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INTERACTIVE PERFORMANCE: PRINCIPLES AND PEDAGOGY

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Abstract

The skin of buildings can be seen as a mediator between interior and exterior environments which are in a state of constant flux. On building facades, whether automated or human-controlled, the demand for transformation is crucial in order to accommodate and respond to multiple inputs, making them suitable to the changing conditions inherent in various time spans. As such, there is a mutual interdependence between dynamic facades and the environment.

In this paper, we outline a lens through which we expand the possibilities that arise from that relationship while referencing the process and outcome developed in a graduate-level design studio co-taught by the authors. Applied research has enabled computational technologies to map our environment, predict climatic patterns, target energy loads, and apply smart systems to design responsive, adaptable, and interactive structures. This has led to a common methodology that prioritizes designing building skins to attain optimal performance. And yet, an efficiency approach alone leaves behind a whole set of human and cultural considerations.

Within the arc of our studio, we applied a more rounded approach to the sustainable design of dynamic facades by considering both quantitative functional characteristics as well as the communicative and interactive potentials that are context driven. We developed a comprehensive understanding of environmental and social factors -- urban and rural sites, biology, culture, materials, and technology -- the connections between them, and their transformations over time, be it on a seasonal, diurnal, momentary, or geological span. We analyzed adaptable strategies from built and living skins, studied the programmatic and spatial implications beyond the skin and applied both low and high-tech building technology principles aligned with context. As a result, building skins were designed not as barriers but as dynamic elements of exchange within a greater ecology, to respond and contribute more meaningfully to the design of the built environment.

Under this approach, as building skins perform, they reveal how inhabitants relate to their context, both enabling them to gain a deeper understanding of their own environment, and of the multifaceted exchange that is active at the interface that is the building skin.

Keywords

Dynamic Skins, Interactive Architecture, Sustainable Performance, Design Pedagogy

1 Introduction and Background

Skins are membranes which mediate the exchange between the inside and the outside of an organism. The role of the skin in that exchange varies dynamically in response to internal and external stimuli. It can be, for instance, a heat exchanger through sweating, a mechanism of defense or protection through camouflaging or skin tanning, an energy harvester through photosynthetic processes, or a means of visual communication through expression. The morphology of skins in the natural world is correlated to their performance, which makes them inspiring and useful analogues for thinking about the function of skins in buildings. Yet the skins in the built environment are, more often than not, static. Collections of hermetic glass towers are abundant in urban centers. However, recent examples exist that transcend the static nature of the status quo, like the Al Bahr towers, which deploy a kinetic folding skin that mitigates solar heat gain and improves interior light quality [1].

Dynamic transformation can be attained not only by employing geometric principles and moving mechanisms, but also by harnessing the inherent properties of the very materials with which we construct. For instance, in the case of the retrofitted Hanhwa Headquarters facade, the characteristics of the solar cells in the photovoltaics make it possible for the facade to harvest solar energy [2]. Or in the case of the Prosolve 370e building, the façade acts as a filtering device to reduce pollution in Mexico City by using a titanium dioxide coating to break down nitric and nitrogen oxides when exposed to sunlight [3]. Recent research has studied the absorptive characteristics of clay for use in evaporative cooling of spaces in hot arid climates [4]. And although changeability--like the tendency of materials to weather, thermally expand and contract, and their potential for movement--is often resisted in the production of buildings for pragmatic reasons, this capacity for transformation presents great potential for responding to changing conditions if channeled productively. For instance, whereas the distortion of wood can be seen as a failure, the HygroSkin Pavilion uses the properties of thin wood veneers to open or close the pores of a skin in response to moisture content, potentially promoting air flow [5].

Whether through mechanical or material means, or by using low-tech or high-tech systems, the capacity of facades to transform is critical when aiming to adapt to a constantly changing environment. Adjusting based on specific loads allows building envelopes to perform in a targeted way, minimizing energy consumption and carbon footprint. Moreover, technological and computational advances have helped optimize skins in response to either environmental or human inputs. The development of more reliable construction methods, research on materials systems, along with more accurate weather predictions and simulations, sensing mechanisms, and behavioral tracking, have recently generated adaptable, intelligent, and responsive facades and promising building skin prototypes. For instance, the Media-ICT building in Barcelona limits solar heat gain by employing an ETFE facade that activates inner layers pneumatically when embedded light sensors are exposed to sunlight [6]. Or the thermo bimetals of the Armored Corset prototype feature a self-ventilating skin that uses the differential thermal expansion coefficients of metals to open or close a cladding system when exposed to targeted temperatures [7]. Meanwhile, the automated facade for the HouseZero prototype utilizes sensors, weather data, computation, and motorized openings to successfully regulate outside air informed by the immediate climatic conditions of the site. Additionally, it incorporates augmented reality technology, accessible to the inhabitants, allowing them to visualize airflow [8].

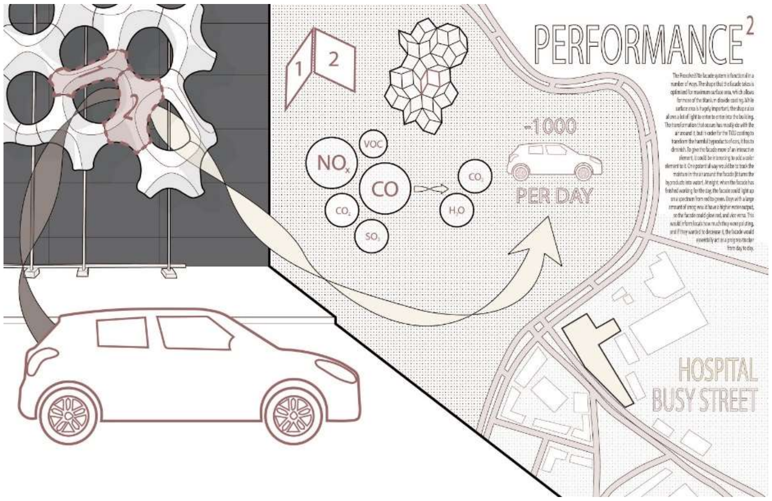
While technology-driven strategies hold great promise for achieving more sustainable possibilities with architectural design, it is important to highlight the strong likelihood that, in an effort to deliver indoor human comfort through automated or otherwise imperceptible means, designers can create an experience that is characterized by a detachment between humans and their surrounding environment. Thus, while we can recognize the benefits of and the need for energy efficiency driven envelopes and systems, we must simultaneously set our sights on the latent opportunities within the design of building skins to engage people, offering experiences that promote learning, appreciation, and caring for the environment and a better understanding of our role within it. This agency and empowerment through knowledge and behavior can take innumerable forms but remains largely unexplored in practice.

In this research we explore the mutual interdependence between dynamic facades and the environment. How can building skins act as elements of exchange within a greater ecology, and help humans understand themselves within it? Can the skin itself host new forms of habitat beyond that which the natural world already provides, and propose new ways of inhabitation? What are the extents of the interface that happens at the building skin? What are the performative, programmatic and experiential implications when addressing differences in height and the width of the spaces on either side of the skin? What opportunities arise for building skins when we account for human consciousness, engagement, and other human factors beyond comfort as part of our approach to sustainable design? These questions informed the development of a graduate-level studio co-taught by the authors. The studio structure and some examples of the investigations are featured below.

2 Studio Methodology

Prompts were developed to study how the performative capacities of building skin design are intrinsically related to their human and environmental context. In the development of their skins, students analyzed the context they were designing within, articulated the type of transformation enacted by the skins, the stimuli that triggered change, and the different time spans in play.

Sampling from a wide range of disciplines including Art, Architecture, and Biology, a collection of dynamic skins were documented. These precedents varied in their technological advancement, efficiency, and ability to express narrative [9]. For each, students identified the following parameters: design scope, context, stimuli, materials and technology, formal order and type of transformation relative to the function of the skins. Students worked from a variety of possible functions, considering the skin as a host of habitat, as a mechanism of defense, as a means of creating privacy, as a device for solar harvesting or solar control, as a self-repairing membrane, as a heat and humidity exchanger, or as a vehicle for communication. They also ascertained how notions of performance were evident and where both functional and phenomenological aspects worked in tandem (Figure 1a).



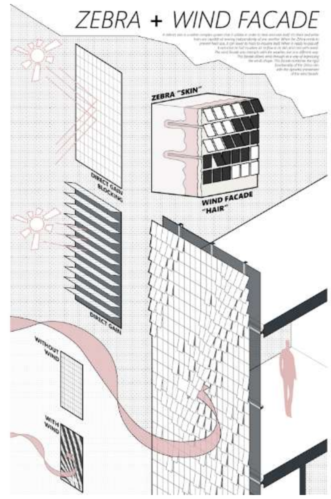


Figure 1a. Analysis of Prosolve 370e facade (left). Figure 1b. Zebra and Wind Veil Chimera (right), by Sean Flannery and John Dye.

Subsequently, students combined two skin precedents, one biological, and the other architectural, into the design of hybrid skins with the goal of expanding the kind of transformations enacted by them (Figure 1b). For this exercise, they reexamined how each of the original skins performs and the context and circumstances in which each existed. In joining them, they identified emergent opportunities as well as limitations.

Students examined four different contexts: Nuk, Greenland; Kyoto, Japan; Napo Province, Ecuador; and Marrakesh, Morocco. Each presented a range of climatic conditions and cultural identities which were recorded through an in-depth analysis of environmental, historical, and cultural aspects. Additionally, students analyzed examples of skins from both the natural and built environment to study the way in which these adapt to the specific contexts mentioned above.

Having documented the ways in which environmental and cultural contexts enable interactions between the inside and outside of natural and built skins, students adapted their hybrid designs to the specific sites and their environment. Students considered the morphological characteristics of the site, density of construction, programmatic uses, solar orientation, predominant materials used, socio-cultural factors, and natural landscape features.

Students identified technologies related to the performance that they were seeking, explored the implications of employing either high-tech or low-tech approaches, or a combination of these, to make the aspirations for their skin a viable facade proposal. They considered the skin in at least three sectional conditions: ground, mid, and top, paying close attention to the performative opportunities brought by these differences in height. On a smaller scale, they defined the type of mechanisms that their proposal would use to achieve transformations, the materials to be used, and how their properties would allow a dynamic exchange (Figure 2).

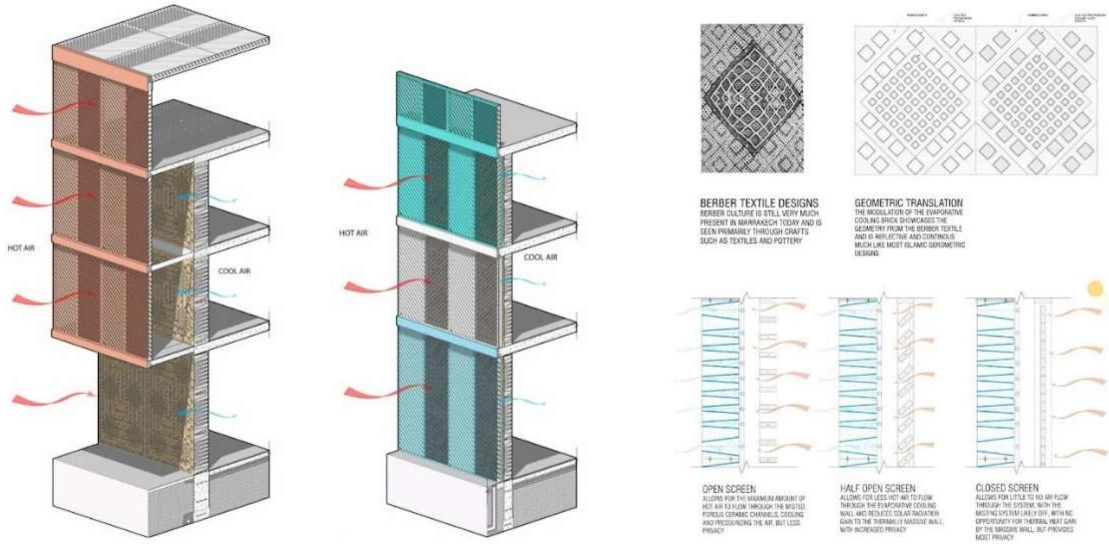


Figure 2. Berber textile-inspired ceramic porous wall, by Michael Montano and Rachel Kelly.

The skin was articulated at various scales in response to both environmental and cultural inputs. One of the main considerations in the development of their proposals was to consider the spatial and programmatic implications regarding both the difference in height and the spaces on either side of the building skin. For example, the adjacencies to a street or to the sky brought spatial opportunities, limitations, and programmatic activities that became intertwined with the skin, making it dynamic. Thus, the program emerged informed by human needs, desires, rituals, and other contextual social factors that originated with the exchange enacted by the skin in a particular site and its interrelated environmental circumstances (Figure 3).

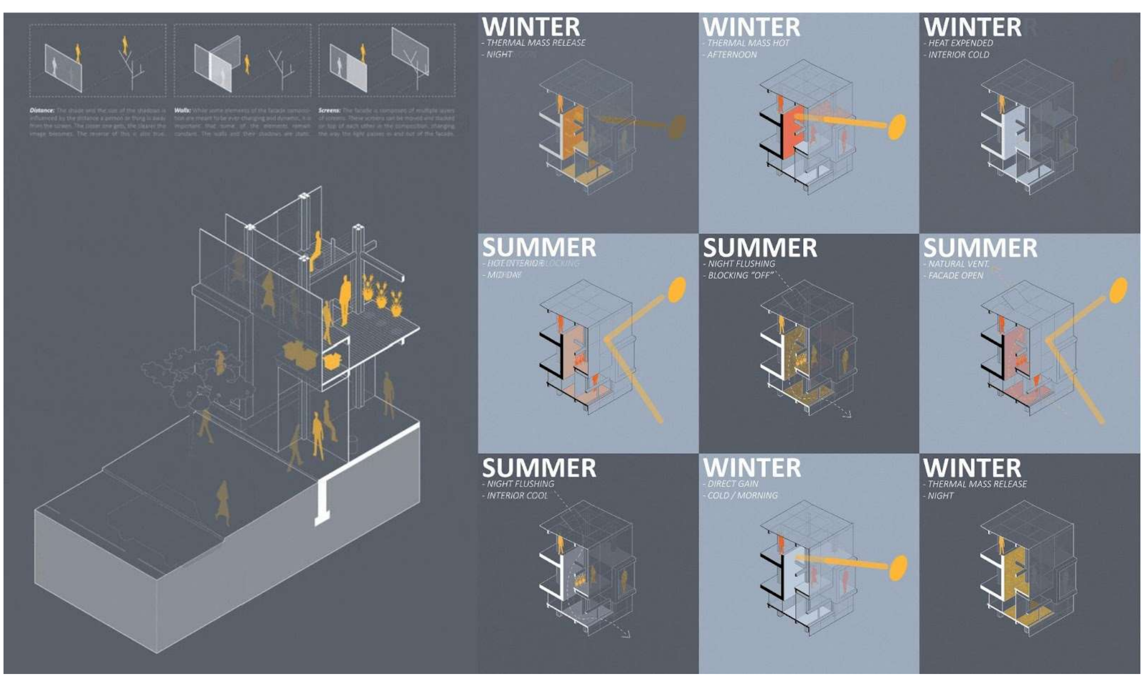


Figure 3. Programmatic activities in relation to diurnal and seasonal cycles beyond the skin, by Sean Flannery and John Dye.

The multi-faceted qualities of skins were tested through drawing animated wall sections that explored the types of transformations over time. Using animations and simulations, students examined the inputs that cause the skin to react dynamically, in response to environmental, human, or digital factors on both sides of the skin. They specified the extent to which users participate in the transformation and their level of control over it, and they defined the span of transformation (instant, hourly, diurnal, seasonal, annual), exploring the spatial and experiential implications (Figure 3).

Through the prompts outlined above, students developed projects that had their own drivers and constraints. Two student projects are presented here.

3 Learning Through Habitat

This project explores the idea of designing a school informed not only by anthropocentric parameters, but by the symbiotic relationships between humans and species, and in so doing, fostering an understanding and an awareness of the environment. The proposal features a school located in the rainforest of the Napo Province near the city of Tena, Ecuador that aims to serve the children of the Napo community by allowing them to learn about the flora and fauna of the area both within the "classroom" and while experiencing first-hand the environment from which they are learning. The approach takes advantage of the abundant educational opportunities offered by the natural world, in a context where culture values the sharing of knowledge through experience across generations.

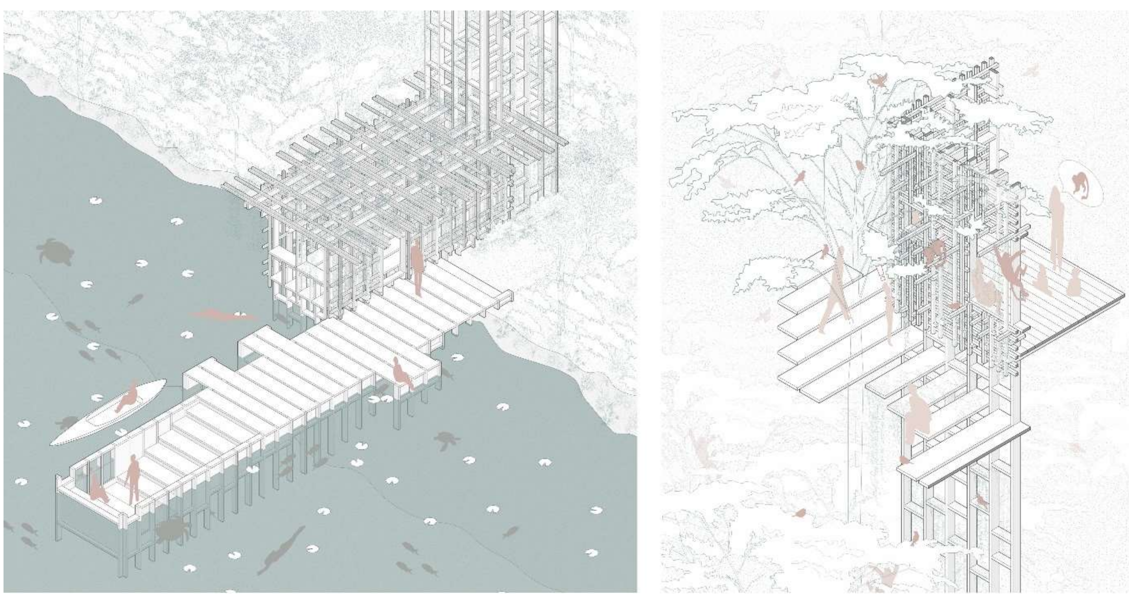


Figure 4. *Learning Through Habitat* ground, mid and top condition of the skin, by Karolina Domagala, Katie Whitin and Sean Flannery.

A series of pavilions located at specific heights are designed to host various animal and plant species while providing circulation for humans and sheltered areas for resting and learning. Using building materials found in the rainforest, the skins of the enclosures transform to respond to environmental and human opportunities brought by the elevational changes found in the Ecuadorian rainforest. For instance, the ground pavilions situated at the riverbank enable amphibians, salamanders and fish to nest in their thickened walls, while providing an anchor to tie down the canoes used by the indigenous community. In the middle section, vertical elements create an armature for bromeliads and orchids to grow and thus nurture the plentiful frogs and butterflies. This frame also supports a series of stairs that allow people to enjoy their surroundings and learn while traveling from one pavilion to another through the didactic journey that the architecture offers. The facades of the upper pavilions have a collection of horizontal rods for woolly and capuchin monkeys to play, and for macaws to perch while allowing inhabitants to experience expansive views of the treetops. The skins accommodate niches of various sizes and depths. Some pockets provide a place for plants to grow and animals to feed and take refuge, while others connect the interior with the exterior allowing children to inhabit the facade. Through the building skin, a dialogue is established with the different species which it invites. The use of low-tech strategies takes advantage of the precipitation in the area by directing rainwater to feed animals and irrigate the plants from the top down. The design of this project's skin exemplifies the potential of blurring the lines between the needs of plant and animal species and human needs and interests.

4 Embedded Community: Global Climate Change Awareness

The idea that we can design for change over time can be engaged at a variety of time intervals. Extending our understanding of time to a geological scale -- considering change over millions of years -- we can recognize that we are living in a period of rapid change in global climate brought on by human activities. These changes are shifting patterns of behavior in humans and other species worldwide, and we can expect that this will continue. Projecting forward we can then see a future in which areas of the world that experience extreme cold today will gradually become more appealing places for human habitation. Taking this long time span perspective as a point of departure, this project imagines an environmental research campus, sited in Nuuk, Greenland, which deploys scientific research coupled with growing environmental tourism as a means to build awareness of, and engagement, with climate change. The role of the skin extends beyond simply that of heat retention and daylight regulation and instead becomes a means of communication through its visible presence. Sited advantageously on a peninsula, it is visible to all incoming marine traffic, standing forth as an emergent beacon or icon.

As a model for environmental consciousness, the performance of the building skin is seen as an opportunity for demonstration. A variety of strategies engage with the challenges presented by cold temperatures and limited daylight. Active systems for harvesting and distributing heat and electricity are coupled with well insulated exterior envelope strategies. Translucent fiberglass sandwich panels provide daylight while retaining high-performing thermal insulation. Retaining walls and radiant floors make use of local stone as structure and finish material, providing a low embodied energy resource for construction. Meanwhile, spanning floors and roofs are imagined as cross laminated timber, as a means to capture carbon in the structural surfaces of the buildings. In addition to contemporary technological approaches, the project takes inspiration from vernacular turf houses, utilizing the natural topography to embed some buildings underground, while allowing other portions to emerge from the landscape. This low-tech approach enables less of the interior volume of the buildings to be exposed to the cold air, thus enhancing the thermal efficiency of the exterior skin.

Figure 5. *Embedded Community* site plan, section diagrams, and site sections, by Daniel Cusmano and Cameron Germond.

Figure 6. *Embedded Community* Thermal flows and wayfinding strategies, by Daniel Cusmano and Cameron Germond.

The roofs of freestanding structures play host to solar photovoltaic and solar thermal technologies, providing electricity and heat to support interior activities within the campus. Closed loop ground source heat pumps exchange heat with the warm underground, while interior radiant floors and vertical screens provide an efficient and targeted means of achieving human comfort.

Phospholuminescent panels are deployed to provide ambient illumination and wayfinding associated with public spaces, while also offering a potential physiological offset to the effects of light scarcity that are typical during winter months in Nuuk. Meanwhile the sloping surfaces of roof planes of embedded structures allow opportunities for recreational activities -- providing seating for a soccer field, or a slope for winter sports. The many manifestations of building skin thus become participants in the social fabric of the place.

5 Conclusions

Contemporary building skin design often centers its efforts on achieving human comfort and productivity within buildings, and although we are witnessing innovative developments that continue to improve their efficiency and efficacy, it is important to expand the range of factors that design responds to as we strive for a more comprehensive notion of sustainability. Beyond energy use and the optimization of building systems, we must address environmental conditions, socio-cultural dimensions, temporal considerations, phenomenological opportunities, and other contextual influences as a means to achieve well-being for both humans and other species in support of a healthy ecology.

Our perspective considers building skins as a dynamic interface between interior and exterior spaces, capable of responding to the constant flux of environmental and human factors, and as a zone in which these forces coalesce. We conceptualize building skins and their performance as the result of a mediation between environment, human (physical and socio-cultural) needs, and those of other species through different time spans. Furthermore, the way the skin responds to different scales -- global, regional, urban, block, building, and human -- and to different height conditions -- ground, middle, and top -- becomes richer when skins are dynamic elements that perform in relation to time.

The design of our graduate level studio and the student work demonstrate many design potentials for building skins when considered from this vantage and that building skins constitute a valid starting point for the development of spatial concepts. As the area of the exchange enacted at the facade is expanded, new formal, spatial, and programmatic opportunities emerge within that threshold and beyond the skin. The interface between inside and outside spaces can be a territory to host habitat and a zone for didactic engagement and experiential exchange among humans and other species that have been invited to participate. In doing so, building skins become active elements in redefining the extents of the natural world and challenging how we relate to it. They offer circumstances in which human behavior can be shaped through a dialogue that is not exclusively anthropocentric. The design of the skins can thus help impart a deeper understanding of the environment, inspire ownership, user participation, and stewardship in both the life of the building skin and beyond.

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