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Dancers, musicians, circus artists, and athletes have at least two things in common: they have to perform well in high-pressure situations and face challenging physical demands. There is barely any time to recovery, which makes performing artists and athletes prone to injuries due to overload. To reduce health problems and to optimize athletes' and artists' health and performance, Codarts Rotterdam (university of the arts) together with RASL has launched the PErforming artists and Athlete Research Lab (PEARL). This research centre received a grant of 1.7 million euros which was obtained from the National Association of Applied Sciences (Nationaal Regieorgaan Praktijkgericht Onderzoek SIA). Dance companies, orchestras and sport teams all support the importance of PEARL, because health problems can lead to discomfort, medical treatment, and inhibit talent development due to absence from rehearsals or training practice. In extreme cases, athletes and artists have to end their career due to health problems.

Eight fieldlabs with state-of-the art equipment
PEARL consists of several field labs: the departments of Music, Circus and Dance of Codarts Rotterdam, Feyenoord Academy, Dutch National Ballet, Scapino Ballet, Rotterdam Philharmonic Orchestra and Circusstad Rotterdam. The research projects of PEARL are carried out in these field labs, which contains state-of-the equipment to screen and monitor the health of performing artists, and athletes. Data is collected under supervision of embedded scientists and translated into relevant information for performing artists, athletes, and their staff. An online web-based system (Performing artist and Athlete Health Monitor: PAHM) was developed by Codarts Rotterdam to facilitate this process. PAHM enables dance companies, orchestras, sport teams and universities of the arts to collect and analyse data on health problems of their artists and athletes. The tool automatically sends surveys to the respondents, stores the data in an encrypted database and visualises the results in a dashboard. Currently, more than 1,000 performing artists and athletes use PAHM to monitor their health, resulting in the biggest data set worldwide targeting athletes' and artists' health.

Bridging gaps

PEARL is the first research centre in the world linking performing arts, sports, education, science and businesses. The PEARL research team consists of ten scientists with expertise in the field of human movement science, physiotherapy, dance science, exercise physiology, sport psychology, big data science, software engineering, and qualitative research. In addition,

the PEARL consortium consists of ErasmusMC, VUmc, Hogeschool Rotterdam, Nationaal Centrum Performing Arts (NCPA), Nederlandse Vereniging voor Fysiotherapie in de Sportgezondheidszorg (NVFS), het Nederlands Paramedisch Instituut (NPI), and Johan Sports, Sportgeneeskunde Rotterdam. Combining these different fields of expertise is necessary to tackle the complex problems that are currently investigated in the different PEARL research projects.

Examples of PEARL projects

Several PhD students conduct research at PEARL.

Examples of these projects are:

1. Monitoring the health of performing arts students: This project focuses on the physical and mental health of students enrolled in five Codarts bachelor programmes (Dance, Dance & Education, Circus, Musical Theatre and Classical Music). The aim of the project is to gain insight into the amount, risk factors and preventive measures regarding injuries, illnesses and mental complaints of the Codarts bachelor students.
2. Injuries in pre-professional dancers, a performance psychological approach: This project investigates the association between mental factors and injury risk. Furthermore, it focuses on the influence of injuries on mental health of injured dancers and takes a closer look at the role of mental factors in the 'return to perform' process.
3. Big data and injury prevention: During training and matches, athletes wear sensors to monitor the heartbeat, distance, and speed. These data may play an important role in finding the right balance between load and load capacity. However, analysing these data is a major challenge for coaches and their staff. In dance, these data are not collected on a large scale yet. This project is the first study that bridges the gap between sport and dance science. The aim of this project is to collect sensor data of multiple sport teams and dance companies. State-of-the art computer science techniques are used to analyse the big data sets and identify possible risk factors for health problems in athletes and dancers.
4. Nutrition: There is a lack of studies focussing on the association between nutrition and injuries. This project investigates whether low protein intake is associated with an increase in injury risk in circus artists and dancers.

From knowledge to practice

Both universities and universities of applied sciences are part of the PEARL consortium, which gives the opportunity to bridge the gap between fundamental knowledge and applied science. PEARL even has a higher ambition and wants to translate gained knowledge into practical tools. For example, the PEARL research team collaborates with the Dutch National Ballet, and the Scapino Ballet to develop new monitoring tool to measuring dancers' workload. Several research questions are

addressed including “How do you measure endurance in dancers?”, and “Do dancers with low endurance have an increased risk for sustaining an injury?”. By collaboration with entrepreneurs, these new insights are translated immediately into practical tools. For example, sensors measuring load management in athletes will be used to measure total distance, accelerations, decelerations in dancers during a performance. This enables sensor developers to validate their tools in a new market leading to new potential customers.

From knowledge to improving education
The new tools and insights give the collaborating dance companies insight into the minimal endurance levels needed for dancers to perform certain choreographies. Dancers with low endurance levels receive tailor-made rehearsal programmes. Furthermore, PEARL encourages the dissemination of knowledge via workshops, masterclasses and presentations. In addition, the education programme of Codarts Rotterdam will be further developed based on the new insights gained via the research projects of PEARL. This all serves the ambition of PEARL to make an important contribution to better performances, injury reduction and optimisation of the health status of athletes and artists.

Bridging the Gap: Trans/disciplinary Practices in the Age of Climate Change

When talking about the relation between the arts and sciences one cannot ignore the groundbreaking lecture by the British novelist and scientist C.P. Snow, in which he criticizes the strong division between what he calls “the two cultures”. (Snow, 1959) Snow concluded that the intellectual life of western society was radically split in two cultures, with the sciences on the one side and the arts/humanities on the other. With an eye for detail he describes the different worlds of his scientific and literary friends, occasionally peeking over the walls of their separation, only to retreat as fast as possible to their own worlds: “there seems to be no place where the cultures meet”. (Snow, 1959) According to Snow both parties are “self-improving” themselves with this strong division, but are also shaping a hindrance to solving the world’s problems. “At the heart of thought and creation we are letting some of our best chances go by default”, he claimed, concluding that “there is only one way out of all this (...) by rethinking our education”. (Snow, 1959)



While Snows’ lecture proves that this pivotal discussion already dates back to the 1960s, and while one can trace a history of artistic experiments in art/science relations from the 1960s and 1970s all the way up to the present, it’s surprising to note how long it took before these concerns were taken up as a serious challenge for education. In the 1990s *Leonardo*, an international magazine on the use of contemporary science and technology in the arts, concluded that “in a multidimensional universe created by science and technology, art educators still teach what used to

be (...) Although new areas of interface between art, science and technology are sprouting up all over the world, the vast majority of institutions are only adding new media to old structures.” (Sheridan, 1990, p. 165)

Entering the 21st century, luckily things have changed for the better in several respects. Internationally, within higher art and design education interdisciplinary curricula and master programmes have been and are being developed, while secondary and vocational education seems to be lacking behind somewhat in this development. At universities one can witness a proliferation of new study paths, and an increase of interdisciplinary and multidisciplinary education already at bachelor level. University colleges and other variations of liberal arts and sciences are growing.

In the Netherlands this recently led to the concern, voiced by “The Young Academy”, a platform of five young KNAW-researchers in *NRC*, that students are not grounded enough anymore in disciplinary knowledge. According to them an interdisciplinary approach has an added value, but should not go at the expense of existing disciplines. 1

Acknowledging that finding the right balance is important, what seems to be really at stake considering the above, is not only the renewal of education within art academies on one side and universities on the other side, but the efforts of cutting through the duality of the education system by means of founding new research consortiums across both worlds. Both the Rotterdam Arts & Sciences Lab (RASL) and the Amsterdam Research Institute of the Arts and Sciences (ARIAS) are examples of this. 2 These cross-disciplinary consortiums aim at intersections, encounters and collaborations between artistic research and research in the humanities and social sciences. The collaboration between artistic research and other disciplines aims to shape debates, raise alternative research questions and sketch speculative horizons of research, contributing to urgent research questions connected to the urban environment, new forms of education and “critical making”, digital and techno-scientific culture, climate change and migration.

This might seem to be an overly ambitious agenda at first sight, and a certain sense of modesty and realistic perspective on what one is effectively able to contribute to these so-called “wicked problems”, is certainly at place. This article nevertheless will try to argue that we live in a time, which asks us to think across disciplines as an inevitable new reality. Taking climate change as an example, this article explores how the urgency of this topic has resulted in an international discourse amongst academics and cultural practitioners alike about the necessity of thinking across the arts-sciences divide and

develop new transdisciplinary practices. 3 While international scientific publications from different academic disciplines are putting this subject up for debate, artists and designers are already exploring transdisciplinary practices in response to climate change *in practice* for over a decade. Studying these practices might help us to not only get an idea about how arts-sciences collaborations work or are being played out in practice, but also how they might inspire educational, curricular developments in the future.

From matters of fact to matters of concern

Before I write more on how and why climate change as a many-headed monster urges us to think differently about disciplinary divisions, I'd like to take a small detour to recent developments in philosophy. Within critical philosophy and the philosophy of science, several contemporary philosophers and academics, amongst others Karen Barad, Bruno Latour, Isabelle Stengers, Donna Haraway and Anna Lowenhaupt Sting have already successfully complicated as well as neutralized the disciplinary divide between the arts and sciences. 4 They have put decisive arguments on the table against the division between the arts/humanities and the natural sciences as radical different knowledge epistemologies. Each arguing in their own way for a new kind of realism, which transcends the classic object-subject dualism into making a shift "from matters of fact" to "matters of concern", as framed by Latour (2004a). According to Latour we have to start thinking in terms of "multiplicity", not in terms of "subtraction". (2004a, p. 232)

A researcher is not the one "who debunks, but the one who assembles [...] the one who offers the participants arenas in which to gather". (Latour, 2004a, p. 246) In other words: the arts, as a wide variety of aesthetic and creative practices, and the sciences should be seen as *multiple and situated* rather than *singular and universal*. (Latour, 2004b, Gabrys and Yussof, 2012, p. 16)

Although one might think this is typically a kind of plea originating from the humanities, both Isabelle Stengers and Karen Barad build up their arguments starting from the "hard", natural sciences – Stengers studied chemistry and Barad holds a doctorate in theoretical physics. Karen Barad (2007) coined the by now famous concepts "agential realism" and "intra-action". Inspired by the study of quantum physics she claims: "We are not outside observers of the world. Neither are we simply located at particular places in the world: rather we are part of the world in its ongoing intra-activity". (Barad, 2007, p. 184) According to Barad subject and object do not pre-exist as such, but emerge through intra-actions. Instead of privileging one discipline and reading others against it, we should think in terms of "transdisciplinary

engagement” and attend to the fact that boundaries between disciplines are not pre-set but actively constructed. (Barad, 2007, p. 91) Being part of a material-discursive practice the boundaries between disciplines can be questioned: *“Practices of knowing are specific material engagements that participate in the (re)configuring the world. Which practices we enact matter – in both senses of the word”*. (Barad, 2007, p. 91)

Similarly according to Stengers science is much more than gathering facts and data and she describes the dichotomy between “matters of fact” and “matters of concern” aptly as follows: “Every scientific question, because of its vector of becoming, involves a responsibility”. It calls on “one’s capacity to feel: the capacity to be affected by the world, not in a mode of subjected interaction, but rather in a double creation of meaning, of oneself and the world.” (Stengers, 2000, p. 148; Gabrys and Yusoff, 2012, p. 18). Also Stengers questions the idea of having strictly defined boundaries between disciplines, and instead favours the idea of what she calls “an ecology of practice.” Disciplines and practices are not static, there are always “new possibilities for them to be present, or to connect. It does not approach practices as they are [...] but as they may become.” (Stengers, 2005, p. 186)

The cultural turn in climate change research

The above described recent views in critical philosophy are not only concerned with contesting the object-subject duality in scientific research, but along with it other deeply ingrained dualities inherited from humanism such as nature-culture or human-non-human, as well. It therefore comes as no surprise that particularly a “wicked problem” such as climate change, challenges our thoughts about the arts-sciences debate. Particularly recent years scholars have called for “strengthening the integration of social sciences and the humanities in the global environmental change research”, and in the context of this article even more important: for an overall “cultural turn” in climate change studies and action. (Galfassi, et al. 2018, p. 72) I would like to single out two lines of argument in this discussion. One displayed in an article entitled: “‘Raising the Temperature’: the Arts in a Warming Planet” co-written by a large number of authors from different universities, the main author being affiliated to the Stockholm Resilience Centre (Galfassi, et al., 2018). And one displayed in two articles co-written by Jennifer Gabrys, professor at the Department of Sociology at Goldsmiths and Kathryn Yusoff, professor at the School of Geography, Queen Mary University of London. (Gabrys and Yusoff, 2011, 2012)

Gabrys and Yusoff start off with the premise that “... climate change is as much a political, social,

and cultural event, as it is a scientific one". (Gabrys and Yusoff, 2011) This is underlined by the authors of the other article stating that: "as climate change impacts biophysical, social, economic and political systems, is best seen not solely as a technical problem but as a challenge requiring cultural, adaptive and creative responses." (Galafassi, et al. 2018, p. 71) A concentration on scientific, technological and economic approaches to climate is replaced by an attention to climate as a dynamic, cultural and societal force. In other words, according to both viewpoints climate change is being re-imagined as an ethical, societal and cultural problem.

The collective concludes: "The multifaceted challenges of climate change cannot be addressed by science alone (...). Improving societies' capacities to respond to climate change requires an open and engaging transdisciplinary process with large and diverse populations and reimagining public goals." (Galfassi, et al. 2018, p. 73) Based on literature research they list an extensive set of possibilities of the potential role of the arts in climate change transformations. They mention for example: creative imagination and serendipity; story telling; exploring futures imaginatively; science communication and possibilities for political engagement; pre-figuring potential futures through direct action; transdisciplinary learning processes of knowledge integration; awareness of more-than-human worlds and the embracement of social-ecological complexity. (Galfassi, et al. 2018, p. 74) The authors also witnessed a significantly increased activity of artists engaged with climate change from the late 2000s onwards. They conclude that "Art in climate transformations is best seen as an open inquiry process, unconstrained by standard scientific methods, and involving not just artists and scientists but also communities and change agents across multiple domains of action" (p. 77), but the article does not dive any deeper in the material specificity or differentiation of these practices, nor does it provide examples of artists or designers attached to it.

This is where Gabrys and Yusoff make a difference, providing several examples while making the processes behind the artistic practices more tangible. According to them the imaginative practices of the arts and humanities play a critical role in thinking through the representations of environmental change. But rather than reducing the arts to a process of social learning they pay attention to the mutual and equivalent exchange of the arts and sciences. Arguing against "deculturing" climate change they conclude: "Rather than define arts and sciences as separate disciplines in need of intersection, however, many new creative and scientifically informed practices are emerging that focus especially on new

opportunities for political participation and public engagement with climate change". (Gabrys and Yusoff, 2011) They describe three characteristics of these "new cultures of climate change" in the arts and design: firstly the imagination of the future of climate change; secondly the ability to develop adaptive strategies that can be embedded in everyday practice, and lastly: the critical engagement with the practice of climate science. (Gabrys and Yusoff, 2011)

Speculation, science/fiction

The first example they mention of "the new cultures of climate change" is futurity. As an area of study futurity has received increasing attention in climate change studies, particularly in relation to risk management and scenario building. But according to Gabrys and Yusoff not enough attention is paid to cultural and creative methods of environmental imagining, as well as how the arts and humanities play an important role in thinking through representations and images of climate change and giving tangible form to the imagination of different worlds. "Climate futures require approaches not only characterized by calculability and risk but also imaginative acts that open new spaces and practices for dealing with the effects of uncertain futures". (Gabrys and Yusoff, 2011) According to them fiction, as opposed to rational approaches, can show us a changing world and to "experience it's dislocation across social, cultural and emotional registers". (Gabrys and Yusoff, 2011) Predictive methodologies of climate science policy differ markedly from materialist forms of knowledge. This is more akin to the descriptive arts of the humanities, in the production of probable, preferred, or hoped for futures, challenging us to recognize the changed conditions of climate change.

Gabrys and Yusoff give different examples of science-fiction literature to illustrate this aspect, but don't mention the interesting developments in and examples of speculative research and storytelling in arts and design practices. Speculative design for instance is seen as a means of speculation how things could be, aiming to open up new perspectives on so-called "wicked problems". By speculating designers re-think alternative products, using fiction and speculation on future products, services, systems and worlds, thereby initiating a dialogue between experts (scientists, engineers and designers) and users of new technologies or products (the audience). Speculative designs find part of their inspiration in science fiction, which has a long history of creating imaginary scenarios with which audiences closely identify. It is a strategy applied within design, but is also integrated in the art field, and alludes to hybrid practices.

An example of this is for instance the work *Ecosystem of Excess* (2014) of the artist, researcher and designer Pinar Yoldas. Yoldas studied Media Arts and Sciences, Cognitive Neuroscience as well as Information Technologies and Visual Communication Design, and this multi-disciplinary background can be clearly recognized in her work. Her work *Ecosystem of Excess* is inspired by scientific research on the so-called “plastic soup”, the Great Pacific Garbage Patch and the speculative presumption how life would evolve if it started in contemporary oceans polluted by micro plastics. Inspired by real-life bacteria that can metabolize plastics, Yoldas envisions and designs plants, insects, reptiles, fish and birds, and gives them organs to interact with their plastic environment. An example of this is the so-called petrogestative system, a digestive system specialized in crumbling hard plastics to allow their absorption. With *Ecosystem of Excess* Yoldas shows us an eerie laboratory with future species and organs. Moving in between digital technology, speculative design, biological sciences and constructing installations as well as sound and video pieces, Yoldas has coined the term “speculative biology”. According to her speculative biology is a form of artistic research, which involves the design of tissues, organs, organisms and biological systems in order to “catalyze creative critical thinking, thereby addressing the narrow scope of contemporary art”. (Yoldas, 2016)

Re-locate-ing and re-public-ing climate change

A second example of a new culture of climate change described by Gabrys and Yusoff is the “acceptance for the need of adaptive strategies that can be embedded in everyday practice”. (Gabrys and Yusoff, 2011) Practitioners and researchers within art, design and architecture focus on climate change not as something “out there” but “in here”, entangled in contemporary local practices. If future imaginings can be thought as a process for developing adaptive capacities and emotional resilience within changed environments, adaptation strategies offer a pragmatic alternative through iterative and local everyday practice. The built environment, land use, urban agriculture, and infrastructure – the city, the community, and the scaled down unit of the home – are sites for adaptation proposals and projects, not just at the level of planning and engineering, but also through creative practice and climate-change imaginaries.

Gabrys and Yusoff provide several examples of artistic practices in this direction, mentioning the work of the New York artist May Mattingly, the British artist Nils Norman and the notorious American activist collective The Yes Men. In the context of this article I would like to single out a

work of the design collective Superflux. Superflux is a speculative design studio, which creates stories to confront the spectator with the instability of a changing world. In their installation called *Mitigation of Shock* (2017) they aim to show what our lives might be like, if we do nothing to combat global warming by taking us into a flat in London – in the year 2050. Walking through the installation the visitor gets various cues, which refer to a time of extreme weather, poor air quality and world crop failures. The people living in the apartment are forced to experiment with artificially growing their own food from mealworms and plants to oyster mushrooms, which means that half of their apartment is turned into lab setting. As Jon Ardem, one of the two founders of Superflux explains: “The disconnection between scientific, data driven predictions of global warming, and the lack of immediately visible signs contributes to a space of cognitive dissonance [...] But it is also a space which offers the opportunity to confront our fears, to experiment with ways in which the shocks of the impact of climate change can be mitigated. [...] **We want to conduct experimental design responses to first world disasters that are likely to happen in the near future, by prototyping alternatives today. Tools, methods, materials and commons that individuals can learn, use and share in order to gain agency and capacity to mitigate the shock of climate change.**” (Arder, 2016) *BuggyAir* (2016-ongoing) is another project they developed, which goes back to a different principle. It is an air pollution sensing kit that parents can mount on their bike to measure how much air pollution their children are subjected to. With a team of designers, researchers and technologists and experts of air quality they built a set of 10 sensors kits distributed around parents in London measuring, monitoring and collecting data regarding their children’s exposure to specific air pollutants.

This is closely related to the third example of a new culture of climate change Gabrys and Yusoff refer to, namely the notion of citizen science. The topic of environmental data is often seen as an area of scientific concern. Empirical study produces observations and measurements that enter data infrastructures, which are the basis for scientific understanding and policy decisions. Yet an increasing number of creative practitioners are working with data, not just to visualize or sonify data in the context of arts-sciences collaborations, but also to question what constitutes data, to experiment with how data are produced, and to recast the relationships that are articulated through data. Using visual and design strategies, artist and designers make use of a form of “radical empiricism”, trying to uncover and make public what remains hidden for the general public.

As Gabrys and Yusoff describe: “Creative practitioners are now seeking to expand modes of climate science production to reconsider the social spaces of climate interaction at the science-policy-public interface [...]. The artistic projects rework the scale and site of data and data generation, from the remote to the intimate”. (Gabrys and Yusoff, 2011) The visualisation of and sonification of climate data allow for new points of entry and connection within and through the data. Examples of artistic and design practices in this direction abound. One of the interesting examples Gabrys and Yusoff mention is the artist duo Gavin Baily & Tom Corby. Their recent work includes the use of meteorological and geological information about the climate, in order to visualize the hidden aspects of environmental sites and landscape, and to produce speculative geographies and experimental maps. At the heart of this work is an interest in data, employed as a medium beyond a conventional analytic approach, stressing its critical, experiential and affective potential. *The Northern Polar Studies* is a large-scale screen-based installation, which uses data sets from drifting buoys and satellite measurements of Arctic sea ice. This data has been used to model the retreat of the Arctic going back to the 1980s by examining the age and distribution of sea ice. In animating this data visually, the work reveals phantasmagoric three-dimensional shapes and figures visualizing the landscape of environmental ruination over an extended time period.

Another earlier example I would like to mention is the project *Feral Robots* (2005) by the artist and engineer Natalie Jeremijenko, who studied biochemistry, physics, neuroscience and precision engineering. *Feral Robots* is an open source robotics project designed to enable distributed and co-located teams of lay participants to ‘upgrade’ low-end commercially available toys with chemical sensing equipment, additional microprocessor hardware to enable environmental data collection and coordinated flock (or pack) behaviour. The adapted robots ‘sniff out’ environmental toxins, that is, they follow concentration gradients of toxins sensed by their dog’s noses. Not dissimilar to popular robot wars events, this project instead involves the release of ‘packs’ of feral robotic dogs that are designed and modified for release on sites of community interest, including public parks, school grounds and industrial sites.

The lab inside out

The practices mentioned above develop new forms of public engagement within climate science and politics. Engaging with climate change (beyond science) in multiple ways asks questions of sites, networks, knowledge, and practices of constructing, producing or invoking climate. Most importantly: the urgency of climate change seems

to give rise to new formations of practices at the intersections of arts and sciences. As Gabrys and Yusoff conclude: “In comparison to arts-sciences discourse that focuses on how to define these disciplines and demarcate their possible intersections, practices of arts and sciences in relation to climate change shift and relocate in new sites of shared concern – often outside the laboratory or the gallery.” (Gabrys and Yusoff, 2012, pp. 6,7) To conclude I would like to mention two examples of these practices being developed outside the laboratory and the gallery in which the arts-sciences relation is played out: the transdisciplinary studio and the importance of field research as part of artistic research in relation to climate change.

According to Bruno Latour nowadays we should talk about the ‘*the world-wide lab*’. By this he means to say that “since the sciences have expanded so much that they have transformed the whole world into a laboratory, artists have per force become white coats among white coats, namely all of us engaged in the same collective experiments”. (Latour, 2004c) Climate change unfolds in the world, beyond the confines of any single discipline or sealed laboratory space. The lab no longer operates as the ideal referent or even counter-referent for understanding practice related to climate change. According to Donna Haraway expanded definitions of collectives are needed also including nonhumans.

One remarkable example of laboratories turned inside out is the rise of the so-called “transdisciplinary studio” in the artworld. International artists such as Tomás Saraceno work together with interdisciplinary teams in laboratory kind of studio settings, and collaborate structurally with scientific research partners and centres. The former notion of the lab is appropriated and inverted into the model of an “ecology of practices” in which different disciplinary knowledges can be combined in often, complex research projects. Tomás Saraceno’s oeuvre could be seen as an ongoing research, informed by the worlds of art, architecture, natural sciences, astrophysics and engineering; his floating sculptures, community projects and interactive installations propose and explore new, sustainable ways of inhabiting and sensing the environment.

An example of such work is *Aerocene* (2017-present). *Aerocene* is an artistic project (and not-for-profit organisation) consisting of a series air-fuelled sculptures that will fly in the longest, most sustainable journey around the world without the use of fossil fuel. These emission-free floating sculptures, made from silver and transparent Mylar, are designed to travel around the earth without helium, batteries or solar panels. Instead, they glide on wind currents and are kept afloat by

solar and infrared radiation. As a researcher, Saraceno has collaborated with MIT meteorologists in the lab of the Department of Earth, Atmospheric and Planetary Sciences (EAPS), to study the jet stream and determine potential flight paths for his aerosolar inflatable's. But the work moves beyond the lab in every possible way, engaging a wider public to built and experiment with their personal *Aerocene Explorer*.

The fact that the scope of climate change is not limited to the laboratory; also finds its origin in the fact that next to climate models the majority of climate science relies on data gathering in the field, in remote areas. Following the so-called 'ethnographic turn in art', artists and designers have shown an increased interest in researching and representing less presented voices in the global discussion on environmental justice, engaging themselves in field research with local communities and indigenous cultures. Ursula Biemann is an artist, writer, and video essayist. Her artistic practice is strongly research oriented and involves fieldwork in remote locations where she investigates climate change and the ecologies of oil, ice and water. An example of this is *Forest Law* (2014), a project in which she collaborated with Brazilian architect Paulo Tavares. The project is based on research in the oil-and-mining frontier in the Ecuadorian Amazon— one of the most bio diverse and mineral-rich regions on Earth, currently under pressure from the dramatic expansion of large-scale extraction activities. At the heart of *Forest Law* is a series of legal cases that bring the forest to court in order to plead for the rights of nature. It tells the story of the indigenous people of Sarayuku who won one of these trials based on their cosmology of the living forest. The project emerges through a process of video-graphing their journey through Amazonia and the stories of the people they encounter, collecting diverse kinds of documentation, ultimately resulting in a multimedia art installation and an artist book.

Ecologies of practice

The intention of this article is to show how transdisciplinary practices in art and design responding to climate change, may indicate the ways in which the field of arts and sciences with respect to climate change undergo a transformation, both in their practices and subjects of study. Its intention also is to show how relevant these new intersectional practices are for the future of art and design education. How do we create educational spaces in which students are capable to learn how to emotionally and imaginatively respond to these kind of wicked problems such as climate change, while basing their experimentation on solid research? What kind of historical heritage or ethical consciousness – of

the scale of the problem and the intergenerational nature of it – do we teach our students? How can we teach them to think and design speculatively? How do we teach them, most importantly perhaps, how creative practice can do more than mediate science and instead bring into play new approaches to publics, science production and politics? Most and for all the wickedness of a problem like climate change forces us to think in terms of ‘ecologies of practice’ and multiplicity, progressively exploring and transgressing boundaries between artistic and design research and the other ‘sciences’.

Notes

1. Maarten Huygen, ‘Zorgen over snelle groei studies met losse vakken’, *NRC Handelsblad*, 25-3-2018.
 2. The Rotterdam Arts & Sciences Lab (RASL) is a collaboration between the Willem de Kooning Academy, Codarts Rotterdam and Erasmus University Rotterdam. The Amsterdam Research Institute of the Arts and Sciences (ARIAS) is a research platform by the Amsterdam University of the Arts (AHK), Gerrit Rietveld Academie, Amsterdam University of Applied Sciences (HvA), University of Amsterdam (UvA) and Vrije Universiteit (VU)
 3. >> explain the terminologies transdisciplinarity/interdisciplinarity
 4. See: Karen Barad, *Meeting the Universe Halfway. Quantum Physics and the Entanglement of Matter and Meaning*. Durham and London: Duke University Press, 2007;
- Donna Haraway, ‘Situated Knowledges: the Science Question in Feminism and the Privilege of Partial Perspective’, *Feminist Studies*, No. 3 (Fall 1998), 575 -599, 1998;
- Bruno Latour, *The Politics of Nature. How to Bring the Sciences into Democracy*. Cambridge (Mass.)/London: Harvard University Press, 2004;
- Isabelle Stengers , ‘Introductory Notes on an Ecology of Practices’, *Cultural Studies Review*, 11(1), pp. 183-106, 2005;
- Anna L. Tsing, *The Mushroom at the End of the World. On the Possibility of Life in Capitalist Ruins*, Princeton and Oxford: Princeton University Press, 2015.

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