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Comfort, Cooling and Critical Accountability: a teaching tools and research odyssey

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Abstract:

Comfort, Cooling and Critical Accountability: a teaching tools and research odyssey

How do we ensure the next generation in the building profession are best equipped to respond to the challenges of providing comfort in a rapidly heating world? As environmental science educators it is our job it is to pass this responsibility to the next generation. For those whose work will be in the global 'south' this task is especially crucial as we know that achieving thermal cooling is more energy consuming and harder to achieve than through heating. In today's world with greater communications and IT usage might this become easier to achieve? The internationalisation of students in universities also means that the research and teaching of environmental design courses to students whose ultimate work and practice location will be sites in the "tropical south", needs to be addressed. Today there is a great need to revisit the notion of a tropical design syllabus and associated design courses to be taught to Western universities' international student cohorts. Here we review the history of tropical education across the world. It then considers the current status of environmental design teaching, taking into account the incorporation of new tools for environmental science pedagogy; environmental modelling, environmental apps, applications such as AI and VR. Finally, it suggests how future environmental design teaching might benefit from incorporating new pedagogy to deliver sustainability-focused environmental science teaching, to tomorrow's practitioners and researchers.

Keywords:

Environmental design pedagogy, internationalization, digital teaching tools

INTRODUCTION

Over various periods for more than five years the co-authors of this paper taught environmental design at year two level, at Edinburgh School of Architecture, (ESALA) at the University of Edinburgh. They taught to student audiences from international backgrounds, many of whom came from, or had lived in the global 'South' . The environmental design course taught was one of the first to embrace an internationalisation of its curriculum by engaging students with research tasks which enabled them to consider other climate considerations, and the issues related to sustainability in contemporary design. The course also allowed the introduction of new forms of environmental measurement using 'apps' and basic modelling techniques. This paper discusses case study instances of this, and then goes on to explore the challenges this early attempt at globalised environmental design teaching produced and what future changes and issues will need to be dealt with.

> The paper runs as a discussion with case study examples being given by the co-authors and the drawing of a conclusion and literature review in the course of the text. We see this as an initial attempt at a larger body of work likely to result in a monograph on environmental design and thermal comfort teaching to global audiences in transnational institutions.

1.0 Context

This is a joint paper collated to describe the experiences and instances of teaching which has informed a thematic approach to thermal comfort teaching to mostly undergraduate students at the University of Edinburgh from c. 2012 – 2017, when the co-ordinator of the teaching left to take up a chair in Architecture at Manchester. In 2011 the architecture schools at Edinburgh College of Art and Edinburgh University had just merged to become the 'super' school ESALA, and this resulted in the unification of different teaching methods in Environmental design, amongst other subject areas.

> This was seen as an opportunity more than a challenge to re-imagine what an environmental design course might offer to students from increasingly international backgrounds. Edinburgh University is a Russell group institution, of which ESALA is now a part. The school regularly has more than 40% international student enrolment in its undergraduate architecture course.

> The previous environmental design courses that had been taught at Edinburgh College of Art, and the University had up until the merger had remained largely unaltered from the development of the RIBA-ARB required teaching competencies in relation to environmental design and building physics tuition for architecture students as had been defined in the late 1980s. The opportunity thus arose to review the curriculum and develop a more 21st century student-focused environmental design programme with a new, younger academic teaching team. It also allowed us begin to consider and engage with emerging key themes in teaching, pedagogy and contemporary ways of measuring environmental design performance and analysis.

> This paper focuses only on the thermal comfort aspect of teaching, but the curriculum that was developed also radically overhauled teaching in the area of daylighting and lighting comfort, mainly through the efforts of our colleague Gillian Treacy. There was also some

overlap in this area as initial work on apps development and thermal modelling analysis was undertaken in conjunction with Treacy, (Treacy and Uduku, 2015).

2.0 Thermal Performance and Design Teaching at Edinburgh; *Uduku, Satish BK, and Treacy*

At ESALA, from 2011 onwards, teaching at second year level in environmental design has taken place exclusively in semester one over an 8 – 10 week period. It involved a condensation of a wider teaching programme which had taken place before at Edinburgh University for its second-year students, and a partially studio based teaching programme that had been introduced for ECA students which again ensured that in the past teaching of environmental design took place for a longer part of the academic year.

Both systems had also initially focused on exam-based systems where students were tested on their knowledge of building physics themes such as the calculation of U-values, and thermal load at various period in buildings. A review of student outcomes and knowledge highlighted early to us that students often 'crammed' environmental formulae to pass examinations, with very little of this information being applied to their architectural designs in studio. This directly contravened the contemporary pedagogic related to student centred learning, and agency in their application of the environmental knowledge gained to their design aspirations in studio. Furthermore, much of the work being undertaken was case study focused, and involved examples which were either Edinburgh-located or at best focused on Europe, and consequently the environmental design requirements for northern climatic conditions. This was despite the increasing number of international students who now made up the student body.

Our task then was to 'internationalise" the curriculum and also consider how best through our teaching to embed key 'gateway' concepts in environmental design teaching to our international students who we recognised as being the 'generation X' Digital Natives, who would and could use technologies innovatively. What follows is the presentation of a number of tuition case studies which various collaborators on this paper have used that exemplify this approach. The final part of the paper pulls these strategies together and describes the teaching approach which we simultaneously and sometimes individually achieved over this period of teaching at ESALA at the University of Edinburgh.

3.0 The Environmental Design Case Study

This non digital intervention involved our changing a small building case study that had been focused solely on working on environmental conditions in a shaded square in Edinburgh University to expecting all students to conduct an environmental case study of a small building in one of a number of different climatic zones. This was used as an 'end of teaching' examination where students could analyse the case study building using the thermal analysis and other environmental design measurement tools to come up with a credible environmental analysis of the small building in its climatic setting.

As a final formative evaluation teaching tool, this proved particularly successful in assessing student understanding of themes and concepts taught over the term, and importantly gave the course relevance to students from different climate zones to Europe. The best student work often foregrounded students whose work in studio would also go on

to achieve critical success, with many of such students going on to win end of year awards for their work in more than just the environmental design course we were involved in delivering.

Examples here are given of Satish BK's tutored case study work, in this case an environmental analysis of the Richard Murphy's Dance Base Studios in Edinburgh, by, this is contrasted with Ola Uduku's tutored Tropical Dwelling Case Study, in Indonesia.

Fig. 1 Dance Base. Case Study (Edinburgh)   Fig. 2 Tropical Dwelling Case Study (Indonesia)

4.0 Digital Tools for Teaching

In this section we discuss the evolution and incorporation of the development of the use of digital tools, from basic models to apps for teaching the environmental design course at ESALA. Whilst much of the initial process was initiated by Treacy and Uduku, Zhao has been involved in its further development and has incorporated this in his PhD studies. He provides a commentary of his his further development of the EdenApp mobile application as a thermal comfort evaluation model which he has tested amongst ESALA students. This model is being considered for use within a more global context with collaborating schools in Africa and elsewhere in the future.

4.1 IES 'Lite' for Architects

In 2012 Uduku and Treacy acquired an RKE development grant to develop a 'stripped-down' form of the thermal modelling programme IES, which we called IES-Lite. The ambition of the project was to create IES-lite as a an undergraduate-friendly thermal modelling programme which could be used by our 2nd year architecture students to engage with the thermal analysis of their designs using only basic features of the IES programme. We had previously used the Cambridge University, Martin Centre's, mini 'LT' programme to consider issues such as shading and overheating, but had found this has significant limitations. (Baker and Steemers, 1996) IES lite gave students the chance to use different climate files to consider different locations in the world, they could also change building materials and facades and gauge levels

of cooling or overheating, and therefore thermal discomfort, and finally it enabled them consider shading and daylighting.

We trialled the use of the programme for two teaching years with limited success. The climate data files were the most useful part of the programme as students could get some idea of the thermal comfort and required ventilation (in air changes per hour) that their buildings would need. Also, the programming of shading worked well as different times in the year and day could be calculated accurately with the programme algorithms to show realistic views of shading. The particularly complicated nature of the programme however meant that it would never be an easy analysis for non-fully technology and arithmetically focused students, and so we went on to consider other options.

4.2 EdenApp

EdenApp evolved from our experience of IES lite, as a different method of engaging students with environmental measurement and evaluation. First of all it focused on lighting and assessment of the daylight factor. As documented elsewhere it enabled students work with their mobile phones to determine lighting levels and then undertaken in real time the calculation needed to determine the daylight factor in the space being considered. A further part of the app was developed to show students if the factor meant that the areas were either too bright or too dark for optimal visual comfort. Further iterations of the app were developed to consider temperature, noise levels, and there are still future ambitions to develop a comfort chart; similar to the Olgyay Chart (Olgyay, 1963) which might respond to climate variations across the world.

EdenApp has been successful in its ambition and follows on from our learning from IES-lite, the app is very much focused at the education market, and has clear basic teaching objectives. We found its development however was challenging as we neither were app programmers, Phd student Yiqiang Zhao joined the team and helped with the further development of thermal analysis which he describes later on in this paper. We were mainly however reliant on an early "technopreneur -programmer", Cosmin Dumitrache, who helped transform our ideas for the app into reality, with a further grant received from the University of Edinburgh. The weakness of support in the Edinburgh University system for this form of development unfortunately meant that as he left for Silicon Valley the development of the programme slowed down considerably. EdenApp still has a liminal presence on apple education tools, and occasional requests to use it are received from across the world, there is the ambition to work further on its development in future.

4.3 EdenApp Thermal Comfort – Yiqiang Zhao

The success of EdenApp – Lighting sensor increased the possibility of developing from more perspective. As a result, EdenApp – Thermal Comfort was developed for thermal comfort calculation (Zhao, Uduku and Murray-Rust, 2017). By adding some basic parameter and connected with Bluetooth sensors, it could provide real-time Predicted Mean Vote (PMV) calculation, which is the metric for indoor thermal comfort in ISO 7730 and ASHRAE 55. We tested the app but found out that several parameters such as globe temperature and low-speed wind speed need a professional sensor for measurements. Furthermore, the cost is quite high compared with traditional temperature sensor and anemometer.
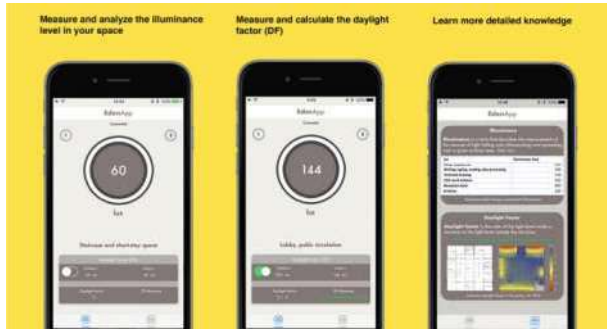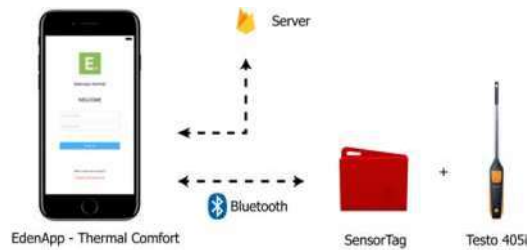
Figure 3: EdenApp – Lighting

Fig. 4: EdenApp – Thermal Comfort

The price, feasibility, stability and connectivity will all influence the accuracy of reading and student's user experience. Since we realised that sensor had become a crucial part of the whole learning process, based on Smart Thermal Comfort (STC) sensor box (Zhao *et al.*, 2018), we developed a portable version which could measure air temperature, globe temperature, relative humidity, hot-wire air velocity and illuminance (Figure 4 left). It could give users an accurate real-time environmental data dashboard. To further increase mobility, we used Arduino-based circuit and Bluetooth Low Energy (BLE) technology to made the latest version of portable EdenApp sensor box and fully integrated with mobile app (Figure 4 right). It cost only £40.
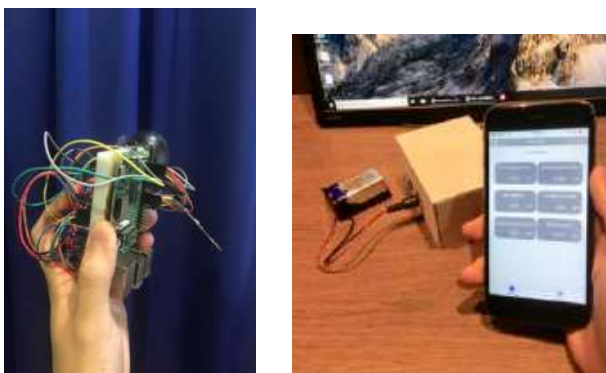

Fig. 5: EdenApp portable sensors, first generation (left), current version (right).

Compared with traditional expensive and limited measurement facilities in university's lab, EdenApp could significantly reduce the cost of facility while remain the same function and accuracy. By linking with smart phone, it could give each student more interests and opportunity to join the study game, using real-time measurement tool to learn those invisible

environmental parameters. There is no time or space limitation, just open the app and sensor whenever they want.

In 2018 we tested the thermal comfort app in several field trips for undergraduate architecture students in ESALA. The aim of the trip was to let students measure environment parameters in different buildings and get a basic understanding of how thermal comfort standard works. For example, one of the sites was St Albert's Catholic Chaplaincy in Edinburgh. This is a mixed-mode one-floor building with mechanical heating system. Our visit took place in November when windows were all closed and heating system was working properly. A number of five-student groups each worked with a portable sensor set. They conducted measurements, comprising air temperature, relative humidity and air velocity data using the portable sensor, metabolic rate and clothing level. These were entered by the students through the app. Then the PMV was calculated within the app. Within each group, students discussed the range of each environment parameter, and the comparison between PMV and their own actual thermal sensation vote. Tutors then answered student's questions. The process worked well but we found out many students reported the PMV result was not accurate. This was despite the sensors having been calibrated before use and students having had instructions before using the sensor sets.

The PMV model used for the sensor set had been devised within a laboratory environment whilst the adaptive model was generated based on the student generated field study data. There was thefore a paradigm shift from using the PMV to adaptive modelwhich better considers occupants' ability to adapt themselves to suit their surrounding environment. The PMV model still serves well in mechanical HVAC system building whilst the adaptive model is better suited for tropical areas where mechanical ventilation is not in use. In places such as the UK especially winter, PMV is still the only way in ISO or ASHRAE standard to predict thermal comfort. However the PMV model was based on average data which is difficult to predict for individual thermal comfort levels (Kim, Zhou, Schiavon, Raftery, & Brager, 2017; Liu, Schiavon, Das, Spanos, & Jin, 2019). In education, after students measuring the environment data, calculating the PMV result and comparing with their actual thermal sensation vote, many of them asked the question: "[the] PMV is not accurate, why?"; "I feel much colder than the PMV result, can the model adjust based on different buildings?"; "Why not use a smart home sensor in the room [being measured] and let the AI self-learn optimize the heating? "

When facing these questions, it is difficult for teaching-based fellow to realize or explain. There are several options: 1. We could say that's the shortcoming of current standards. The details are quite complicated and need time to solve. 2. We could draw a PDD distribution diagram to explain how PMV applying to multiple-occupied space. 3. We could explain the latest framework to predict individual thermal comfort.

For example, Personal Comfort Model is a new framework to localise thermal comfort within individual level. By using Internet of Things (IoT) sensor and Machine learning, the model self-learns occupant's comfort preference, relearns the pattern in different buildings and apply the setting in HVAC control system. Meanwhile, using EdenApp shows the students how the whole data collection process works.

Our students are part of a younger generation who have a totally different educational experience of growing up in a technologically advanced world than their teachers. They are extremely interested in discovering and using new technologies such as sensors, AI, personalisation service and so on. Amongst these three options, EdenApp creates the

opportunity to attract students engaging with the course in a real-time and field-based way. This method shortens the learning curve and increase the possibility of student's independent study skills rather than traditional passive lecture or tutorial-based learning process.

4.4 21ˢᵗ Pedagogy in Environmental Design – Thermal Comfort Teaching
Whilst this has in many ways been a learning journey for both the lecturers, tutors and staff who have been involved in the evolution of environmental design teaching at ESALA, the changes to pedagogy and teaching were well received by students. Overall satisfaction, as measured by student feedback was good, with 10 – 12 students, (approximately 10%) of each cohort achieving A+ grades in the environmental appraisal which students were expected to carry out.

We have found that students are ready to engage with digital methods of teaching and the use of the various evolutions of the EdenApp, for daylighting and more recently thermal comfort measurements has been easy to follow. The most difficult part of the process has been finding the sensor attachments for the mobile phones. Lighting sensors were easy to source, as they already existed for photography applications, more specialist sensors required more extensive research, but as discussed by Zhao there are more specialist sensors that work as arduino based sensor kits were adapted to develop the thermal comfort sensor.

The main challenge to teaching we found however was the adoption of new pedagogic methods across different architecture school curricula. For many schools there remains the tension between incorporating environmental analysis and teaching into the studio or leaving its pedagogy as a separate element of the taught curriculum, which is sometimes outsourced altogether in teaching to specialists. In this model the use of experimental apps such as EdenApp are unlikely to be introduced as the specialist link with such programmes is purely delivery related. In other instances, environmental design teaching, although integrated in the studio pedagogy, is taught strictly to textbook themes, with historic examination-based tasks still in use.

We feel that through our longitudinal experience with student cohorts in Edinburgh that the development and use of different 'tech' approaches to teaching can be relatively easily incorporated into undergraduate curricula and importantly the different pedagogic focus has made its uptake and popularity with students a positive experience. The challenges to its further development are less technological but more links to research and teaching at a PG level.

This is a fundamental issue across architecture teaching at part one or undergraduate level. Research led teaching is considered difficult to engage with in first- and second- year teaching more because there is a reluctance to explore and challenge what is considered 'core teaching' which focuses on gateway concepts to understanding. In environmental design this largely covers the building physics issues such as thermal comfort lighting and acoustics. As lecturers and tutors we have been able to engage specifically with this and demonstrate that it is possible to be research focused and creative with our teaching and thus transform curriculum delivery at this level.

The building of a strong research team to carry the project on however requires more critical thinking at departmental research strategy and teaching management level. The integration and development of research teams whose work integrates into architectural teaching remains a relatively new phenomenon across architecture schools. What is needed is a commitment at research level to maintain and develop research teams who can work to

constantly engage with various parts of the architecture teaching and curriculum development so as to ensure that these respond both to new trends in teaching technology and pedagogy – so this does not rely on staff interests only and therefore can often lack sustainability and long term development.

In the case of ESALA, this experience suffered this fate. From 2017 onwards, the initial teaching and research team dispersed. The lead co-ordinator left to take up a chair in Architecture, at a different institution. The lighting specialist moved to another part of the University, and has further developed her own interests in lighting teaching with students in Interior design. Most of the graduate tutors who had worked with the programme have now completed their PhDs, and went on to develop their careers elsewhere. The core team of environmental design researchers and tutors who had been involved in developing these pedagogic changes thus were disbanded. Yiqiang Zhao however does continue to work with EdenApp and other applications in his soon to be completed PhD at the University of Edinburgh.

In the meantime, the ESALA teaching programme at undergraduate level retained much of the analogue, non app-based interventions, but in essence no longer directly engages in the integration of environmental science research in its teaching. If we are to develop and support local interest in environmental design and performance analysis amongst architects, without engaging undergraduates early in understanding this using environmental tools they are conversant with we are losing the initiative in this process. Furthermore with the internationalisation of teaching and shared use of digital platforms the potential for involving transnational teaching and research collaboration is now truly global.

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