Rocha, 2013). In fact, as Willam Huff recounted in an essay for the catalogue of an exhibition on Tomás Maldonado, when he was put in charge of the Foundation Course in 1955/56, he introduced a strong "dose of Concrete Art" into the curriculum, which included two topics from the field of geometry: the theory of symmetry and the visual topology (Huff 2009, p. 108). An in-depth account of this intermingling of concrete art and the contents of basic exercises in design was provided by Marcel Herbst, who clarified that while some works by Concrete Art artists were not intended to follow rules, many others were based on rules, especially those of Richard Paul Lohse and Max Bill, because they were based on problems to be solved and mathematical calculations and could therefore easily be used as exercises in the context of a Basic Design course (Herbst 2017).

In 1988, to mark an exhibition on the HfG in Ulm that was held in the city of Genoa, Tomás Maldonado wrote:

"[...] it is not true that the Ulm school's theoretical framework was exclusively the outcome of our internal debate about the Bauhaus. What is more: I am convinced that outside of that debate there were disciplines and currents of thought that exerted an influence that was decisive in some regards for our understanding of design and how to teach it. It must be remembered that our curiosity was boundless, in those years, towards all that was new or seemed to be new. A feverish, greedy curiosity that was particularly attracted by certain disciplines that were just beginning to emerge at that time: cybernetics, information theory, systems theory, semiotics, ergonomics. But also, and in no lesser proportion, by other more consolidated disciplines such as the philosophy of science and mathematical logic. The impetus for our curiosity, studies, and theoretical struggles came from our desire to provide a solid methodological basis for design work (Lindinger 1988).

Hence the Foundation Course headed by Maldonado underwent key changes that entailed the introduction of interdisciplinary theories, systematic analyses, and practical experience, thereby contributing to shaping the HfG's offering to students of the new design. This development went hand in hand with a restructured curriculum, whose composition over the four-year duration of the course, as shown in Fig. 2, gradually progressed from mainly basic training in non-applied design in the first year to mainly applied design subjects in the fourth (Campos, Roldán, Sánchez Moya 2015).

The innovative didactic approach that Maldonado brought to Ulm did not just concern the new disciplines introduced into the Foundation Course or the contents of his own Visual Methods module (introduction to visual education), but subsequently also the introduction of other disciplines as part of new courses that were to further modify the HfG curriculum. Furthermore in 1958, Maldonado also proposed publishing a school journal, the HfG Journal Ulm, as a vehicle for presenting and disseminating the ideas developed at the HfG and the students' work to a community of designers, academics, and other professionals around the world.

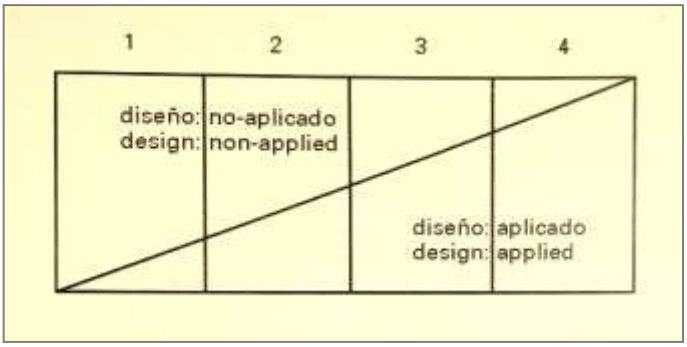

Fig. 2. – The curricular model developed by Tomás Maldonado for the HfG at Ulm (Lindinger 1988).

6. Tomás Maldonado: courses and teaching methods

Hence, from the early years of the HfG, Tomás Maldonado was actively involved in teaching courses there: in 1954, he was an assistant lecturer on the Foundation Course (Grundlehre) headed by Max Bill, while in autumn 1955 - and up until 1967 - he became a full lecturer.

The academic programs from those years document that in 1955, Tomás Maldonado taught visual methods to the first-year students taking the Foundation Course (Grundlehre). Beginning in 1958, he also taught a course in semiotics to the second and third year students in the visual communication and information streams, while in 1966/67 he taught theory of design to second year students of product design (Lindinger 1988, pp. 280-282).

Hence, Maldonado's interest and disciplined enthusiasm in those years were channelled into meeting the need for innovation in the teaching of design. But what constituted an innovative approach to teaching design in that era?

Maldonado believed that learning could be strengthened by leveraging knowledge from different disciplinary fields via interdisciplinary and transdisciplinary work. His own innovative teaching was informed by scientific research and the analysis of statistical data (Leopold 2013).

Giovanni Anceschi, one of Maldonado's students at the HfG, wrote in an article about the foundational nature of Basic Design: "[…] which means claiming that the act of giving shape must be tackled using logical-conceptual and scientific instruments, and also means bringing design inside, and up the level of, the 'connective tissue' of the sciences […]" (Anceschi 1983, p. 21).

Hence, Maldonado's focus as a teacher was on defining an experimental teaching model for the foundation course in design, which was to include some of the themes covered in Josef Albers' Basic Design course, but would also be based on Maldonado's own intense quest to incorporate the scientific method, with the utimate aim of teaching design in such a way as to lay the ground for students to learn different modes and techniques of representation. He also introduced systems thinking, which he applied to many of the topics that he taught at the HfG, and which enabled him to devise extremely impactful learning experiments (Aydemir 2018).

Indeed, in relation to his approach to teaching depiction/representation at the HfG, Maldonado emphasized in his interview with Hörmann and Krampen that "[…] depicting has nothing to do with representation and so it was important to teach, those who needed to learn representation, a different way of going about it […]" (Hörmann and Krampen 2002).

He would begin his classes by providing a theoretical introduction, followed by analytical exercises: bidimensional and tridimensional exercises and studies for applied design, to be conducted using visual representation tools and techniques.

In his book *Reale e virtuale*, published in 1992, Maldonado wrote, in relation to the auxiliary resources used in design (models, exercises, graphs, etc.), that:

"[…] You do not design or communicate with elaborate three-dimensional representations only, but also with two-dimensional ones that are produced spontaneously, which are intuitive in relation to a problem needing to be solved [...]. But drawing, especially *drawing to design* is a type of modeling that, as we are taught by contemporary cognitivist psychology, raises a series of issues that are far from trivial. Because drawing to accomplish design simultaneously takes the form of drawing while designing and designing while drawing. And this interactive co-existence between the means (drawing) and the end (designing) enables progress towards or outright identification of the desired solution." (Maldonado 1992, p. 102). Maldonado's visual methods classes were based on active learning techniques, serving to prepare students for subsequent visual training that would be interdisciplinary and crossdisciplinary, drawing on constructivist and connectionist theories among others.

The practical bidimensional and tridimensional exercises were carried out using traditional visual representation tools and techniques. Drawings were produced manually, in order to stimulate the brain hand-eye coordination with an extraordinary care and precision demanded.

The point of the exercises was to guide the students, in a way that was supportive but rigorously non-directive, towards solving scientifically formulated problems in a systematic and self-directed manner.

In a study on learning from educational experiments, Ayse Zeynep Aydemir at the MEF University di Istanbul, defined the experimental educational activitiy conducted at the HfG and specifically Tomás Maldonado's systems-thinking approach as based on a technique known as "scalelessness". This term describes a work method whereby details and concepts are first presented on a small scale and subsequently translated into a design process, but also revisited to make changes. The timeline in Fig. 3 illustrates the deployment of the five categories of educational experiment defined by Aydemir in design schools across the world. These categories are participation, systematicity, complexity, linearity, and simultaneity. Among them, it is interesting to note that experiments based on systematicity first appeared in the early 1950s, which is precisely when the HfG was founded in Ulm.

Tomás Maldonado's classes in visual methods required his students to engage in sophisticated exercises in design. From the outset, he himself devised and set these exercises, with a view to guiding the students towards meaningful, reflexive, and mindful learning outcomes.

All possible resources, including instruments, materials and techniques, were made available to the students, who were assigned the task of solving problems using geometric formulas or mathematical calculations. These practical exercises were systematically supplemented by moments of collective and individual reflection, as well as by discussion of the strategies that individual students had deployed to define their personal solutions.

The approach just outlined is confirmed by the written testimonies of William Huff and Gui Bonsiepe, both of whom took Maldonado's foundation course as students.

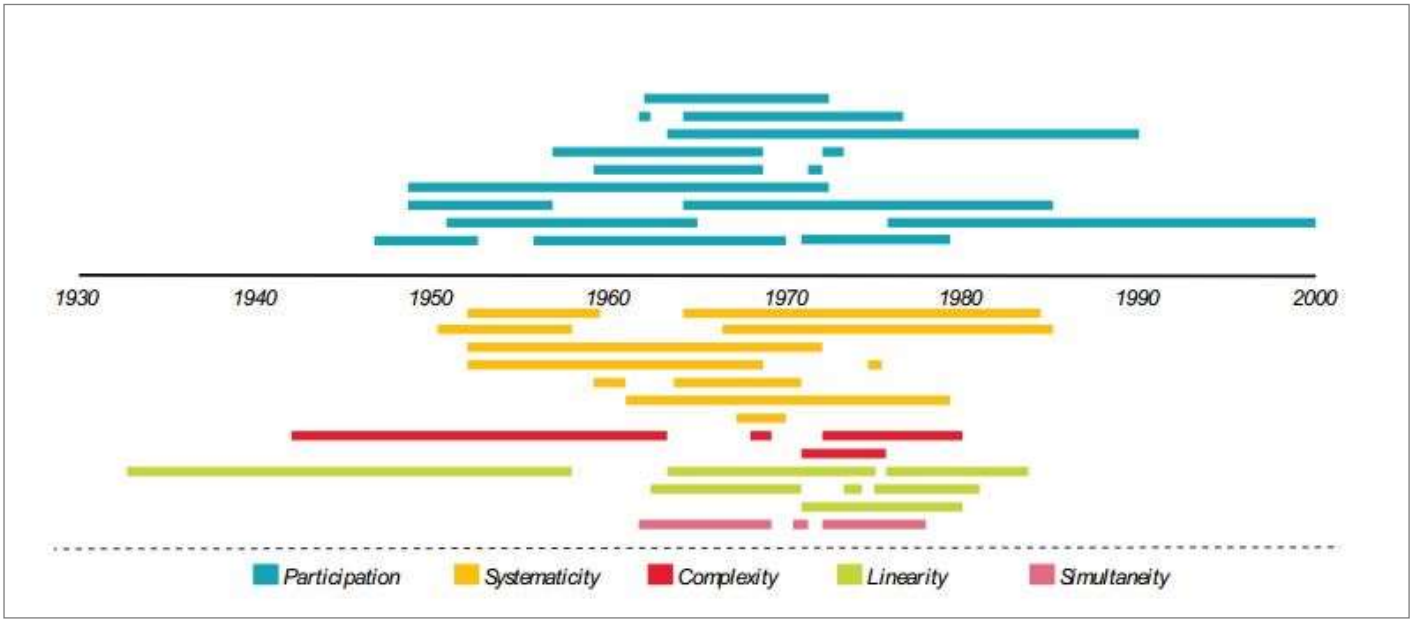

*Fig. 3. – The graph shows the majority of educational experiments conducted in design schools, divided into five categories and arranged along a timeline from 1933 to 1990 (*Aydemir 2018).

Gui Bonsiepe, who went from being a student to teacher, first at the Department of Product Design and after at Visual Communication from 1961 to 1968. He recounted that Maldonado, who had taken over responsibility for the first year of the HfG course in 1955, would began his course with the in-depth analysis of a set of exercises, also incorporating the required mathematical background and Gestalt psychology into these classes. Bonsiepe also stated that: "The foundation course exercises were also designed to develop the students' aesthetic abilities and were described as non-applied exercises in design, to distinguish them from the applied exercises in solving practical problems to which the subsequent years of the course were devoted" (Bonsiepe 2019, p. 126).

The summary table in Fig. 4 below is a key educational and historically valuable document that is held in the HfG-Archiv/Museum Ulm. It sums up the themes and a set of exercises that Maldonado devised for the first-year foundation course students taking his visual methods module.

William Huff, also a student of Maldonado's and later himself a teacher on the foundation course at the HfG in 1963 and 1965-1968, wrote that Tomás Maldonado's foundation course included ten practical exercises, whose original German titles invented by Maldonado are reported in brackets: 1. Sierpinski's surface (Sierpinskifläche); 2. Peano's surface (Peanofläche); 3. Weierstrass curve (Weierstrasskurve); 4. black as a colour (Schwarz als Farbe); 5. symmetries (Symmetrien); 6. exact - non-exact (Genau-Ungenau); 7. non-exact - exact (Ungenau-Genau); 8. perception of space (Räumliche Wirkung); 9. equilibrium of three surfaces (Gleichgewicht dreier Flächen); 10. interferences (Störung). He further added that "For the three-dimensional exercises, it was necessary to also take classes in finite mathematics, the theory of symmetry, groups theory, and visual topology" (Huff 2009, p. 111; Bonsiepe 2019, pp. 141-142).

In addition to these first ten exercises, Maldonado devised others for the students of Visual Methods in 1956-57 and over the following years (Huff 2009, pp. 111-112; Neves and Rocha 2013).

Most of these exercises included the use of colour in the form of a single hue or gradient, depending on the solutions that were sought/found in fulfilment of the task set by Maldonado. This meant, as earlier mentioned, that the students were required to complete the exercises manually with traditional drawing equipment because computer technology was not yet available to them. Nevertheless, Maldonado was already speaking to the students about cybernetics (founded by Norbert Winner in 1947), complex systems theory, computational calculus, information theory, and the theory of signs.

The first exercises that required the use of colour by applying the laws of geometry and mathematical calculation included the Peano/Hilbert curve and Sierspinki surface, both key elements in the development of fractal objects as studied by Benoït Mandelbrot (Lindinger 1988, p. 47).

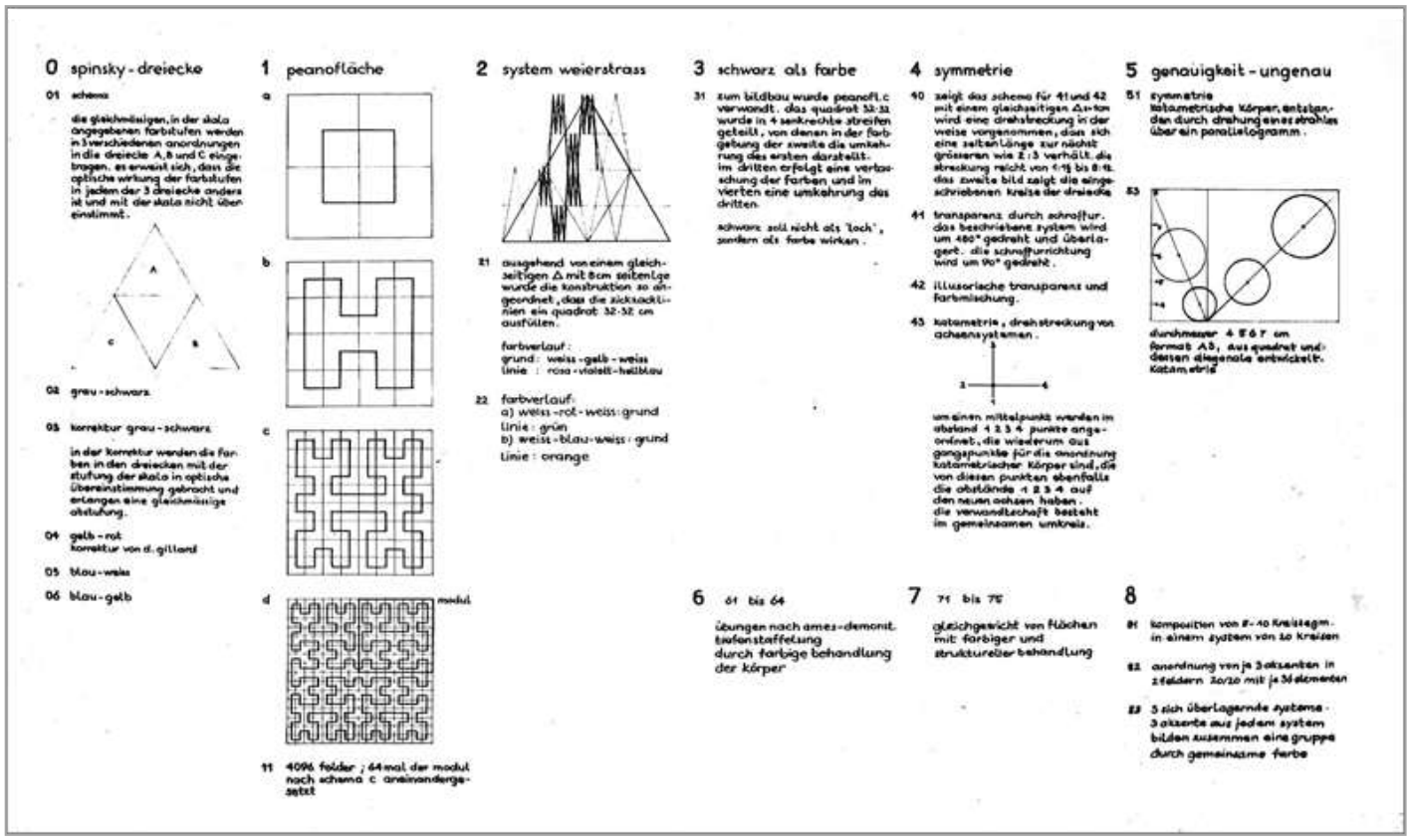

Fig. 4. – Chart showing the themes of the exercises assigned to the students attending Tomás Maldonado's Visual Methods course in 1955/56, source: HfG-Archiv/Museum Ulm. The following are the English translations of the titles of six of these exercises (numbered from 0 to 5): 0. Sierpinski's surface (spinsky dreiecke or Sierpinskifläche); 1. Peano's surface (Peanofläche); 2. Weierstrass curve (system weierstrass or weierstrasskurve); 3. black as a colour (schwarz als farbe); 4. symmetries (symmetrien); 5. exact - non-exact (genauigkeit - ungenau).

If we now go about analyzing these exercises, which were part of the foundation course common to all four design curricula offered by the HfG, we can clearly identify the interdisciplinary and crossdisciplinary approach that Maldonado worked so hard to achieve.

The even more interesting aspect of these exercises is the mathematical-scientific component leveraged by Maldonado to initiate the students into learning about the use of colour and the value of colour visual perception with and without colour**.**

In stressing the importance of knowing how to use geometry, while observing that not all designers are equally competent in this regard, William Huff described how Maldonado used to introduce his tutorials: "[…] Tomás Maldonado applied the formula of semiologist Charles Morris to his explanations of design, likening design, or at least applied design, to language. Indeed, both possess the same three basic components: the syntactic component, the semantic component, and the pragmatic component: that is to say, structure, meaning, and function. Differently to applied design, which is essentially linked to architecture, graphic design, and industrial design, *basic design* is purely concerned with the syntactic component or 'structure'. Now, 'structure' may be defined as the 'organization of different parts'. Two terms, therefore: 'parts' (or 'elements') and 'organization' (or 'relationship'). System and structure are interchangeable in practice, albeit that the former evokes a notion of dynamism and the latter a notion of staticity. In mathematical language, which constitutes a special way of describing structures, we use the terms 'members' and 'operations' [Huff 1984, pp. 36-37). Hence, some of the exercises that Maldonado assigned to his students displayed a key characteristic which consisted in the fact that the repeated component, once defined, would generate a particular kind of image (Neves and Rocha 2013).

In this way, Maldonado taught his students how to explore the relationships among, and organization of, the components of a structure (the overall image, the whole) and how to explore a structure composed of individual elements.

In his exercises, he used colour to identify any of the three compoments of the language of design listed above by William Huff. Depending on the exercise assigned, colour could be used as a syntactic component, that is, as an element communicating the structure of a figure/image. Or colour might be used to highlight the element making up a structure (form). Or, finally, as a component that was pragmatic and functional to the message that was to be conveyed (function). Colour was thus understood to be a variable within the system of signs or signals with which information may be communicated and visually encoded.

To better exemplify how these exercises were executed in practice, the next figures display the products of four actual practical assignments carried out by three of Maldonado's students (Fig. 5 - 6 - 7 and 8): Dominique Gillard and William Huff in 1955-56 and Urs Beautler in 1956-57.

The images in Fig. 5 reproduce an execution by the student Dominique Gillard, of Exercise No. 1, entitled "Sierpinski's surface" (Sierpinskifläche). Maldonado used this exercise to introduce students to the theme of the relationship between full spaces and empty spaces; and to how these spaces are visually perceived and understood by the observer when four shades of the same chromatic hue are used to make explicit the functions of full versus empty space. Thus, in the example shown, each set of same-sized triangles was assigned one of the four shades of blue (from the smallest to the biggest and vice versa). The different patterns thus created provide the observer with a perception of the different triangles as empty spaces or full spaces, depending on how the shades of colour were arranged.

The task assigned to the students was to construct a geometrically derived surface by applying the mathematical formula for Sierpinki's triangle, invented - as its name suggests - by Waclaw Sierpinki in 1915. Construction of this figure begins with an equilateral triangle, whose internal space is divided into four equal parts so as to generate four smaller equilateral triangles. This operation can be iterated recursively such that each new triangle can generate four more and so on.

The choice of Sierpinki's triangle for this exercise is intended to pave the way for interdisciplinary teaching/learning: it is a fractal geometric form derived from the application of a mathematical formula; its replication gives rise to a surface; the addition of chromatic colour schemes can produce different visual perceptions of this surface, thus enabling the communication of alternative messages.

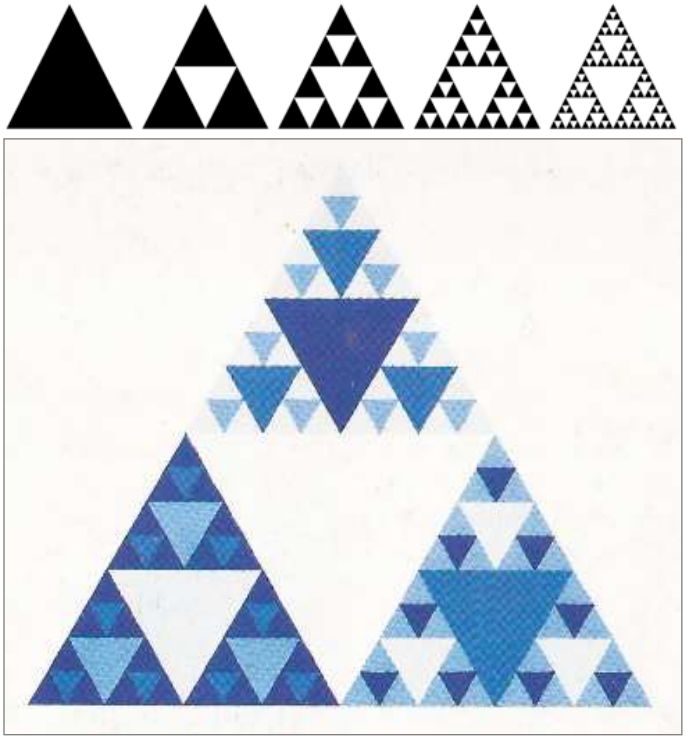

Fig. 5. – Practical exercises with "Sierpinski's surface" (Sierpinskifläche)*, a.a. 1955-1956, lecturer: Tomás Maldonado, student: Dominique Gillard, source: HfG-Archiv/Museum Ulm.*

Fig. 6 offers a worked example of Exercise No. 2, again executed by Dominique Gillard, and entitled "Peano's surface" (*Peanofläche*): These images were created by applying the curve theorized by the Italian mathematician, logician, and applied linguist, Giuseppe Peano, in 1890. A Peano curve is defined as a continuous line that is generated by joining all the points on an orthogonal grid situated on a given plane. Again, this exercise was based on multiple iterations of the basic Peano curve sequence. The first image in Fig. 6 is a line drawing of a surface defined by a structure. This structure, as stated, was generated by recursively repeating the primary Peano curve sequence, in order to trace a continuous line with only one start point and one end point, as an expression of the tension between the finite and the infinite.

In this drawing, the dark/light contrast was then used to highlight the basic sequence, then used to create the structure in the second image. The latter was coloured and defined using graduated shades of two chromatic colours: blue and red. The use of the orthogonal grid in both images was of crucial assistance to the student in planning how to lay out and vary the basic sequence across the plane. The differential shading of the two colours produced two geometric figures. The student's primary focus was on attempting to make these two figures equivalent, such that neither could be defined as the main figure and neither as the background figure.

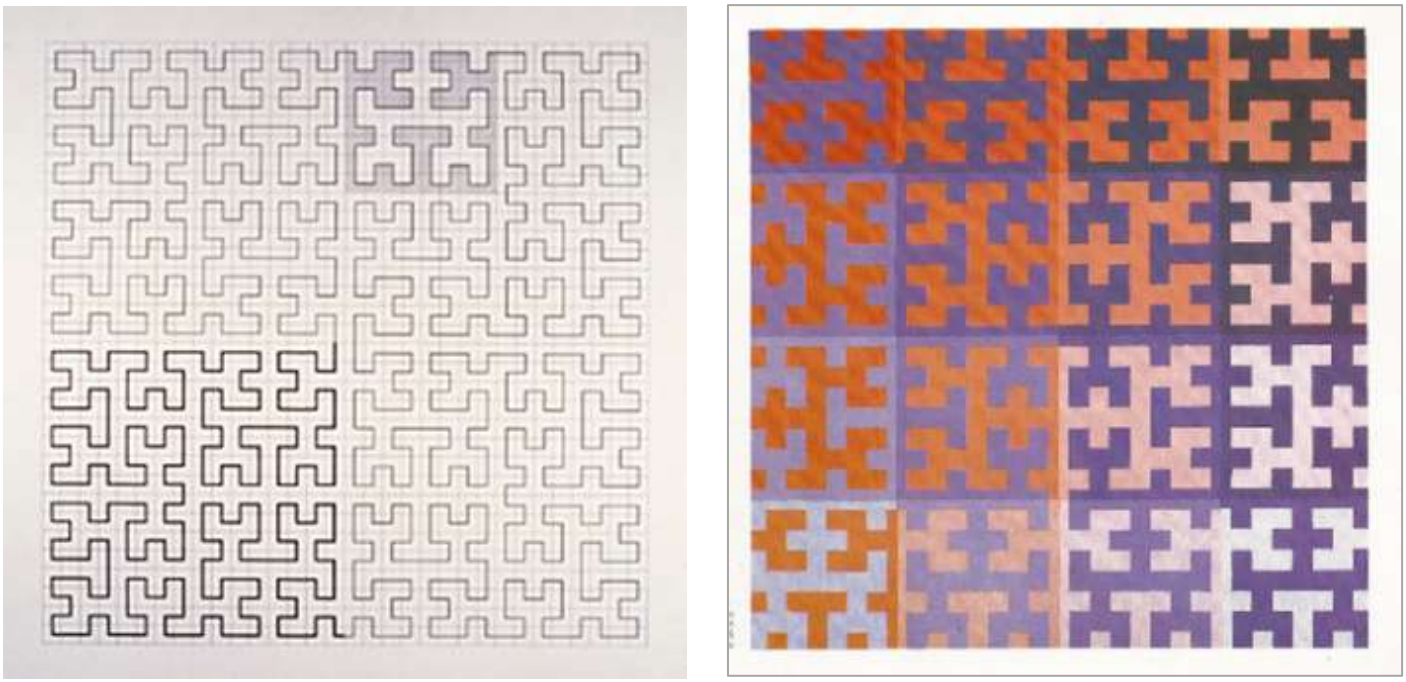

Fig. 6. – Exercises performed using "Peano's surface" (Peanofläche), academic year 1955-1956, lecturer: Tomás Maldonado, student: Dominique Gillard, source: HfG-Archiv/Museum Ulm.

It has been shown that ambiguity is best achieved by using colour values with the same intensity of light and luminosity value, or complementary colours with the same degree of luminosity. In this exercise, the Peano curve was used with a specific teaching purpose in mind: Maldonado chose this curve as a basic figure to work on with a view to fostering rational creativity. Creativity, in that this form was already a recognized artistic phenomenon; and rational because the use of the orthogonal grid was an effective means of encouraging a rigorous approach to the design and execution of the exercise.

With regard to Exercise No. 3, entitled "Weierstrass curve" (system weierstrass o weierstrasskurve), for which no worked examples could be sourced, this too involved using a linear geometric construction, namely a Weierstrass curve, to create a figure out of empty space. The educational purpose of this exercise was to address the visual perceptual problem of the relationship between foreground and background figures, a theme that was very important to Maldonado.

The image in Fig. 7 exemplifies Exercise No. 4. entitled "black as a colour" (Schwarz als farbe) and was executed by Urs Beautler. This practical focused on the use of black in the context of chromatic colours.

Here, Maldonado's teaching aims were to "train" the students' visual perception, refining their ability to visually discriminate between colours and to pick out certain tonal values from a set of chromatic interactions. The exercise on black as a colour was based on a combination of contrasting levels of brightness, such that black is not perceived as generating a "hole" effect but functions as a colour. Correct solutions showed that black, when featuring among set of solid colours, could be perceived as "brightened" and as a colour in its own right.

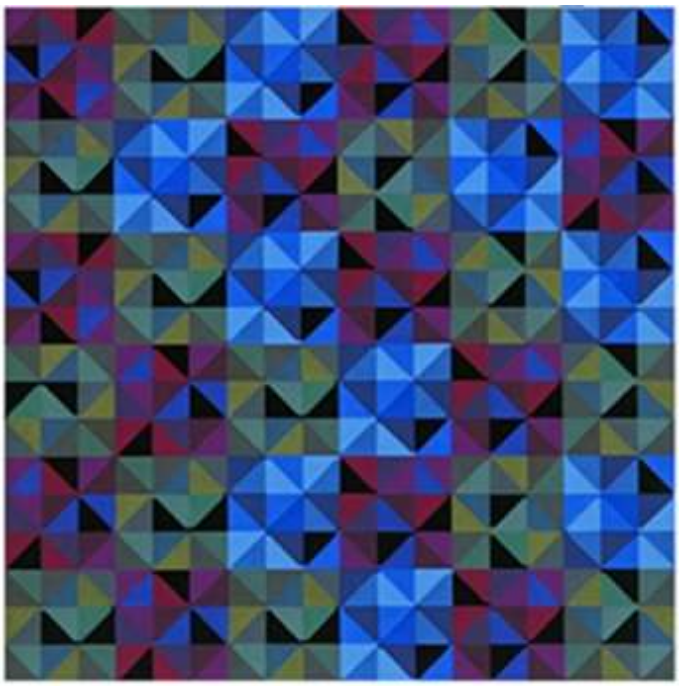

Fig. 7. – Exercise in "Black as a colour" (Schwarz als Farbe)*, academic year 1956-1957, lecturer: Tomás Maldonado, student: Urs Beautler, source: HfG-Archiv/Museum Ulm.*

Again, this representation was produced via a recursive pattern of geometric shapes on a square base: starting

from an orthogonal grid formed by minimun sixteen squares, each square was divided in half diagonally. The underlying grid allowed the students to rationally plan out the horizontal, vertical, or rotational patterns they wished to create, by applying the laws of symmetry.

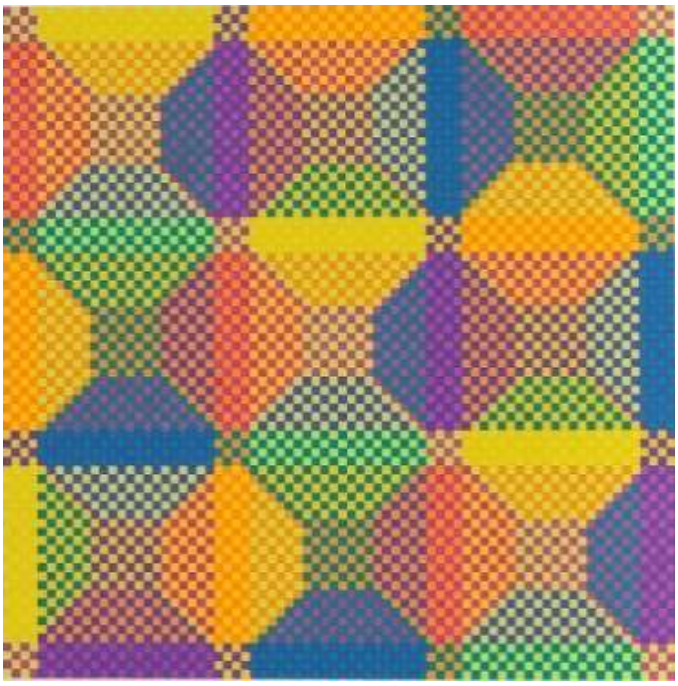

Fig. 8. – Exercise No. 7 "Non-exact - exact" (Ungenau-Genau), *academic year 1955-1956, lecturer: Tomás Maldonado, student: William Huff, source: HfG-Archiv/Museum Ulm.*

Fig. 9. – Tomás Maldonado, teaching at the HfG Ulm, 1954, with Hans G. Conrad, Almir Mavignier, Martin Krampen and one more student, source: Photograph by Sigrid von Schweinitz Maldonado, © HfG-Archiv/Museum Ulm.

The image in Fig. 8 shows a worked example of Exercise No. 7, executed by William Huff. Entitled "non-exact - exact" (Ungenau-Genau) by Maldonado, in this practical, the students were invited to create an image by innovatively applying the technical means at their disposal to work with conventionally accepted formal elements of colour, texture and consistency.

With regard to the program of HfG courses in Theory of Colour specifically, the names of some of the non-permanent lecturing staff who taught on this module were listed by Herbert Lindinger in a piece written for the *La scuola di Ulm* exhibition catalogue. Hence, we find Aemilius Muller as lecturer in "Theory of Colour" between 1954 and 1955; Mervyn W. Perrine as lecturer in "Theory of Perception" from 1958 to 1961; and Fritz Seitz as lecturer in "Theory of Colour" between 1967 and 1968 (Lindinger 1988, p. 40 and pp. 280-282).

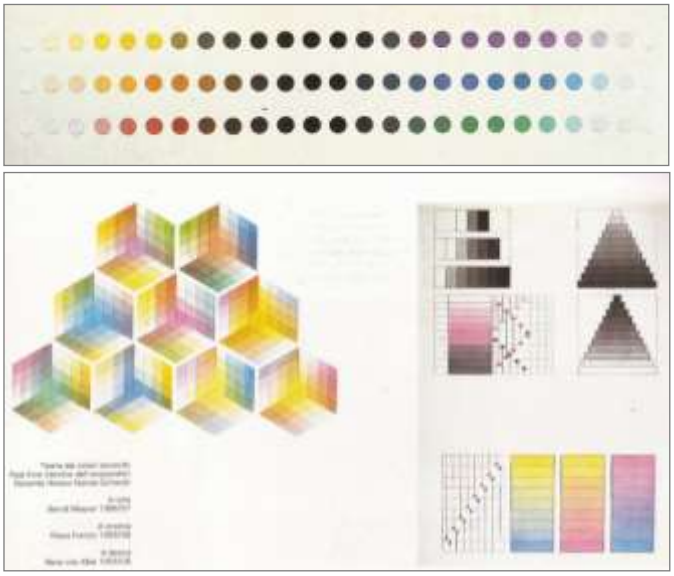

Fig. 10. – These watercolour drawings represent Paul Klee's theory of colours as interpreted by three students at the HfG: top: Bernd Meurer 1956/1957, left: Hans von Klier 1955/56 and right: Klaus Franck 1955/56, lecturer: Helene Nonné-Schmid, source: HfG-Archiv/Museum Ulm.

The Figure 10 documents three practical exercises in colour carried out by HfG students: Top: Bernd Meurer (1956/57), left: Hans von Klier (1955/56) and right: Klaus Franck (1955/56). These watercolour drawings were executed as part of the course in colour theory taught by Helene Nonné-Schmidt, an ex-Bauhaus student who had taught colour alongside Josef Albers, albeit with different educational objectives. The task assigned to students was to interpret Paul Klee's theory of colours. These three drawings are highly representative of the methodological approach adopted by Helene Nonné-Schmidt during the courses she taught at the HfG from 1953 to 1958. This approach reflected her Bauhaus

training, and stands in contrast with the innovative scientific approach adopted by Tomás Maldonado to initiate his students into the culture and theory of colour.

7. Conclusions

This article documents the brilliant educational work of Tomás Maldonado while a teacher at the famous HfG in Ulm. The key pedagogical challenge that he pursued was to develop an innovate method of teaching design that was informed by the scientific method and an interdisciplinary and transdisciplinary approach.

We have drawn here on the abundance of material held in the HfG Ulm archives (*HfG-Archiv/Museum Ulm)*, together with Maldonado's former students' written accounts of the teaching contents and methods that characterized his courses at the HfG, to present his perspective on teaching design and at the same time to note the pioneering nature of his ideas. With the aim of fostering the teaching and learning of new design competences, he developed a novel educational method that influenced how design was taught in a number of different countries around the world.

Among the subjects that he taught at the HfG, we have focused on the Visual Methods module that he delivered as part of the first-year Foundation Course. Even more specifically, we have homed in on the theme of educating to colour as a strategic cultural aspect of designing visual communications and other design products.

The practical work produced by the students who attended Maldonado's classes in Visual Methods offer unique and extraordinary examples of the innovative nature of his teaching experiments with respect to other contemporary approaches. The new principles that he formulated and introduced at the HfG, beginning in 1955, combined scientific method with mathematical calculations and emerging new discipines such as ergonomics, visual communications, signs theory and information theory.

In relation to his teaching of colour more specifically, we have observed that it was aligned with his overall educational approach, with a similar emphasis on scientific method, interdisciplinary and transdisciplinary input, and new Gestalt studies on visual perception. His theoretical classes on colour drew on analytical studies and applications of logic, as well as constantly appealing to geometry, discrete mathematics, and set theory.

Among the practical activities described here, some are extraordinary examples of complex aesthetic-formal exercises based on mathematical formulas, the theory of symmetry, early cybernetics concepts, and early versions of fractals such as the Sierpinski triangle and the Peano/Hilbert curve.

In sum, thanks to the contribution of Tomás Maldonado, the Ulm school in the 1950s saw the emergence of a new pioneering perspective on design and the role of the designer as well as on how the process of designing and producing products was likely to be in the future. In those years, there was still no mention of environmental sustainability, but Maldonado's approach laid the theoretical ground for the introduction of environmental design by virtue of his principle of "cooperation among disciplines".

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9. Statement on conflict of interest

The author declares that no conflict of interest, real or potential, including financial or personal links with other persons or organizations, up to and including the three-year period following the presentation of this work, that could inappropriately influence the reported research outcomes.

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