Architecture, Urban Design, Planning and Urban Climate Interdisciplinary collaboration experiences in teaching and research

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ABSTRACT: This paper discusses collaboration experiences in teaching and research engaging architecture and urban design with related fields (meteorology, geography, medicine, civil and forest engineering), aiming to improve the understanding of the urban climate phenomena, to increase the quality of field measurements to raise local data and to refine the urban microclimate simulations. Concerning graduate teaching, thirteen years ago, a pilot interdisciplinary graduate course started at the Faculty of Architecture and Urbanism, focused on thermal comfort outdoors. To get there, it was necessary to include topics in urban climate, climate scales, solar access in urban areas, urban ventilation, the role of urban geometry, urban surfaces and green, etc., to address variables related to outdoor comfort indexes, both physiological and empirical. This course had graduate students from different backgrounds: architects and planners, meteorologists, geographers, forest and civil engineers, even medical doctors interested in the relation between comfort and health. One year ago, this previous experience derived a new elective discipline for the undergraduate course. At the same time, several partnerships, as the ones with the Atmospheric Sciences, Forest Sciences, and Geography departments, improved not only teaching, but also research activities. The outcome has been to prepare not only academics, but also professionals for architecture, planning and landscape architecture offices, for public administration and services, for NGOs, with emphasis in urban environment issues.

Keywords: outdoor comfort, urban climate, architecture, planning, urban design, interdisciplinary teaching experiences

INTRODUCTION
This paper discusses collaboration experiences feeding teaching and research, engaging architecture and urban planning with related fields like meteorology, geography, medicine, forest and civil engineering. The aim of this interdisciplinary approach was to improve the understanding of the urban climate phenomena, to increase the quality of field measurements to raise local data and to refine the urban microclimate simulations, for teaching and research activities in architecture and urban design field.

THE INTERDISCIPLINARY APPROACH
Interdisciplinary research enriches the knowledge field Urban Climate, especially after the International Association for Urban Climate – IAUC, formed in 2001, following a decision taken in 1999, at the International Conference on Urban Climate – ICUC, held in Sydney, Australia. Initially lead by Timothy Oke, the IAUC gather different knowledge areas around urban climate (http://www.urban-climate.org/). Historically Oke has been very active in this interdisciplinary approach, presenting to the students the acceptance level of the climate-oriented planning practices in Germany. On the other hand, more than three decades ago, he criticized the discipline “for failing to provide what decision makers needed — practical predictive tools that would enable them to configure green space, orient roads and buildings, and optimize the height-width ratio of street canyons in relation to climatic objectives such as thermal comfort, energy conservation or pollutant dispersal” (OKE, 1984).

For an urban climate interdisciplinary approach several contributions can be highlighted: 1) meteorology, contributing with the understanding of the interactions among soil, surface (vegetation and built environment) and atmosphere, even more increasing the micro and mesoscale models resolution; 2) fluid mechanics, contributing with CFD models; 3) urban forestry, adding the quantification of vegetation variables that impact on green infrastructure microclimatic potential; 4) geography, contributing with mapping and remote sensing techniques, and with urban approaches, more familiar to architects and planners than the meteorological ones; 5) biometeorology, formulating comfort indexes for open spaces, and 6) architecture and urban planning, contributing with qualitative and quantitative readings of the urban and building scale roles in urban climatic phenomena, integrating different scales from regional to buildings, encompassing physical, social, and environmental processes.

Part of the architecture and urban planning researchers in this field are involved in comfort groups, carrying out
field measurements and microclimate simulation models for predictive studies of different scenarios for planning and urban design, going much further than the computer aided design, as pointed out by Hebbert and Jankovic (2013).

Since the beginning, the importance of local microclimate measurements and other variables involved were evident. Measurements demand adequate sensors, following measurements protocol at the pedestrian level (different from micrometeorology purposes) to correctly understand local differences found in relation to subtropical and cold climates, where most of literature comes from. Computer models are fundamental, but the measured data in some circumstances are decisive for exploratory studies, simulation models’ calibration and validation, etc. From the didactic point of view, field measurements make a lot of difference both in undergraduate and graduate levels. Measurements are valuable to calibrate the models before carrying out predictive studies to evaluate different planning options or to develop land-based mitigation strategies for urban warming. In the laboratory, sensors were improved and measurements protocols were established, in spite of few references for the urban scale at the pedestrian level.

Concerning the sensors’ exposition in urban areas, it is impossible for architecture and urban planning studies to follow the WMO standard conditions, as pointed out by Oke (2005). Many advances were done since Oke (2004; 2006), both technical documents for the World Meteorological Organization – WMO, which preceded the incorporation of the Chapter 11: Urban Observations in Part II. Observing Systems to the Guide to Meteorological Instruments and Methods of Observation (WMO, 2008). Although focused in urban areas, this protocol are not oriented for architecture and planning needs, demanding adaptation and interpretation from the researcher for different case studies. Therefore, to settle the measuring instruments in human scale, additional precautions are necessary to avoid proximity with heated urban surfaces, anthropogenic sources like vehicles and air conditioning systems, with local turbulences, etc., besides all security issues in urban open spaces. Due to lack in security, many times it is impossible to keep the instruments outdoors for 24h or more, compromising a consistent data gathering for models’ calibration.

THE GRADUATE COURSE IN THE FACULTY OF ARCHITECTURE AND URBANISM
Thirteen years ago, a pilot interdisciplinary graduate course started at the Faculty of Architecture and Urbanism of the University of Sao Paulo - FAUUSP, focused on thermal comfort outdoors. The experience was innovative in graduate courses in Brazil. At that time, there was one elective discipline in a lato sensu course in Architecture and Urbanism, offered in The Federal University of Minas Gerais by Prof. Dr. Eleonora Sad de Assis, besides urban scales topics in comfort disciplines, especially in the Brazilian federal universities. Geography and meteorology bring other references, focusing on urban climatology.

The graduate course at FAUUSP aims to: 1. Characterize urban comfort outdoors; 2. Develop reading and graphic representation of environmental urban phenomena; 3. Explore the relations between urban climate phenomena and urban land patterns, the design of open spaces and buildings; and 4. Define instrumentation and fieldwork protocols, as well as data treatment procedures and the analysis of results. The course has 15 weeks, 4h/week, and encompasses lectures, seminars, laboratory training and fieldwork in the city, including microclimate measurements analyses of results and data treatment. The experience with measuring instruments (unknown for part of the students coming from different schools and backgrounds) start since the beginning of the course, during the lectures, to give them more familiarity with the variables involved in each topic and their registering in the field.

In the first and theoretical part, the course syllabus has a sequence of lectures concerning 1. Comfort outdoors concepts; 2. Outdoors thermal comfort indexes, both physiological and empirical; 3. Solar access, shading and glare urban areas; 4. Urban ventilation; 5. Urban acoustics; 6. The effects of green in urban microclimate; 7. The effects of urban geometry and urban surfaces in urban microclimate; 8. Urban energy balance, climatic scales and theories about urban climate.

In between the lectures, the students develop literature reviews about specific topics, linking the course to their ongoing or planned master dissertation or PhD thesis. When lectures finish, around the eighth week, the students develop a small research plan; they are supposed to finish the research, usually going further in theoretical studies, until the end of the course.

During the theoretical part of the course, all the students are expected to read and get familiar with the basic references in the bibliography. This include classic texts of urban climate (OKE, 2006 and, of course, antecedents mainly from Germany), adaptive thermal comfort (NICOL et al., 2012) and outdoor thermal comfort indexes (VDI, 2008 and others), the relation between urban climate, city and buildings (SANTAMOURIS, 2001); urban climate mapping (KATZCHNER, 2010), urban climate and greenery (JONES, 2014; WONG; CHEN, 2009), climate sensitive design (GIVONI, 1998; EMMANUEL, 2005), urban climate and density (NG, 2010), urban microclimate and landscape design
(BROWN; GILLESPIE, 1995), the microclimate between buildings (ERELL et al., 2010), open urban spaces design (DOMINGUEZ, 1992; NIKOLOPOULOU, 2004; STEEMERS; STEANE, 2004), besides important Brazilian references in these topics coming from geography (MONTEIRO, 1976; LOMBARDO, 1985) and architecture and urban planning (ASSIS, 2006).

The second part of the course is devoted to practice, when the students conduct a survey in the field, analyze the results and exercise data treatment (NICOL et al., 2012). The students have laboratory training and experience the first measurements at the surroundings of FAUUSP building, before going to the city itself. In this phase, they have a preparatory lecture about research techniques in urban climate (fixed stations, transects, instrumentation, measurements protocols, data gathering and treatment). After some training in the laboratory, they plan and put in practice the first measurement outdoors. They present the results, and the teaching staff comment on that, highlighting trials and mistakes before they plan and execute the second fieldwork in the city, usually outside the university campus, evaluating comfort (or discomfort) of people in pedestrians pathways and public places like squares, urban parks, bus stops, among others. Along the course, the student’s evaluation consists of reviews, an individual written exam, fieldwork and a final seminar in groups.

It is worth highlighting the didactic importance of measurements, following protocols when available (WMO, 2008) or attempting to register the variables at street level, aiming pedestrian comfort, closer to architecture and planning purposes. One of the crucial precautions is the correct exposure and radiation shielding of the instruments, all these steps previous and necessary to the models validation and calibration to the local subtropical climate conditions. Doing on-site measurements, students realize that considering only air temperature is not a good indicator for thermal comfort. They register data especially for the difference among variables that are more stable (e.g. air temperature) and others that dramatically change in few meters, depending on the exposure (e.g. surface temperature, globe temperature), etc. Thermocouples in different surfaces, as well as thermographic camera images help a lot the understanding of differential warming surfaces, e.g., dark and light, hard and soft, opaque and transparent or translucent, etc. Field measurements usually take place in contrasting urban environments, therefore the students can experience different sensations and quantify the variables involved in sun and shadow, arid and humid, opaque and transparent radiation transmission, pervious and impervious surfaces, and so on (Figures 1, 2 and 3).

Later on, students find out that applying a comfort index describes better the thermal sensation. Thus, the data gathered during measurements, concerning air temperature, air humidity, air speed and globe temperature (to calculate mean radiant temperature) are inputs to thermal comfort predictive models. In the course, students try out, for example, the worldly recognized Physiological Equivalent Temperature – PET (VDI, 2008) proposed by Höppe (1999), calibrated by Monteiro and Alucci (2008) for the urban climate conditions of the metropolitan area of Sao Paulo, and the Temperature of Equivalent Perception - TEP, an empirical thermal comfort index, developed specifically for open urban spaces of Sao Paulo (Monteiro and Alucci, 2009). After these experiences, the students are challenged to propose design strategies, either qualitative and/or quantitative for urban open spaces (Figure 4).
Figure 3: Fieldwork to evaluate thermal comfort sensation under close but different bus stops, transparent and opaque, in Sao Paulo, Brazil, 2013.
Figure 4: Thermal comfort outdoors and design strategies for the University campus – Mendes, Pizarro, Pinheiro and Pacifici, students of graduate course, 1st semester of 2015.
The course has an interdisciplinary character, crossing urban climate, planning, urban and landscape design. The course is sought by graduate students from other areas in the school and by other faculties from the university. Among the students, there were architects and planners, meteorologists, geographers, forest and civil engineers, even medical doctors interested in the relationships between comfort and health. In this experience, the interdisciplinary nature is more related to crossing the contents of the different disciplines themselves than the teaching/learning styles or even the language barriers of different backgrounds, which are clarified by the teaching staff or even by the group members themselves every time is needed. Annually the program is updated with the ongoing research results of the laboratory and of the related groups involved, at the same time opening possibilities for new investigation fields, articulating results of various research projects.

THE UNDERGRADUATE ELECTIVE COURSE
In 2015, an elective undergraduate course was offered for the first time, to the 4th year students, after completion of the building environment and energy mandatory disciplines in the school, including theoretical basis and design studio. This course had a different approach, less oriented to research and more applicable to urban design (Figures 5 and 6) to incentive the link with other disciplines and Diploma project. These links occurred mainly with landscape architecture, building design of semi-confined spaces, and topics under discussion in the city planning department as the São Paulo masterplan or the zoning code, recently approved. Students’ feedback gave suggestions to make the course even more design-oriented, for example, linking spot measurements to the design proposals that should start since the beginning of the course, with more time to developed design.

INTERDISCIPLINARY RESEARCH FEEDING TEACHING ACTIVITIES
The research group has established interdisciplinary partnerships during the last years. Collaboration with the Atmospheric Sciences Department helped a lot concerning climate change scenarios, human comfort for the elderly and the interactions among soil, vegetation and atmosphere. With the Forest Sciences Department, we learned about vegetation properties related to shading and evapotranspiration, altering urban microclimate. The Department of Geography has a long date history on urban climate (MONTEIRO, 1976; LOMBARDO, 1985; MONTEIRO; MENDONÇA, 2003) and joint works have been done with the Graduate Program in Physical Geography. The Institute of Energy and Environment, specifically the Laboratory of Photometric Testing, has been a partner in issues related to visual comfort. The Institute of Psychology and the Laboratory of Psychophysics and Electrophysiology have developing joint works related to comfort and health.

The World Resources Institute (WRI) is a NGO established in 1982 in Washington, with a Brazilian office since 2013. EMBARQ is the sustainable urban initiative of WRI, which has developed a collaborative work to promote practical urban design solutions for improving mobility and accessibility in crowded areas of the Pinheiros River, the most important business district in São Paulo. This collaborative work result in a research involving a dozen students taking microclimate, sound level, pedestrian and car flux measurements. All data were treated and results were discussed to pursue joint strategies for improving urban mobility and quality of life in São Paulo (WRI Brasil. EMBARQ Brasil, 2015).

Interdisciplinary research allowed: 1. to quantify the impact of climate change in buildings, evaluating thermal performance and comfort, creating local future climate data banks compatible with building energy simulation models, in a partnership with the Atmospheric Sciences’ Department; 2. to raise local vegetation variables for micrometeorological modelling, testing different acquisition methods (hemispherical photographs and canopy analysers), counting on the collaboration of Forest Sciences and Atmospheric Sciences’ Departments; 3. to specify soil and pavement properties for micrometeorological modelling, with Atmospheric Sciences and Transport Engineering Departments; 4) to understand the interactions between soil, vegetation and atmosphere, due to Atmospheric Sciences Department; 5) to quantify the impact of green to counteract urban climate in dense cities, summing up many contributions (DUARTE et al.2016).

PERSPECTIVES FOR THE NEXT YEARS AND OBSTACLES TO BE SURPASSED
Scale differences between micrometeorology and urban climate studies are an obstacle to be surpassed, especially concerning observational data and modelling; urban climate downscaling would allow to understand what happens in the urban block, square or building. On the other hand, for architects and planners, basic knowledge in micrometeorology is very helpful. Climate models are very complex, with unfamiliar variables for architects and planners; usually they are time and computer consuming, compared to the planning and design tools in the architectural field. Even models as ENVI-Met, largely used in this group for graduate research (DUARTE et al., 2015) are difficult to be included in an undergraduate course. However, experiences in Diploma, with students involved somehow in research, can maybe work. For architects and planners, images and visual observing techniques help a lot, such as: 1) combining emissivity measures with thermographic images to read surface temperatures at building and urban scale; or 2) using hemispherical photographs to raise leaf area index or sky
view factor. Techniques like these encompass mapping, images, and photographs, among others.
Figure 5: Design proposal for an open market in Sao Paulo, Feira da Madrugada – Takeda, Pardo, students of the undergraduate course, 2nd semester of 2015.
Figure 6: Urban design proposal for Santa Cecilia neighbourhood – Lima, Massimetti, students of the undergraduate course, 2nd semester of 2015.
CONCLUSION
The interdisciplinary research is routinely exercised in this group, not only for urban, but also for building scale, when it is interesting and needed for broadening the scope and go further. Concerning education, the outcome of the graduate course has been to prepare not only academicians, but also professionals for architecture, planning and landscape architecture offices, for public administration and services, for NGOs, with emphasis in urban environment issues. The undergraduate course is just starting, but the first results are exciting for design purposes, linking other disciplines of the school and Diploma, at the same time attracting the students for future research in the field.

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