PORTFOLIO: RESEARCH AND SCHOLARSHIP

SELECTED SCHOLARLY PUBLICATIONS ON GENERAL DIGITAL DESIGN AND METHODOLOGIES

"The Appropriate Balance between Digital and Analog Techniques."

"Integrated Digital Pedagogy."
*related to Design Communication II Class

"Creating Mental Agility."
Unconventional Computing: Design Methods for Adaptive Architecture
edited by Rachel Armstrong and Simone Ferracina. Cambridge, Ontario, Canada: Riverside Architectural Press
Stand-alone book and part of the ACADIA (Association for Computer Aided Design in Architecture) 2013 Conference Proceedings

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RESEARCH PRINCIPLES

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Proceedings from ACSA (Association of Collegiate Schools of Architecture) National Teachers Seminar, 2011  

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"Balance in Control: The Case of an Urban Design Studio at the University of Arizona."
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"Isomorphic City: a customizable future scenario."
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"Bio-logics: critical impact approaches in trans-disciplinary urban design for arid regions."
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*shows relationship of research and scholarship to specific areas of teaching
The Appropriate Balance between Digital and Analog Techniques

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Abstract: Design is increasingly becoming linked with technology: computer generated algorithms and parameters, analysis tools, CAD/CAM/CAE technologies for prototypes and increasing developments in production tools are just a few examples that support a more dynamic, technologically driven design processes. Information transfer through the web, e-learning, BIM and IPD imply a more transparent, collaborative, inter-disciplinary design process. What does this mean for analog systems in practice and architectural design education? Some information can effectively be disseminated through more of a web-based/video form, but face to face interaction and the ability to quickly sketch ideas are obviously an important part of a design process. Sketching appears to be becoming more and more digitized. Will the hand sketch and non-prototypical physical models eventually become obsolete? The multitude of digital skills and techniques that young architects now need can seem overwhelming. Increased knowledge in these areas is just part of the solution to good design. Designs now are often based on scripting and data libraries that are available online or within software programs: some designers use this data without understanding the implications involved or they show increased levels of detail at inappropriate stages of the design processes. It is essential that we continue to keep the link between seeing, thinking and making, which is inherent in the process of design. Designers need to be process creators, rather than being process consumers. This paper seeks to address the issue of what analog and digital skills are currently most appropriate for design, the interface between them and discusses the increased technological transformation of the academy and the profession.

Keywords: Integrated Design, Technical Agility, Building Information Modeling

Introduction

“Today, the computer is not a new technology to be either celebrated or deconstructed; it is simply a fact. Its logic has been fully absorbed into contemporary practices and habits of thought. In schools of architecture, students and younger faculty are the ones most fluent in these new technologies. No longer seduced by its formal effects nor intimidated by its difficulty, these designers have cultivated an expedient relationship with available technologies.”

-Stan Allen

This paper asserts that technology and computing is now a major part of the design profession and the academy. That being a given what is the direction design education should take so it embraces this fact and what about the analog tools of the past? The assimilation or shifting of tools and technology is a complex issue. It is important to remember that this technological shift, although documented over the past few decades, has had a relatively short shelf-life span compared to the previous analog representation techniques which have been used since the Renaissance.

Since the dawn of the ‘paperless studios’ at Columbia University, in the nineties, we have seen many of these graduates become principles of successful, relatively young firms that embrace digital technology wholeheartedly into their offices. Many of these offices hardly sketch by hand at all and rely on the 3d database model that Branko Kolarevic and Kieran Timberlake accredited to the shipbuilding and automotive industries. “The great advantage the aerospace industry has over architecture is its use of solid modeling. With solid modeling, designers are able to produce a virtual mock-up of their entire product. A virtual mock-up allows them to test for critical performance criteria without having to invest time or resources in actually building anything.” Should the developments with Building Information Modeling (BIM), Integrated Project Delivery (IPD) and the continuing dominance of technology continue this trajectory to its implied end in complete virtual simulation?

We are seeing university curricula shift more and more to the digital as students enter programs increasingly prepared and demanding classes in that area. If this is the trajectory then surely we should just embrace the most advanced technology possible and get rid of more analog techniques from the curriculum of universities around the country?

The Use of Analog Methodologies in ‘Digital Environments’

One successful technological firm, and its ‘off-shoots’ has resisted this path, though. Gehry Partners in Los Angeles, California has arguably been one of the main architectural leaders in what is now known as BIM. “One of the first projects to be developed and realized digitally was Frank Gehry’s design for the large Fish Sculpture at the entrance to a retail complex called Vila Olímpica in Barcelona, Spain 1992.” The digital design process of Gehry Partners has been documented in multiple monographs, edited digital anthologies and in the book ‘Contemporary Architecture and the Digital Design Process’, by Peter Szalapaj to name just a few. The main difference, in terms of process, to most other technically advanced architectural design firms, is that Gehry Partners begin their process with a sketch and multiple, physical models. These physical models are then worked on by analog techniques to an initial conceptual stage, then digitized or scanned so they can be manipulated, rationalized and analyzed in the computer (the software that enables the model to be manually digitized is rhino which is either used as an initial digital platform or as an interface into digital project). The physical model, which usually exists in various scales, is continually adjusted whether by hand or by a digitally driven verification process to confirm the design direction. So why is this analog methodology of the physical model such a large part of their process: is it just solely the result of having a pre-digital design partner? One of the advantages of their process is the physical presence of the model for everyone to see, walk around and touch; the design team, consultants, contractor team and clients/donors to name a few. It is amazing how many lay people can get confused with renderings and plans or even animations of a future project. Advances in abstractions, notations and symbolism help designers to read complex drawings, but these can mean that they are confusing to those not ‘in the know’. Although physical models are ‘real’ it is important to realize they are still generally a representation. The fact that Gehry Partners stresses the process model is important too. Their in-house physical

2 Kolarevic, Branko. Architecture in the Digital Age: Design and Manufacturing. Taylor and Francis, 2004 p.31
model-making techniques mean that these models are live, working entities so pieces can be re-used and manipulated with speed and ease. Dennis Sheldon’s MIT doctoral dissertation, 2002 (Gehry Technologies Chief Technology Officer) documented the concept of building these physical models with paper: these surfaces, with small adjustments, are all developable surfaces that can be unrolled and then constructed out of various real, flat materials. The physicality of the model also allows for potentially more notions of materiality and haptic sensibilities.

Most graduates without computer skills are able to work on these models (assuming a basic skill level in that area of course) with a minimal training period. The skills required to develop the surface models digitally, to a point where they can actually be built with relative economy, is quite complex and time consuming compared to just making superficially blobbby forms or lofting surfaces digitally. The increasing size of Gehry Technologies consultancy gaged, wouldn’t this process be ideal for students starting out their career in academia? Many students sadly still just use physical models as presentation tools rather than design tools. Process physical models can be fast and loose, like a hand sketch, but can be an instant 3d representation with potential materiality.

Materiality in a Digital Age

Digital media is often seen as the antithesis of the ‘real’ or material world. Sheila Kennedy and Antoine Picon have written about ‘a return to the real’ and ‘towards a new materiality’. Stan Allen has written about locating architecture “between the real and the virtual, capable of being in both, yet fully committed to neither.1 Whatever the position there is no point being nostalgic about the past, but a technique or tool that can address multiple senses seems to be a positive. This may be possible digitally in the future, but for now artifacts have a place in the design process. Stan Allen talks about the attributes of a “diagrammatic practice”; they are “relatively indifferent to the species of individual media…i it is, in principle, open to information from architecture’s outside. In as much as it is skeptical about the promise of new technologies, it remains free to take full advantage of architecture’s traditional techniques to organize matter and space.”2 Openness, staying loose and creativity is the key; in this changing world and profession we need to be increasing adaptable and aware of our interconnectedness.

So do we still need to push the ability to draw by hand? Obviously hand sketching has a place; jotting down ideas, communicating with clients, peers and contractors etc. especially if it is three dimensional. It can also be seen as a back-up plan if the computer is not there or not functioning for some reason. Hand drawing can have the same negatives that are often associated with the computer, though: virtual verses real, lack of materiality, representational issues etc. Some view hand drawing as more direct than computation, one less ‘detachment’ and a more direct use of the ‘body’. With advances in technology it is only a matter of time before ‘sketching’ will be digitized to such an extent that this difference may no longer be apparent. OK, we may be ‘sketching’ in the future, but it will not be with paper and pen or pencil. The MIT developed ‘glove mouse’ (MIT course 6.111 digital electronics lab) is just one example of a step in this more digital direction.

Digital Agility

Part of the digital conflict for offices and academia stems from the fact that there are numerous software packages out there and the ones that may have taken over the market as the latest BIM tool are not necessarily the best applications to be using for the more early stages of the design process, not even mentioning the tools needed for visualization, analysis and fabrication.

There is no doubt about the power of BIM and IPD: its change on the architectural profession seems to be increasing daily. Obviously with this shift it is imperative that our students get some interface with these concepts, software and techniques before they graduate with their professional degree. The extent and implementation is the issue. Generally in the higher end design firms the use of Revit, (Autodesk’s BIM software package) for example, is usually brought into designs in the late schematic design or design development phases – using its power as a production tool to the maximum. In certain areas of the design industry there are limits for this software as a conceptual or schematic design tool. Kai Strehlke, the head of design technology at Herzog & de Meuron has written about the same issue; “BIM may be an excellent tool for firms that use standardized architecture. In our office, it is applied for specific projects that are ideally represented by an underlying database. However it is not the right tool for all our projects: First, a lot of young architects are still not familiar with the underlying principles of BIM modeling and find it more intuitive to work with pure vector geometry.”3

At what point in academia should we be introducing a tool that is more adept at design development and construction document phases? My findings suggest that one has to be critical of too much information in the formative years especially when there is not enough design experience and knowledge to know what to edit. So one of the issues is how could this ‘information’ be taught progressively in a way that makes sense and hopefully improves the design output/sensibility? This does not mean that the computer should be avoided until later, but that they should be using more appropriate design, diagramming and visualization software in the early stages of their academic career and progressively working through various stages and software platforms.

Part of the process as a student is gaining experience with several software packages so there is an ability to make appropriate decisions about when to use each tool for what. There is not one piece of software that can do everything if there is a genuine interest in design. Part of what the students need to learn is to be agile so they can interface between digital programs and digital and analog scenarios. This is the advantage for the more technically savvy design firms like SHoP Architects, New York, NY; where they can organize their software usage to the job in hand, working smarter not harder and potentially using different multiple pieces of software for each different project. Importantly, they analyze and disseminates.4

Initiate their digital process and interface issues to continually improve on their in-house methodology and communication skills.

**Digital Craft**

Prototyping and digital fabrication are positive contributions of this technological paradigm shift: offering a direct relationship between modeling and making. It is important for designers to be involved with this process directly. For example; decisions involving certain tool-paths on a model destined for the Computer Numerical Control (CNC) router can have critical results for the final produced piece. “In a paradoxical way, the new techniques and methods of digitally enabled making are reaffirming the long forgotten notions of craft, resulting from a desire to extract intrinsic qualities of material and deploy them for particular effect.” 6 This does not mean that all designers should be emulating the design-builder necessarily, but experience with making improves the potential dialogue with fabricators and contractors. Toshiko Mori, in her research, suggested that the reliance on software programs in the fabrication process can “discourage critical awareness, as they are designed to solve problems quickly and easily; in so doing, however, they leave no room for discursive and speculative thinking.” 7 The main process during most successful designs is an iterative process where often failure can be a necessary part of the learning process. If manufacturing is just seen as a one directional/lineal flow from digital to prototype there is not much room for development and experimentation. The successful design of buildings needs to be a looser, less linear process where materiality is more nuanced.

![University of Arizona Student, Alex Zee Showing his Process of going from the Digital Model to a CNC Routed Output](image)


7 Mori, Toshiko. immaterial/ultramaterial: architecture, design and materials. George Braziller, Inc. 2002 p.xiii

**Hybridized Output/Customization**

Today there is much discussion on parametric design. Architecture has always dealt with parameters, many variables contribute to design; money, program, form, space, site and structure to name a few, but obviously the computer can help us with certain architectural and organizational goals. Whether these are design goals or production goals, modeling goals, versioning or budget goals seems to vary from architect to architect. Generally, today, it is in smaller installations that some of this more progressive work is being developed, but there are also new cities being created where the use of computers can help us organize all the complexities of our infrastructure and environment.

The latest parametric, digital design ‘look’ seems to have become one of flexible modularity – a form marked by irregularity, by the apparent absence of repetition. Advanced fabrication techniques, developments of NURB based software, algorithms and more general knowledge of computing have allowed this customization to occur at a level that was once only practiced by mavericks like Antoni Gaudi. Most of the ‘advanced’ firms, in terms of the digital design process, are known for their ability to create customization in their tools. Originally this seemed to be in the area of software ‘scripts’; designers were not being limited by the software designer’s creative process.

This customization has more recently spread into the tools that build our prototypes, designs or even build our buildings. Factum Arte, in Madrid recently designed a fabrication tool to enable Anish Kapoor to create something between “shit and architecture” the output “are more akin to natural things than to those made by design.” 8 The concrete print technology can print directly from digital files, the results of which were exhibited at the Royal Academy, London 2009 and the Guggenheim, Bilbao, 2010. This desire to be more natural and appear less controlled brings up similar desires to emergent design generators. Kapoor also stated that “technological methods give technological solutions. This is not the case here.” 9 Part of how this is achieved is the powerful impact of the materiality from a property that is ‘soft and wet’ in the sense that its properties change as it dries, hardens. Making one relate more to William Bateson’s notion that, “the appearance of chromosomes is not suggestive of strings of beads of extreme heterogeneity, but rather with that seen, for example, in drying mud.”

In a similar vein, Ball-Nogues Studio, Los Angeles, had to create a machine that enabled them to paint string in specific locations for their installation at MOCA (Feathered Edge), 2009.

This idea of being creative with one’s media and tools is not a new idea, but has generally been one of the drivers of creativity in general.

The idea of pushing the limits of existing tools and customization tends to be also prevalent among the more ‘digitally or design progressive’ schools curricula. Part of the 2010 Architectural Associations DRL Graduate Program’s Project’s Review, ‘Machinic Control’, featured customized fabrication tools that challenged the repetitive modes of industrial production.


9 Ibid
Digital/Craft Hybrids

Digital fabrication has often been proclaimed as the opportunity for the return of craft in our increasingly industrialized environment. One of the interesting developments among some of the most digitally adept is the more literal addition or hybridization of more analog craftwork combined with their digital fabrication pieces. One example of this was the published ‘Basket Weaving’ by Aranda Lasch, 2006, which was a collaboration with the Native American basket weaver, Terrol Dew Johnson to design some new hybrid forms. So far this seems to have been a lone project for them in this more hybrid direction, though. Theverymany’s project ‘Echinoids’ (part of the ‘Wild Child’ exhibit at the Bridge Gallery, NY, NY, 2009) combined digitally, laser cut shapes which were attached to each other with an obviously analog lacing technique; ‘lace is more’.

The incorporation of more traditional ideas of craft seems to have become more prevalent lately, maybe as we enter a more environmentally conscious era? Or is it a desire to ‘soften’ the coldness or abstraction of the more virtual world? Combining possibly older, more analog techniques with more contemporary, digital methodologies gives us the possibility of making new hybridized solutions; potentially using our past to move forward rather than making a break from it and our context.

Conclusion

Change is the only constant in the world, so why is it often met with resistance? I think the penalty for resisting change will increase dramatically over time and like the lines of unemployed architects today may mean that some of these people will never return to the profession, assuming we have a profession in the future. It is important for a school and an office to position itself in a changing profession: keeping itself agile to keep up with issues that are not fixed and will continue to develop and change.

Do we want to be emphasizing the production end of the profession in academia when increasingly construction documents are being outsourced to various parts of Asia? What is it that our future architects need to know to be successful in this world? Surely we need to be encouraging students to be creative to think, lead, make, test, analyze and communicate rather than to be computer or hand-drafting monkeys? We need to be focusing on design, diversity, hybridization and feedback loops rather than a false simplicity or determinism.

About the Author

Susannah Dickinson

Susannah Dickinson came to the United States for graduate school, after completing her undergraduate studies in the United Kingdom. She has become involved in research and projects that stem from a background in digital processes, parametric modeling, BIM, and digital fabrication. This background was largely gained through years of professional experience in the offices of Frank O. Gehry, Los Angeles and SHoP Architects, New York. This technological background is coupled with a belief that it is our responsibility as architects to be concerned with the entire built and natural environment. The interest is in whether technology, in the form of computational design and fabrication processes, can lead to sustainable and ecologically responsive systems; leading to new architectural and urban paradigms for sustainable environments.
INTEGRATED DIGITAL PEDAGOGY

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Abstract. This paper seeks to question how the academy should position itself in this changing environment of Building Information Modeling (BIM), providing a critical analysis of how digital design education is taught. The pedagogical goals of the digital communication stream at the University of Arizona will be addressed; in part discussing the implementation of relevant software and techniques in appropriate venues in a specific class, stream and the curriculum as a whole.

1. Introduction

With the wide-spread use of smarter and smarter tools containing more and more relevant information we have largely moved past the era of Computer Aided Drafting, where most architects implemented software in a way that did not alter their existing working methodologies (i.e. in two dimensions) to finally embracing Computer Aided Design. The term Building Information Management (BIM) has become synonymous with this change; the term is used by various authorities to refer to the products of software, the process for collecting and documenting a building, and the use of information in simulation and analysis to enable decisions about design (Eastman, et al. 2008). The more traditional architectural process of Computer Aided Drafting consists of designers abstracting the building into orthogonal, 2-d drawings. The BIM process, which has a history beyond the institutional definition, constructs a virtual building in three and four dimensions and simulates its performance, avoiding the 2-d abstraction steps (Ambrose 2007). This change implies a different design methodology. Dr. Stan Guidera noted in his ACADIA paper, BIM lates its performance, avoiding the 2-d abstraction steps (Ambrose 2007). This change implies a different design methodology. Dr. Stan Guidera noted in his ACADIA paper, BIM suggests that because of this shift, simply applying new tools and processes to old pedagogical and principles and processes is fundamental. Renee Cheng stated at the national AIA Conference on computation (Guidera, 2006). A superior concept or “digital studio” is organized around the use of digital design; design decisions are made on the screen verses paper. This model is contingent on having faculty with digital expertise or having enough resources to employ assistants or co-teachers with this ability. Digital learning processes can be time consuming, so additional studio outcomes or National Architectural Accreditation Board (NAAB) or other professional accreditation board’s criteria often need to be compromised. These specific NAAB criteria and their apparent lack of knowledge of digital processes is a topic beyond the scope of this paper.

In an era of environmental crisis and complexity, we need holistic, non-reductionist (i.e. complex) design outcomes, but sometimes pedagogically we as educators need to be reductive about a particular design or assignment strategy, as being inclusive of every aspect of computation can be overwhelming to instructors and students, especially at the beginning design stage. There is so much information out there, how do we focus it on what is relevant? Assignments need to limit and strategize over what features are required to be learned and taught. This can be further exasperated at some institutions where the range of student ability is vast. The challenge is to make sure assignments are kept fundamental enough to allow a large range of students to be successful and creative, whilst also ensuring that they are challenging enough to allow the best and brightest to excel.

The following digital methodology applies specifically to the professional undergraduate program at the University of Arizona, where digital communication is one of five streams (including studio), that make up the required curriculum. Currently students learn some basic computer skills in their first-year foundation, with two required three credit lab and lecture classes in the fall of their second and third years respectively. These are large classes containing 50-70 students each. Three years ago the digital communication stream created a digital matrix for the larger school curriculum, to encourage and increase digital use in more and more classes. This included classes which were not specifically designated as digital, as a way to ensure that in the curriculum digital methodologies are becoming pervasive and are no longer seen as just a separate, distinct stream.

2. Background

Guidera refers to the “exclusionary” or “tangential” approach to computing in the studio. The exclusionary approach is either non-existent or proscribed, whereas the tangential approach assumes that digital skills have been previously taught or are taught in separate courses. In both cases only a minimal amount of time in studio is typically given to skill development with computation (Guidera, 2006). A superior concept or “digital studio” is organized around the use of digital design; design decisions are made on the screen verses paper. This model is contingent on having faculty with digital expertise or having enough resources to employ assistants or co-teachers with this ability. Digital learning processes can be time consuming, so additional studio outcomes or National Architectural Accreditation Board (NAAB) or other professional accreditation board’s criteria often need to be compromised. These specific NAAB criteria and their apparent lack of knowledge of digital processes is a topic beyond the scope of this paper.

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SECTION FOUR: DESIGN AND CAAD EDUCATION
3. Digital Methodology

As stated earlier, the digital communication stream comprises of two required support (non-studio) classes. In the first class, students are taught the basics of the Adobe Software Suite, basic rendering, orthogonal 3-d modeling and laser cutting. The following section discusses in more detail the specifics of the second, more advanced class that for the past four years has centered on a precedent analysis. Although the class encourages the digital as a design rather than a production tool, the use of precedents are incorporated to limit the design choices available to students, mainly due to time constraints. Precedents are chosen for their geometrical complexity and/or parametric logic. Most are buildings that have been realized, in part so there is more availability of resources, but also to increase the awareness to students that these geometrical complex buildings are real and are not just contained to the virtual world.

In this particular institution, BIM is often associated with a particular software platform, in this case Revit, an Autodesk BIM platform. Because Revit is a laborious piece of design software, a pedagogical decision was made for students to begin their digital modeling education (in their second year) learning Rhinoceros, a 3-d modeling platform from McNeel that has a much more intuitive interface. Revit is introduced to students in another support course on Materials and Methods, at the same time in their third year as the second design communication class. Early introduction of BIM technologies alone tends to make the weaker or lazier design students gravitate to this one piece of software for ease of production rather than increasing their design ability. This way of thinking and designing usually leads to mediocre results. In contrast students need to be educated that top design firms use multiple platforms as there is not one tool out there that will do everything. These firms are often inventing or scripting programs themselves as they push the limits of platforms and their interoperability. The imperative is for students to become digitally agile if there is an interest in inventing or scripting programs themselves as they push the limits of platforms and their interoperability. The imperative is for students to become digitally agile if there is an interest in design.

Students begin their second design communication class with advanced rhino skills which enable them to build 3-d models of their selected precedent studies (figure 1). During this process lectures and discussion focuses on modeling methodology. Apart from software techniques and geometric logic, emphasis is placed on what should and what should not be modeled, whether surfaces should or should not have a thickness; on how much information is enough to relate to the reality of the built logic. Many students in the early stages of their career, whose knowledge of both time management and construction is minimal, often spend too much time modeling details or parts of their projects that never make it out of their computer into their final studio presentations (assuming traditional methods of representation are used). The amount of detail modeled is important even if models are displayed virtually in the form of interactive environments or animations; on a pragmatic level decreased file sizes allow easier workability.

This approach also reinforces methods of working smarter, not harder. With the widespread introduction of cloud computing for rendering etc. the concept of not modeling or creating more than is necessary for a given task is still relevant to issues of sustainability on multiple levels: relating to how much energy the student is spending, socially and energy-wise. After models are completed these become a tool to test their ability to create 2-d images from their 3-d database (one of the most dominant shifts with 3-d BIM-like packages). In Rhino this is not as automatic as most propriety BIM packages.

This step is important for a couple of reasons; most BIM packages have the ability to create various, sophistications in line-weights and standards, but students need the ability to make presentation quality drawings rather than production drawings. This normally involves interoperability with the Adobe software package. This exercise offers the potential to look at an implicit level of creating information rather than a more explicit level of production i.e. students have the ability to be creative and explore various representation and drawing methodologies too. One particular student, Joseph Di Matteo used his precedent study of Frank Gehry’s Lou Ruvo Center for Brain Health, USA to conceptually create a new type of digital drawing methodology that visually “relates” to the precedent architect’s hand sketches (figure 2).

Another student, Dulce Arambula used this opportunity to incorporate Autodesk’s Ecotect, a software program she had previously learned in her second year to create performative diagrams that “relate” to the acoustic realities of her digital model of Eladio Dieste’s Church of Christ the Worker, Uruguay (figure 3).

SECTION FOUR: DESIGN AND CAAD EDUCATION
After, students are introduced to the concept of parametric modeling; geometric relationships are emphasized which update together in a coordinated way. In this particular course the Rhinoceros plug-in Grasshopper is used. Developed by David Rutten, Grasshopper is not just a stripped down version of BIM. It allows a parametric design dialogue that is not the emphasis of all BIM tools. The interface and logic is different from the students’ previous digital exposures, but offers a more graphic way of engaging with students in scripting logic. In this phase of the course students are encouraged to explore various Grasshopper plug-ins. Performative practice models and live digital workflows are demonstrated, with the goal that students will begin to understand that the ability to simulate and use analysis tools for performance in preliminary stages of a design can lead to ways of form-finding versus form-making. Some students used plug-ins as generative, evolutionary modelers to speed up their iterative process. Digital models are also used to create animations and rendered images.

The penultimate process taught is that of digital fabrication. Subtractive (laser cutting and CNC routing) and additive tools (3D printing) are introduced. Laser cutting is a tool that students are already familiar with at this point in the curriculum, so emphasis is placed in using the tool in new ways, including material testing and creative ways to make complex 3-d forms out of 2-d products (a pertinent architectural challenge that relates to the use of paper models at Gehry Partners). Joseph Di Matteo used this design and rationalization process to make a physical model that could move and twist, to begin to show the formal possibilities of using simple, orthogonal 2-d products; showing how ruled surfaces can be relatively complex, especially if there are multiple sheets (figure 4).

Issues of sustainability are also addressed in these fabrication methodologies, all the while relating to real projects and processes. Conceptually, additive CNC methodologies seem greener, but nesting techniques and realizing the opportunity for second generation mold-making steps can obviously alleviate this assumption. Now more realities can be incorporated into the digital model in an easier way than ever before, e.g. materiality and direct links to fabrication: the architect as master (or mistress) builder. Multiple aspects can be tied together in one model; design, analysis, representation, simulation, fabrication, cost-estimating, construction and post-occupancy evaluation data-bases.

Throughout the course there is an emphasis on documenting one’s individual process, which becomes a tool to remember how one actually completed a task successfully and also becomes a useful pedagogical model to show that design and technology are never complete or static, emphasizing the need for students to stay adaptable and aware of their processes in this digital age. Finally, students are encouraged to create a dissemination piece that incorporates all their previous work for the course. Figure 6 shows an example of one student’s final project.

4. Findings

Most design students enjoy the ability to experiment creatively with contemporary techniques and tools. It was not mandatory that there be a conceptual link to each assignment, but the students who developed a conceptual idea over the course of the semester, rather than those Dulce Arambula, the previous mentioned student who had used Ecotect in her initial studies, continued her exploration with research into what she called, ‘Acoustically Responsive Architecture.’ Dulce stated that her idea came from working on her previous parametric model and animation that led to the conclusion that architecture could be more responsive. She used another processing program, in this case VVVV (by the VVVV group), which allowed her to create a live interface and surface from actual pieces of music. This was later transferred to a CNC router to make physical form that related to the sounds (figure 5).

While the exploration of sensory cognition is not directly relevant to this discussion, it is another example of how the digital is becoming more inclusive in an area which had been previously predominantly sight driven. The connection of 3-d models to a physical output is obviously haptic in the sense that there is a materiality (finally) to the virtual process, but incorporating other senses and performance criteria is a design direction that can enrich the process and end product.
who completed the individual tasks as separate were more engaged, had more advanced digital tool research and ultimately ended up with a better final product.

Figure 6. Final compiled drawing. (Submission by Joseph Di Matteo, B.Arch. candidate 2015)

This should be encouraged, although focusing too much on design aspects is very time consuming for most students in the early stages of their career. To assume that support courses should be completely devoid of design input is unproductive though, practicing design helps one become a better designer, so the more design opportunities a student receives the better. Allowing design exercises into support courses also undercuts the dichotomy that is often present for technical verses design electives; science and art. These separations are not helping us design more holistic environments and also reinforce the computer as a production tool rather than a legitimate partner in the design process.

5. Conclusion / Future Directions

Although this course completes the required digital communication classes for the school, it improves each year as more techniques are pushed down to earlier years. In part, as a result of the curricular-wide digital matrix, the last few years have seen more courses incorporating various digital methodologies. When students complete this required course, in the middle of their professional degree, students have the basic digital methodologies, which they can then build upon throughout the rest of their education and career. With regards to specific foci for future incorporation, it is important to begin an interface with Geographic Information Systems (GIS). Architecture’s traditional discipline boundaries are blurring. If we do not embrace innovative technologies that are crucial for other disciplines and large-scale works then we are potentially risking being pushed to the sidelines. There is also an urgent need to start students in basic programming skills. Many high school science classes are now incorporating basic Net Logo programming skills so we should not fall behind the curve. In my four years at this particular institution there has been an increased demand from students for more “advanced” offerings.

There is only so much that can be taught by faculty in a limited number of courses. Ideally, most studios would be seen as “digital studios” in the future or just completely integrated. To do this we need to increase faculty skillsets and incorporate more bottom up opportunities for our best students (we started exemplar student run weekend workshops two years ago) and incorporate some of the great online open source tools on the web. Students need to be made aware that they are active participants in their own education process. This should be encouraged, although focusing too much on design aspects is very time consuming for most students in the early stages of their career. To assume that support courses should be completely devoid of design input is unproductive though, practicing design helps one become a better designer, so the more design opportunities a student receives the better. Allowing design exercises into support courses also undercuts the dichotomy that is often present for technical verses design electives; science and art. These separations are not helping us design more holistic environments and also reinforce the computer as a production tool rather than a legitimate partner in the design process.

Technology is constantly improving so research blogs and help groups, where questions can be posted and answered, are valid pedagogical models. These groups can also lead to a larger sense of a digital community in the academy and beyond.

It is clear that courses and the larger discipline need to have more future overlap and integration if we hope to educate more holistic, environmentally-sensitive future designers. A first step is making our studios more digital with the ability to integrate as many support courses as possible. Like parametric modeling – some early, upfront work in this area will achieve vast pay backs later on. Large universities often have less flexibility with their curricula than smaller, less bureaucratic bodies do. Knowledge of these university and accreditation board’s procedures and protocols, that are often driving curricula, is crucial if changes are going to be made in a more effective way. One has to understand the underlying rules in order to improve the system, realizing that these should not be fixed in stone, but should be questioned and adaptable to keep up with the changing times and technologies.

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References

CREATING MENTAL AGILITY

Susannah Dickinson

Today there seems to be a general consensus about the need to think and act dynamically regarding the design of the built environment. Thinking dynamically is not a new concept. Karl Mannheim in his 1936 Ideology and Utopia stated that:

It has become extremely questionable whether in the flux of life, it is a giverned, worthwhile intellectual problem to seek to discover fixed and immutable ideas and absolutes. It is a more worthy intellectual task perhaps to learn to think dynamically and relationally rather than statically.²

So why in most academic institutions have our pedagogical models remained so static for the last century? Is it that most academics are dinosaurs that have not kept up with changing times? Do we fear change, seeing this as antithetical to the safety net of tenure? (This is terribly ironic when change is the only constant in life). Or is it that many of our public institutions—including our professional accreditation boards—have become bureaucratic, administrative nightmares with so many rules and regulations that change is often a painful, time-consuming uphill battle? Obviously to remain dynamic and agile we as individuals, networks and institutions need to remain flexible and capable of change.

So how dynamic do we need to be in order to design and think more creatively? Is it about becoming a wandering, peripatetic scholar like those in Ancient Greece or today would the equivalent just mean a huge ecological footprint from flying around the globe too much? With increased technologies like cloud computing and mobile internet are forcing this trajectory daily.

While physical agility/ adaptability will become even more indispensable with global climate change, staying mentally agile or creating mental agility is an imperative: not letting the baggage of life weigh one down. In pressing economic times like the present, there is often the tendency to think in a more short-term, survivalist mode rather than having the luxury to make more intelligent, sustainable choices. Virginia Woolf, in her classic book of 1929, A Room of One’s Own, comments on why there were such few creative female role models in the past. She surmises that this relates in large part to their inability to inherit money, which led to a lack of independence, focus, time and power. So how do we make the time and have the financial freedom to stay mentally agile and creative? Can we have more economic equality without removing the incentive to succeed? It is important to re-evaluate culturally and on a personal level what we are valuing economically.

One of the more optimistic consequences of the digital age is the ability of individuals to connect, network and share information in a more grass-roots, bottom-up fashion than has been previously possible—a new common, global language. Universally hopeful went out with the Modern Movement, but having the ability to communicate and network with others on the same planet has the potential for increasing information and power. So how do we make the time and have the financial freedom to stay mentally agile and creative? Can we have more economic equality without removing the incentive to succeed? It is important to re-evaluate culturally and on a personal level what we are valuing economically.

Porter itself must be abolished—and not solely in the refusal to be dominated, which is at the heart of all traditional struggles—but also as violently in the refusal to dominate (if the refusal to dominate had the same violence and the same energy as the refusal to be dominated, the dream of revolution would have disappeared long ago). Intelligence cannot, can never be in power because intelligence consists of this double refusal.³

4 Baudrillard, Agony of Power. 47 f.
If everyone stopped dominating or trying to control other people, places and things, then surely we would achieve a more ecological balance in the world. We need to start functioning on a level of mutual respect and ethics rather than dominance and greed, realizing that if we are to move forward en masse we need to be less concerned about personally getting ahead in a traditional sense. We need to start understanding that in this time of rapid change we cannot or should no longer plan for permanence or predictability. Rather, we need to plan for more adaptability.

What will these more dynamic pedagogical models look like? Hopefully, as one who is aging, there is some sense of wisdom that can be passed on to the younger generation, but maybe in a more hybridized, balanced form of cooperation and collaboration rather than dominance and control. Collaboration, in a pragmatic sense, can help to share the workload, but can also mean a more diverse set of perspectives, insights and knowledge from people with different backgrounds and expertise. We need to break down the academic silos that many of our institutions have created. The challenge is to look at issues more holistically. Aldo Leopold—a major influence on the environmental movement—stated his concern over increased academic specialization in the middle of the last century:

There are men charged with the duty of examining the construction of plants, animals and soils which are the instruments of the great orchestra. These men are called professors. Each selects one instrument and spends his life taking it apart and describing its strings and sounding boards. This process of dismemberment is called research. The place for dismemberment is called a university.

A proposed future culture of collaboration across boundaries and focus on longer-term goals will create a renewed research culture, different from those that exist in most architectural institutions today. Ideas and research should be more interlinked with design rather than being a separate precursor, afterthought or financial pressure. In fact, defining the problems and questions is often more important than developing solutions. Just because one is networking or collaborating in new ways using the latest data or technology does not guarantee success—our whole design process and work flows need to be readdressed. Today, many professional architects complain about the lack of power that the profession has, but many act more like harlots, doing whatever their rich clients tell them to do. We need to start expanding our professional scope, realizing that everything is inter-connected and has effects on others and the environment. We can no longer sit on the sidelines as if our actions did not affect society and the environment as a whole.

Currently we have the potential of incorporating large quantities of data and information into our work, but how we make decisions about their filtering and use is crucial. This may suggest a break from our most current models of practice. Educational institutions need to re-invent themselves as places of research, ideas and critical thinking—attracting the brightest minds rather than being a necessary step up some traditional, known corporate ladder. They need to be places where diversity is celebrated against the antithesis of a banal globalization, where some sense of value and ethics is part of the equation. Changing our apparent trajectory may not happen overnight, but it is imperative that we at least begin to move in a new, awakened direction.
Architecture and Biological Systems

ABSTRACT

“Luxury at present can only be enjoyed by the ignorant; the cruelest man living could not sit at his feast, unless he sat blindfolded” (John Ruskin, 1905)

The emphasis on ‘perform ative’ architecture and practice has seen an increase in recent years partly due to the current economic and environmental crises. Developments in parametric design, monitoring and analysis software are an obvious part of this, and the way we are looking at now is of the natural world; they tend to be simplified algorithms at this point. Alfred Caldwell has stated that nature seems so complex and alive, but “nothing in nature is arbitrary”. Have we imported enough of the parameters of life into our design equation? Do we need to be focused on what we know and need. Change is a process and takes time, but there should be some sense of urgency in our current situation.

In the midst of this environmental crisis, it is time we understood more about the planet we inhabit. Human ‘progress’ has led us to this crisis and detachment from ‘nature’. However, technology can help us understand these natural systems at another level then we previously had known. The study of Biomimetics is increasing in architectural curricula across the country. Is it superficial image making or an understanding of the systems and their performative aspects?

So far these examples are infinitely less complex than the natural world; they tend to be simplified algorithms at this point. We need to make sure we are not just ‘performing’ in a superficial way, though; adding a few analysis diagrams to our presentation repertoire is not enough. Simply cladding buildings with morphogenetic skins will not get us to where we need to go.

In our Information Age it is ironic that one of the main information areas that certain architects are looking at now is of the natural world – Biology. Michael Weinstock has stated that Physics was the driving force of the 19th and 20th century; Biology will be important in the 21st century.

Environmentalism is not a new issue. Historically, whether in the guise of conservationism or the arts and crafts movement environmental issues gained momentum as the world became more developed and industrialized. Recently there has been more mainstream acceptance of environmental concerns in the wake of the current global economic crisis, population boom and global warming. The building industry is a major player in this environmental crisis because it uses approximately one third to one half of all available resources. For this reason alone it is apparent that building processes, resources and systems should be critically reviewed.

The environmental concern is not just about the shortage of future natural resources, but about the effect the pollution and waste has on human health issues, human psychology and further environmental impacts.

Star-based, willful architecture projects are diminishing for most. Tighter budgets mean that architects need more concrete reasons for their design decisions: there is a need for a larger sense of responsibility than many architects have shown in the recent past, a broader sense of ‘ethics’. Making sure buildings ‘perform’ responsibly is a key issue today. Innovation and technological advancement are not important for their own sakes; developments need to be balanced in consideration with available resources and human culture and psychology.

One dilemma is how such a holistic approach can only be enjoyed by the ignorant; the cruelest man living could not sit at his feast, unless he sat blindfolded” (John Ruskin, 1905)

The human being: reason, abstraction, language, self-consciousness or inner sensibility, aesthetics, free will, a more elaborate sense of time and relationships.

Buildings and architecture are generally at the lower end of the spectrum, historically in the
very bottom category. As we try to analyze our built environment’s performance it makes sense to study the systems of the higher levels and to evaluate which components should be potential goals for architecture. Realizing that complexity for complexity’s sake is not the critical answer.

Nature, even at the level of geology is dynamic; it is constantly changing, adapting, modifying and evolving, whether we are able to perceive this with the human eye or not. “In the morphogenesis of biological organisms, it is the animation of geometry and material that produces form. Geometry and material hierarchies produce dynamics.”

Some of the main characteristics of natural systems are:

1. Good economics of energy and materials: optimization.
2. Rich, diverse systems from small, relatively simple components and materials.
3. Form, structure and material are generally all interconnected.
4. Survival techniques are maximized: e.g. carrying capacity, the relationship to surrounding environments (ecological), usually always process-driven systems.
5. Always dynamic systems: all nature is constantly changing and adapting.
6. Self-organization techniques are utilized; they produce emergent behavior, from sub-cells to ecosystems (systems within systems).

Items 1 through 4, one could argue, are the more straightforward examples that are well on the way to being achieved in architectural design at this point and 5 through 6 are potentially more extreme. All of these criteria need to be looked at in more detail to understand what works and why. With regards to optimization, for instance, this has historically been treated very differently in biology versus buildings. In biology to achieve efficiency and optimization there is a high amount of redundancy and complexity in the material hierarchies. This redundancy allows adaptation to changing environments, and is a much less linear approach to the way we usually engineer buildings. Biology’s stochastic process, rather than a deterministic one, generally means that the standardization of components and members is precluded.

Regarding materials, “biology makes use of remarkably few materials, and nearly all loads are carried by fibrous composites; cellulose in plants, collagen in animals, chitin in insects and silk in spider webs.” These materials have much lower densities than those normally used by the construction industry. They work not because of this fact alone, but because of the way they are put together. For example, the same material is used in blood vessels as in more rigid bone. Fiber composites are anisotropic (the property of the material depends on a direction, e.g. a grain in wood). These materials generally provide higher levels of optimization then ones which are more homogeneous. Generally, they are good in tension and bad in compression (tension based systems per weight are usually more efficient than compression systems). This lack of performance in compression is solved in various ways in nature; either by pre-stressing the fibers so they hardly ever experience compression, the creation of fibrous networks where changes in orientation avoid compressive loads acting along fibers and finally the addition of minerals which help to carry the compressive loads.

Geometry, pattern-making and folding strategies are other very apparent teachers in the natural world. In human bone, for instance the cellular solids are polyhedral versus the more regularly organized, minimal surfaces equated with beehives.

Ecology is one of the sub-disciplines of biology that is very relevant to architecture today and often used as an adjective to projects and disciplines. It is “the branch of biology that deals with the relationships between living organisms and their environment”, (Oxford English Dictionary). The main point is to see an object as a system that relates to its surrounding systems (context) as a process. The main biological processes are photosynthesis (carbon dioxide chemical transfer to organic compounds using solar energy), reproduction (information transfer), metabolism (process of taking in energy for living processes and expelling waste), homeostasis (self-regulation) and hydrogen technology. There are also biological phenomena that are often the result of environmental stimuli, for example tropisms; geotropism, phototropism, hydrotropism and thigmotropism to name a few.

There are many more lessons to be learnt from nature and our environment, including entropy, synergy and cybernetic theory. Cybernetics is the study of control and communication; systems in biology primarily focusing on how animals adapt to their environment, and how information is passed from generation to generation. Artificial intelligence, feedback systems, self-organization and emergent theories are all subsets of cybernetics. Self-organization is widespread in animal architecture and behavior creating decentralized, distributed, emergent, complex, non-linear systems from simple, local rules. Surely we should be teaching these principles in our environmental control classes, so we can understand systems theory in a broader context.

APPLICATIONS: HOW DO WE TRANSLATE THESE PRINCIPLES?

How much of this knowledge is important to use for architects in the quest for performative design? It should not just be about superficial skin making or adding a couple of analysis diagrams to our presentations. Surely we should not just be making skins or buildings dynamic or be interactive just for the sake of it: this, in a pragmatic sense, can just create maintenance issues and be an energy hog. Do buildings need to strive to be alive? How interactive do we want/need them to be? If we look at ‘architecture without architects’, generally in pre-industrialized societies, the built environment seemed to be in a more harmonious relationship with its natural environment. Building traditions developed over usually hundreds of years and generally used local materials, maximizing as many passive systems as possible (more akin to nature). This architecture was not alive, but was generally more informal in the sense that there was a level of adaptability and connection to a larger whole that was apparent. For some cultures this was also a result of people adding on and subtracting to their dwellings over generations rather than just moving or building new houses as the western world tends to do today. Most people ultimately want some control over their environment so a total top-down approach to design and planning sometimes inhibits the sense of freedom and life. As humans have the ability to have choices, free will, self-interest and self-awareness this tends to prevent any strictly predictive models from applying to human problems as they do in natural sciences. Although there is no point being nostalgic about the past there are lessons to be learnt, which coupled with our increased technological knowledge will hopefully lead to more satisfactory results that ‘perform’ at higher levels. Technologically we have advanced tools for design, fabrication and construction which mean we should be able to design ‘smarter’ environments for ourselves: we are no longer constrained by the concept of standardization in a literal way as an economic model.

We do need to view buildings and all the related systems as a longer term concept: one which factors, or tries to factor in all potential life-cycle costs. This implies a cultural shift or legislative shift at a minimum. How can we expect people to just suddenly be not interested in making quick profits in our capitalist society? There is obviously the demand from consumers that is shifting slightly, but generally this is a very slow, uneducated, media-driven process.
Ecological, inter-connected systems in the natural world have no separation of form, structure and material: they all act on one another and cannot be predicted by the analysis of any one separately or in a different context. Isn’t this how architecture should be; critically sensitive to its region and holistic? In academia it is generally in studio where all our support/core clauses are disentangled, to come together. Shouldn’t this ‘coming together’ be more than the typical studio class which is usually only about a third of our semester or quarter’s required credits? Most curricula’s separation of materials, structure and systems are a potential interfering issue. With the increasing specialization of professions and the academy it is imperative to get input from other areas of knowledge and expertise to develop a holistic design strategy. The development of Building Information Modeling and Integrated Project Delivery (BIM/IPD) is, in theory, pushing us to a more integrated, cohesive model of working. But we need to make sure we are not just using this methodology to do business as usual. Using a 3d digital database does not imply an interconnected system with its environment. It merely implies more potential coordination of existing rules of design and construction. We need to see buildings as interconnected, dynamic networks.

Relation-based aspects of parametric computer modeling programs are closer to the information-processing in nature. New ordering methods with computational means; self-organization bottom up verses top down are a useful design tool today. With anything, though, it is important to remember that it is not just valid because one is using some contemporary technology. We need to move beyond this to be critical of the inputs and how they relate to a knowledge-based design aesthetic that is appropriate on many levels. We also have a long way to go computationally. Live analytical feedback loops via parametric software are continuously developing, but are still relatively complex and clunky. This generally means that optimization and simulation tools are still used for analysis after an initial design is developed rather than as a live, design generator.

Much of the embodied energy in buildings comes from the production of building materials; thus improvements of energy use in production processes is a crucial part of any overall strategy for energy conservation in the built environment. Much of the energy takes place in the manufacture of a few extensively used materials which involve high temperature kiln processes, notably clay bricks, cement, tiles and glass.

In most contemporary buildings walls become barriers to isolate space and separate us from nature; resolving this paradox is what forces buildings to include many of the technologies and infrastructure we use today. Living systems resolve this paradox by creating adaptive interfaces rather than barriers. Some recent advances are building walls that can be porous and permeated. Rain screens and double skins are just the first step in this process, to make buildings more breathable. Ultimately we need to be resolving this in tandem with the material, structure and form.

“The spider conducts operations that resemble those of a weaver, and a bee puts to shame many an architect in the construction of her cells. But what distinguishes the worst architect from the best of bees is this, that the architect raises his structure in imagination before he erects it in reality” Karl Marx, Das Kapital, (1867).

There is no design in biological evolution; it’s fluid process works as an open systems regulated by the laws of nature only and is in contrast to the more rigid, authoritarian and oppressive system we generally use to design our built environments. Some could see this self-organizing approach to design as the first step in making the role of the architect redundant. Every technology needs to be designed, but in the short term at least, the emphasis towards this strategy may make the role of the architect unfamiliar. Architects would only become redundant if they did not make the transition themselves from a Cartesian-based world to a systems-based one. This necessary adjustment would apply to other disciplines too. The new ‘systems’ architect (in the living technology sense of the word) will need to be an interdisciplinary practitioner as a matter of survival.

**EXAMPLES**

Human interest in technology and nature probably goes back to the beginning of time. More recently one of the main associations has been with Frei Otto and his development of the Institute for Lightweight Structures and Conceptual Design, in Stuttgart, Germany. Current academic programs that seem to be embracing this methodology are generally approaching this issue beyond the traditional scope of architecture, in many cases incorporating or collaborating with individuals or groups from other disciplines. The Architectural Association in London, particularly the Emerging Technologies and Design Graduate Program (EMTECH) that includes George Jeronimidis, a doctor of physical chemistry and director of the Centre for Biomimetics at the University of Reading, has been the primary leader in the current approach to biomimetic design. The publications of its architectural faculty, Michael Hensel, Achim Menges and Michael Weinstock and their protégées are having a large impact on the profession today. One of their ex-students, Neri Oxman at MIT, is working on the synergy between geometry, physical matter and energy, with the implication that modeling, analysis and fabrication occur simultaneously. To do this, she states that one must first abandon the conceptual structure of a divided and hierarchic process separating the analytic and the synthetic, and arrive at their ultimate integration. “A new philosophy of design is slowly emerging which anticipates and supports the merging of matter and energy on the way to proto-design.”

The Lab Studio at UPenn initiated in 2007, is a hybrid research and design unit between the architecture department and the medicine and engineering institute. Their research is applied to both professions. The Center for Architecture and Situated Technologies (CAST) at the University of Buffalo has an emphasis on ‘soft materials and the capabilities of an elastic, responsive architecture’ and the Center for Architectural Science and Engineering (CASE), collaboratively founded in 2006 at the University of Buffalo has an emphasis on ‘next-generation building systems.’ The development of smart materials is continuously advancing. Smart materials are those that are potentially changeable and thus responsive to transient needs. There are generally two types: those that absorb an input of energy and undergo a change (e.g. shape memory materials) and those that transform energy from one form to another (e.g. photovoltaics). The implied trajectory is that concrete (this alone counts for 5% of all carbon emissions) and metal (a limited resource) will be things of the past leading to more use of synthetic ceramics, polymers and composites. It is also interesting to note that nearly every material can be turned into a foam structure, which can relate to the cellular solids in nature, like bone. Many of these smart materials seem very two dimensional still and will hopefully be developed with form and structure, concurrently in the future, relating possibly to the structural and organizational principles learned from nature.
The relationship between material and construction approaches also need to be connected to have really sustainable buildings; they need to be ‘native’ and responsive to their particular environment. Advances in freeform construction and additive fabrication methods in layers verses mold-making and machining from large blocks (subtractive methods), seems to have potential for future techniques. Direct, additive fabrication methods are generally more sustainable than subtractive methods. There are three approaches today that can create full-scale structures; the first is at Loughborough University, England; with their ‘Threshold Deposition Device’, the second is Enrico Dini’s ‘Monolite’ process in Italy and the UK and the third is Behrokh Khoshnevis’s, ‘Contour Crafting’ at USC. These printers, beyond the fact that no form work is needed, are also capable of incorporating local materials and mineral systems specific to the locale in their construction process. There is also the whole realm of research in robotics; whether as a tool for digital fabrication and/or construction.

Protocell technology builds on the belief that conventional materials will only take us so far on the road to sustainability. What these researchers suggest is that we need to parallel biology rather than trying to abstract some of the principles; making synthetic life, with the help of research in the field of biochemistry. This is perhaps the most extreme research philosophy related to nature. Although potentially alien to the natural world, it would speak the same language in terms of chemistry and physics. For many ‘nature’ is still an image relating to an Arcadian wilderness, that in reality no longer exists. Nature and humanity become more linked every day and with the development of protocells it becomes apparent that the relationship between the natural and manufactured is blurring too. Humans are in fact part of nature, so are not all our manufactured products natural too? Maybe this could be a positive; generally dualisms have tended to categorize and polarize issues and people rather than providing balance. This protocell technology is being researched at various institutions and universities around the world. Most of this research is making cells which are fairly simple chemically and so would be potentially totally economically viable. One research center is at Los Alamos, New Mexico where their protocells have just three components: ‘a metabolism (the chemical processes used to obtain energy and create the protocell’s building blocks), an information system (which instructs the metabolism) and a container (which keeps everything together).’ Philip Beesley, an architect and Professor at the University of Waterloo, Canada recently incorporated this technology with his team in an installation representing Canada for the Venice Biennale, 2010; The Hylozoic Ground Project.

CONCLUSION

There are numerous examples of architects and academics incorporating biomimetic principles into their work. This happens at various scales, from installations to urban plans. Many of the examples mentioned incorporate a few of the issues apparent in biological systems. It is the holistic aspect that seems generally lacking today, but maybe this is just a matter of time and at present is too overwhelming for individuals, groups or a computer’s capacity to handle the complexity that is involved. There is an obvious balance between understanding and synthesizing: biology is complex so a reductionist view will not work, it needs to be complex and needs to consider many facets, including humanistic concerns.

ENDNOTES

2. Ibid
"The waves of the sea, the little ripple on the shore, the sweeping curve of the sandy bay between the headlands, the outline of the hills, the shape of the clouds, all these are so many riddles of form, so many problems of morphology, and all of them the physicist can more or less easily read and adequately solve."

D’Arcy Wentworth Thompson
On Growth and Form

This project submission focuses on a ‘Biomimetics’ Seminar Class held in the spring of 2011 at the University of Arizona. Biomimetics is the study and application of biological principles as essential design parameters. This study needs to go beyond a metaphor; it is not about mimicry, but about understanding the nature of the material itself, looking at our environment and its interconnections as a way to move forward. Negotiating design and performance with engineering and fabrication is one of the central topics of architectural discourse; driving this is a growing awareness of ecology and sustainability which this course intended to address.

The main areas of focus were:

i. Understanding the concepts of nature and technology and their connection.

ii. The study of generative design strategies for complex geometry; parametric design, emergence, self-organization, swarm intelligence, data integration and agent-based design.

iii. Research in the area of how architecture can perform more ecologically; integrating performative tools and simulation into the design process to ensure more appropriate environmental adaptivity.

iv. ‘Material is an active participant in the genesis of form’ (Manuel De Landa) - studying options of how materiality becomes one of the design parameters.

Linkages between digital technology, biomimetics and sustainability were made as all stem from the same aspiration in the study of systems. This was fundamental in the use of parametric modeling tools where students began to think in terms of relationships versus single objects. Ecological, inter-connected systems in the natural world have no separation of form, structure and material: they all act on one another and cannot be predicted by the analysis of any one separately or in a different context. Isn’t this how architecture should be; critically sensitive to its region and holistic? The goal of the course was to focus on process, recursive design and experimentation; technologically and environmentally, looking at ways to ‘find form’ rather than ‘make form’ and create valid feedback loops. The course became a research lab, initially studying precedent work and processes in this field, but culminating in two group projects. Of the fifteen students most were third and fourth year undergraduates, with two Master of Science students. One group created ‘Data Scape’; a biomimetic surface installation, while the other group created ‘Performative Porosity’; a research project, designing an evaporative cooling wall for an and climate with ceramic foam.

"ORATION"
"APPLIED RESEARCH THROUGH PEDAGOGY: INSTALLATION/MATERIAL SCALE"
"SCHOLARLY PUBLICATIONS ON BIOMIMETICS"
"PROJECT PROCEEDINGS FROM ACSA 100TH ANNUAL MEETING, 2012"
"related to Biomimetics elective seminar; 2011"
Abstract. The following group installation was part of a seminar on biomimetics at the University of Arizona, USA. The design began with research into various natural systems, namely cell growth and morphogenesis and digital tools. In nature cells contain preprogrammed responses based on intrinsic properties which allow for differentiation and adaptation to external forces. This logic of cell morphology was developed into the installation design. Form specificity and topological variation was developed through the manipulation of a material system, bending and loading identical components to adapt to external forces, such as the sun, while simultaneously navigating the site, providing structure and ultimately architectural space.

Keywords. Biomimetics; pedagogy; simulation; design/build.

1. Introduction

Anthony Vidler in his essay ‘Architecture’s Expanded Field’ of 2008 wrote that biological analogies were one of the four dominant emerging principles of contemporary design. He believed that these new expanded boundaries for the profession could help to create a truly ecological aesthetic for the first time.1 Historically, he states that the biological influence in design increased with the dissemination of Charles Darwin’s theories in the late nineteenth century and with research into DNA and cybernetics in the mid twentieth century. In this paper the authors have chosen to equate biological analogies with the term biomimetics. The Centre for Biomimetics at the University of Reading, UK defines biomimetics as "the abstraction of good design from nature."  It is not about mimicry or the simple observation of nature, but more about an investigation into its systems and processes and how these can help us move forward with our societal and environmental concerns.

Recent architectural discourse on the topic of biomimetics has been led by the publications of the Architectural Association’s Emerging Technologies and Design Program [AA Emtech] in London, UK, originally founded by Michael Weinstock and with important contributions from Michael Hensel and Achim Menges. Their writings have also reintroduced a generation to the work of Reyner Banham and Frei Otto, to name a few, emphasizing the need for form-finding verses form making, questioning the trajectory of the developed world’s commitment to designing "massively structured methods of environmental management." (Banham, 1969) The following project, Cellular Noise, attempts to work from the philosophy set out by Reyner Banham and Frei Otto, and currently being developed with the help of computational processes by the AA Emtech group and its followers.

The design and fabrication of the installation was part of a 3-credit seminar class on biomimetics at the University of Arizona which took place in the spring semester of 2013. Initially students researched various concepts, digital processes (Figure 1) and precedents related to biomimetics, and then they worked in groups to propose design/build installation proposals for the remainder of the semester.

Figure 1. Example of research into digital tools (source: Tim Winstanley graduate 2013)

Design/build projects encourage a level of reality that is beyond a virtual or representational resolution emphasizing a whole expanded field of pedagogical issues, from the relationship of the digital to the real to the resolution of craft. In this specific class the goal of the installation was to question the typical trajectory that architecture follows and to see if studying the natural world (the ultimate in performative design) could lead to new forms and systems that would be more sustainable (socially, environmentally and economically).

2. Biology as a precedent

Any approach to architectural design that aspires to engage with biological precedents must, by nature, originate from a process of continuous integra-
tion, of synthesis. "Biological organisms have evolved multiple variations of form that should not be thought of as separate from their structure and materials. Such a distinction is artificial, in view of the complex hierarchies within natural structures and the emergent properties of assemblies. Form, structure and material act upon each other, and this behavior of all three cannot be predicted by analysis of any one of them separately." (Kotnik and Weinstock, 2012) As in the description of natural form that evolves from processes of morphogenesis, architectural design too, can be thought of as originating from a process of negotiating between the potential inherent in a material system and a complex field of external parameters or forces. "Just as the association of material systems with gravitional fields depends on their mass, so the association of systems with morphogenetic fields depends on their form. Hence a morphogenetic germ becomes surrounded by a particular morphogenetic field because of its characteristic form." (Sheldrake, 2009) The physical evolution of form is generated through the simultaneous morphology of complexification (continual reintroduction of a higher order morphic unit) and specification (continual adaptation of individual units to evolving localized conditions). This process of deriving overall form from the multiplication of units and their continual re adaptation is precisely the kind of open network form generation model that has profound potential if deployed in architectural design, the effective replication of which begins to address a new territory of possible efficiency that is demonstrated in biological systems.

The ultimate design was based on research into cell growth and morphogenesis. The basic unit at play in Cellular Noise involved a material system embedded with an implicit potential in the form of its multiple performance. The design process itself operated as a complex ecology of prediction, composed of a series of physical and digital components, that, over time, analogous to a ‘morphogenetic field’ of evolving parameters, represented the collection of inflections and mutations that engendered a final form. Through this process, all forms of modeling and design evaluation, from simulation to prototyping were simply steps in the evolution of a design, not yet representations of a preconceived design. "What we are witnessing is a shift in the traditional relationship between reality and representation. We no longer progress from model to reality, but from model to model while acknowledging that both models are, in fact, real. As a result we may work in a very productive manner with reality experienced as a conglomeration of models ... Models have become co-producers of reality." (Eliasson, 2007) (Figure 2)

3. Digital and Analogue Process

The design process began with the establishment of a material system that was specific yet flexible enough to absorb permutations in performative criteria. The resolution of initial form was first understood through a series of physical and digital prototypes. Beginning with scale prototypes to establish material principles that would generate this form, digital physics simulations were then incorporated to expound the geometric scope and performative properties. Full scale physical prototypes and digital simulations became a feedback loop between the digital and analogue; as knowledge of material properties informed the calibration of the digital model and the extrapolation to form and structure. This process was complex particularly with the less predictable elastic materials. Eventually a simple yet broadly variable form was reached, composed from a single loop of elastic material and a tensile fabric membrane, chosen precisely because the level of its simplicity was also the breadth of its potential. The geometry of the base unit is defined in topology as an Enneper Surface, taking the curvature of a hyperbolic paraboloid, formed by the pre-stressing of the material system. Prototypes included the testing of various materials in the elastic structural chord (polyvinyl chloride, polyethylene, polycarbonate, aluminium, steel, and fiberglass reinforced polymer) in combination with multiple composite fabric materials and stitch formations in the tensile membrane (Figure 3). The final material section was the combination of cross-linked polyethylene tubing (PEX) and a constraining synthetic fabric membrane, known as Power Mesh, leading to a balanced material composite, the tubing’s elastic material property, gave it a high range of deformation, while the stitch of the fabric gave it equal omnidirectional tensile properties. Throughout the dimensioning and material choice processes that made up each unit, it was understood that a preliminary layer of formal specification, in the form of the ‘tightness’ or ‘looseness’ of a particular unit, could occur within the material balance of each unit. Principally, the stress of the fabric when forced into tension applies an internal
force too great for the ring to resolve through bending, causing it to deform through torsion (twisting) which results in its buckled form, "the folding of rings results from a continuous evolution of their torsion and curvature. The stored elastic strain energy can then be used for self-deployment." (Mouthuy et al, 2012)

This behaviour and the precise manipulation of this material balance was the impetus for defining overall performance, controlling the potential variation to the optimization performance, as the outer curve of the geometry shifts, its curvature and torsion are inversely proportional. This proportionality meant that the geometry could be broken down at four critical points (maximum torsion, and minimum curvature) dividing it into four arcs, each incidental to an individual plane, the intersection of which produced a tetrahedron bounding geometry (Figure 4).

This capacity and potential for the tuning of each unit to a specified form was modelled and simulated digitally in Kangaroo, a physics simulation plug-in created by Daniel Piker for McNeel’s algorithmic modeller for Rhino, Grasshopper. Initially slider tools were incorporated into the parametric, digital model that could vary the membrane tightness relative to an outer circumference dimension. These initially varied for each simulated fabric type until the Power Mesh was selected. The Kangaroo simulations calibrated this elastic deformation and established the initial module’s form (Figure 5).

This calibration became a feed-back loop between the digital and physical models, with the outer ring circumference being finally set at nine feet, a size which was physically manageable by one person. After multiple simulations and physical prototypes the fabric diameter became 50% of the tube diameter. In reality the final diameter of the fabric membrane was ultimately larger as it was dependant on the wrapping/fastening mechanism of the fabric to the tubing of the ring. This detail was not simulated in the digital model, though. The Kangaroo model was designed to allow different properties relating to elasticity, stress and strain for the ring, which represented the outer tube, versus the membrane, which represented the fabric. This variation allowed the model to approximate the two different material behaviours (Figure 6).
There were also multiple digital iterations of how the fabric should be subdivided in order to approximate equal tension. More uniform tessellations were ultimately selected over those which biased the geometric centre. After the initial module became more defined aggregations of modules were explored. This resulted initially in clusters of three modules, chosen for structural simplicity and strength. The final system of connections through which the clustering was achieved was a series of stitches that joined two units along partial lengths of each edge transferring loads through alternating unidirectional stresses. These joints between units were approximately a third of the circumference of the tube, which allowed the cluster to be open enough to receive another cluster. This behaviour and variation was again determined in part by simulations in Kangaroo, where connection lengths were varied from a quarter to a half of the circumference of individual units. Digital simulations showed this entire clustering process (Figure 7).

The digital analysis of incidental solar radiation levels modelled in Autodesk’s Ecotect and Geco, by uto for Grasshopper, relative to the simulated geometric permutations lead to further resolution of the clustering logic. Scale prototypes were studied in tandem to produce overall geometric ordering of multiple clusters as a structural variable, e.g. unit to unit connections as an additional layer of stress in the material balance, introducing asymmetrical formal variation into the matrix of possible deflections.

Finally the understanding of surface geometry to optimize lighting and visual effects became a key area of study. Testing and prototyping continued with various lighting systems, coloured fabric combinations and environmental measurement tools. These digital and analog prototypes enabled the testing of certain light and material effects, such as the reciprocity between material translucency and geometric layering in the dispersion and diffusion of light through the fabric membrane, and the testing of layering and color in the fabric membrane to achieve an ideal balance of natural light reflection and absorption.

The final form was complex in its variation and resultant performance, with a particular part to whole relationship: its final specification was a direct interdependence between structural versatility and topological complexity. Cells on the outside remained relatively normal in shape, providing lighting/shading, while cells closer to the centre of the overall cluster were more distorted from their original shape, absorbing a higher range of stresses from all directions and transferring greater loads. The final performance of the piece as a structural system in fact depended on its inherent flexibility, withstanding strong winds and rainfall, as well as acting as an ideal shading device, provide light enclosure and shade whilst permitting air movement and ventilation (Figure 8).

The final performance indeed resembles the complex emergent patterns of cell morphogenesis; each unit inherently falling into a specified order with an overall system in order to remain cohesive. The differentiation of units as well as the three dimensional geometric nature also led to the desired overall lighting and shading outcome as well as the dynamic moiré visual effect. The complex variation in form was ultimately resolved through the clustering logic, which synthesized all the physical parameters including structure, light permeability, solar deflection, and visual effects; "very complex behaviours can emerge from the action of simple operations, and, by extension, very complex forms can emerge from the action of comparatively simple machines." (Davies, 2005) The reality of which is that simple variability led to complex specificity, confirming the principle that an approach to design through a logic of synthesis and interdependency generates not only efficiency but elegance.

4. Findings

Much of the final project’s resolution and methodology imitated issues of real-life building scenarios. The project was fortunately completed on time and on budget (including prototyping), but the pressure of producing a final product did lead to some compromises along the way.

As a whole the process had a fairly successful outcome for a small, semester long undergraduate class for twelve students. Due to the short design time regrettably it was not possible to involve a structural engineer as planned, however the process of operating with several scales and methodologies of prototyping concurrently was indispensable to the final resolution. Even with the coordinated effort of physical and digital modelling and simu-

Figure 7. Stills from a three-module cluster simulation

Figure 8. Images of final installation from day to night showing varying lighting conditions
lation it was difficult to predict the full behavior of the modules in a larger composition. Given greater time and effort it would have been productive to develop a digital model that could simulate the forces of connecting modules more accurately. The more that can be simulated in advance, although often technically challenging, is obviously an asset to any project. Any media, process that can help predict a design/build (which is always more laborious than anticipated) is a positive environmentally too.

5. Conclusion

Biomimetics as a principle design driver was successful to varying degrees. The project began to integrate ideas of materiality, form and force in a lightweight approach to a 3-dimensional system of enclosure, shade and experience. "The lightweight construction principle is one of the most important foundations for the evolution of objects in living nature and in engineering." (Otto, 1998) The project adapted itself in its overall form and external context like the morphology of cells, but is that enough when compared to the dynamism of the natural world? Not to say that everything needs to be dynamic in a literal sense, but responding to environmental elements, like the sun, does imply some level of flexibility within the system. The project failed to reach this aspiration for an adaptable system related to the sun’s path. It would also be optimal, on a next iteration, to have a more rigorous digital model with input from a structural engineer skilled in the analysis of non-linear systems.

During the process of the course there was much discussion on sustainability and the desire for the ecological aesthetic that Anthony Vidler had originally forecast. The project anticipated a change in thinking from a more typical heavy, linear structure to a lightweight, more fluid outcome. This enabled a fast, fairly straightforward fabrication and installation process. The materials were also very affordable; sustainably issues of economics and the environment were addressed, but what about the social aspects? The project was obviously a collaborative effort, but was creating a 3-dimensional enclosure enough in terms of having some social outreach? The intended outcome was to design an enclosure for the Beaux Art Ball, but it was also seen as an opportunity to engage (at least temporarily) with the community (Figure 9).

Endnotes

2. http://www.reading.ac.uk/biomimetics/about.htm

Images and Acknowledgements

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References

ABSTRACT: This paper will present the work of a related undergraduate architecture design studio, ‘Sustainable Skylcrapers’, which took place in the fall semester of 2011 at the University of Arizona. In this studio the intent was to find ways of form-finding versus form-making; using natural and built infrastructure, systems and flows to create new design strategies, relationships and building typologies. The studio’s stance was that it is not okay to maintain the status quo, but that we need fundamentally rethink the direction we are moving in. Emphasis was placed on research as a speculative and iterative process rather than on final products.

SUSTAINABLE DESIGN PROCESSES

INTRODUCTION

Sustainability is not a new issue. The Brundtland Commission in the late 1980’s defined sustainable development as ‘development that meets the needs of the present without compromising the ability of future generations to meet their own needs.’ Recently there has been more mainstream acceptance of environmental concerns in the wake of the current global economic crisis, population boom and global warming. The building industry and urban environment are major players in this environmental crisis: the U.S. Department of Energy reports that the commercial-built environment produces 48 per cent of the nation’s greenhouse gases annually and 66 per cent of all electricity generated by power plants is used to operate buildings. For these reasons alone it is apparent that building processes, resources and systems should be critically reviewed. The environmental concern is not just about the shortage of future natural resources, but about the effect the pollution environmental concern is not just about the shortage of future natural resources, but about the effect the pollution

ecological and human culture and psychology. One of the main shifts that need to be made is away from the pressure of short-term goals to longer term ones. Nature is the ultimate in performance-oriented design so it is no wonder that attention is finally being paid to it. This coupled with increasingly levels of knowledge and technology set the stage for a new level of ecologically-based design. Architecture has hopefully moved past the idea of single object buildings and is gaining focus on a more ecologically-based, systems approach, like nature, where organisms function in relationship to each other and their entire surroundings. In our Information Age one of the main information areas that certain architects are looking at is of the natural world. Technology can help us understand these natural systems at another level then we previously had known.

The study of biomimetics (the abstraction of good design from nature) is increasing in architectural curricula across the world. The author had previously published a paper in the area of biomimetics which in our increasingly globalized society, the connection between environmental, social and economic issues. This inter-connectedness was explored in the students’ work towards varying degrees and successes.

CONCEPTUAL FRAMEWORK

Making sure buildings ‘perform’ responsibly is a key issue today. Innovation and technological advancement is not important for their own sake; developments need to be balanced in consideration with available resources and human culture and psychology. One of the main environments (ecological), usually always process-driven systems.

5. Always think ecosystems: all nature is constantly changing and adapting.

6. Self-organization techniques are utilized; they produce emergent behaviour, from sub-cells to ecosystems (systems within systems).

One could argue that items 1 through 4 are the more straightforward examples that are well on the way to being achieved in architectural design today, and items 5 through 6 are potentially more extreme. Understanding these in relation to how natural systems operate is more complex though. For instance with regards to optimization, this historically has been treated very differently in biology versus buildings. In biology to achieve efficiency and optimization there is a high amount of redundancy and complexity in the material hierarchy and the adaptation to changing environments, and is a much more linear approach to the way we usually engineer buildings. Biology’s stochastic process, rather than a deterministic one, generally means that the standardization of components and members is precluded. With regards to materials, “biological makes use of remarkably few components, nearly all are carried by fibrous composites; cellulose in plants, collagen in animals, chitin in insects and silk in spider webs.”[1] They work not because of this fact alone, but because of the way they work. The reason why materials generally provide higher levels of optimization then ones which are more homogeneous. Generally, they are good in tension and bad in compression (tension based systems per weight are usually more efficient than compression systems).

Ecological, inter-connected systems in the natural world have no separation of form, structure and material; they all act on one another and cannot be predicted by the analysis of any one separately or in a different context.

One of the pedagogical challenges was to tie together all of the necessary strands for success: comprehensive design, biomimetics (including human aspects), environmental concepts and digital methodologies.

Digital Technology holds a fundamental role in this time of rapid change; various digital platforms and their inter-connectedness were explored to accommodate the most effective workflow processes e.g. parametric and algorithmic design tools and analysis software. Emphasis was given to ‘digital agility’ rather than dependency on one particular software platform. Linkages between digital technology and sustainability were made as they both stem from the same aspirations in the study of systems and connections (relationships). This was fundamental in the use of parametric modeling tools where students began to think in terms of relationships versus single, isolated objects. “Parametricism finds its design researches on a totally new ontology that abandons the Classical/Modernist compositions of inert, rigid geometric figures and puts in their stead a world of malleable, adaptive elements (radicals) that engage with each other to form differentiated systems which in turn are associated with each other via scripted dependencies.”[2]

Students were required to think critically about their choice of parameters, going beyond mere explorations. This entailed developing ways of integrating design techniques and system performance. It was not just about mastering computational techniques, but a mode of rethinking architectural design thinking, always encouraging students to work smarter not harder.

The development of Building Information Modeling and Integrated Project Delivery (BIM/FPD) is, in theory, pushing us to a more integrative model of working. It merely implies more potential coordination of existing rules of design and construction. We need to see buildings as interconnected, dynamic ecological networks.

STUDENT WORK

The following work is from a fifth year, undergraduate architecture studio which took place in the fall semester of 2011, at the University of Arizona, Tucson, Arizona, USA. This ‘Sustainable Skylcraper’ Studio’s premise assumed a desire to increase density where appropriate and to protect the natural landscape from urban sprawl as much as possible. Initially it was clear that sustainability needed to be defined in broader terms than the systems/relationships related to biomimetic and environmental performance concepts. It needed to include social and humane aspirations too. This led to the understanding that density alone could not solve all of our current environmental and economic problems.

Figure 1: Three Main Issues of Sustainability; Environmental, Social and Economic (Submission by Shaun Poon, BArch Candidate 2012)

Designer Input into Site and Program

Students were encouraged to pursue their own program and site, although distinct from New York City and Hong Kong were suggested. The site selection and program processes had a major impact on design outcomes. The initial decision about which program(s) a project should include and where the project should be located are
fundamental in developing a more sustainable trajectory. One key example of this was the proposal by Shaun Poon to add a vertical textile factory in the financial district of Hong Kong (the Central District). The Central District is an area of Hong Kong that is currently facing many economic challenges dealing with the topical issue of big-boxes versus the regular people. Shaun’s design hypothesized on how the poorer 99% of the population could regain control of their own lives. The proposal introduced a mixed program of a Silk factory (China is the largest silk exporter in the world) and living quarters whose aim was to be a catalyst to start to readress the environmental, social, and economic issues in the area.

The presence of a factory would help to educate a generation that has had an increasing detachment to the process of making and understanding where their products come from. It would also reintroduce the business of making as an asset in the corporate dominant district. Environmentally friendly closed loop systems were implemented in the production of the textiles (mainly silk), which turned the manufacturing by products into nutrients that were then redistributed back into the factory and living units creating a sustainable cycle of production. The project changed the concept of waste, turning it into value, which could then be beneficial on multiple levels. Programmatically creating a factory that had production and distribution in house meant there would be less energy wasted during the exportation process of products too.

The live/work scenario meant that energy getting to and from work was reduced which would also save time and money. This would also provide life in the neighbourhood past typical peak hours of the business world. The creation of a more localized network can be beneficial in building a self-sufficient community that begins to give back to the economy rather than take from it (Fig. 2). The Silk Factory’s programme and site selection dismisses the current segregation of most cities manufacturing areas, encouraging new, clean manufacturing to occur everywhere and promoting new depths of live/work adjacencies.

Mixed-use ultimately is a key component to social, environmental and economic sustainability for the masses. One project labelled this mixed use, ‘a city within a city’ (Fig. 3). Students took the social diversity aspect to different levels, some arguing that it was not just about mixed-use, but a greater need for sustainability which would enable true sustainability.

The student-led programmatic and site selection process takes time out of the studio’s semester, but is a key element which engages the student on a much deeper level then if both of these elements were prescribed for them. Site selection was important on several levels; some students responded to the concept of transit oriented development, with one actually combining the transit center within their design, while others were more influenced by natural factors. Sulaiman Alothman, proposed the formation of a new building typology in Kuwait City, Kuwait (Fig. 4).

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An assignment was created to study digital and analog methods of form-finding for tension-based structures (Fig. 7). There was also a desire in some students to explore minimal surface form finding akin to much of the natural world. These studies became hybrids of analog and digital testing, using the latest parametric plug-ins, with physics engines to assist with this form finding process.

CONCLUSION
Relation-based aspects of parametric computer modelling programs are closer to the information-based processing in nature. With anything, though, it is important to remember that it is not just valid because one is using some contemporary technology. We need to move beyond this to be critical of the inputs and how they relate to a knowledge-based design aesthetic that is appropriate on many levels. We also have a long way to go computationally. Live analytical feedback loops via parametric software are continuously developing, but are still relatively complex and clunky. We need to make sure we are not simplifying our algorithms, though, due to this complexity or we will never improve our built environments. Ideally we need to simulate these dynamic systems real-time, factoring in as many issues as possible, including life-cycle and social costs.

Some groups were able to combine more analysis tools than others. BIM is about information, but also ideally, about using this information in a smart way, the 4th dimension using time and energy. This interface is crucial if we are to move beyond the green-washing that is the current general state of affairs and incorporate these principles in the earlier design stages.

The projects would have been more developed in a studio in the curriculum, but seems valid for at least one semester reaffirmed this. The studio ended up being more of a brainstorming experiment that addressed multiple issues. Finding this balance between bottom-up verses top-down educational models is continually a challenge, but generally the learning environment is enhanced with the ability for everyone to be creative and to learn from each other.

How far do we need to adjust our current trajectory in order to be truly sustainable? Apart from just creating alternative energy in abundance don’t we need to learn how to design and live more efficiently? As William McDonough has stated “being less bad is not good.” [4]

REFERENCES
BALANCE IN CONTROL: The Case of an Urban Design Studio at the University of Arizona

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Abstract
For the first time, in history, the majority of human beings live in urban regions. Although cities are among the most complex human-made systems, they are unfortunately environmentally, economically and socially unsustainable. How can we change this? This paper discusses an undergraduate architectural design studio, Future Cities, which pushed for an environmentally holistic design process, moving past the idea of single, object-like buildings. The studio taught various digital and research methodologies to aid in the complex issues of urban form. Emphasis was placed on balancing the huge amounts of data and information that is available in our technological age, with the need to retain the human perspective and experience.

Keywords: Carrying capacity; computational design; ecological design; sustainability; urban design.

INTRODUCTION
The Future Cities studio took place at the University of Arizona, Tucson, Arizona, USA during the Spring Semester of 2011. The studio consisted of 9 different teams comprising of 13 fourth year undergraduate architecture students. Students could work individually or in teams of up to three people. We also had input from one of our Planning Professors, Dr. Ryan Perkl and two additional masters students from the School of Landscape Architecture and Planning. Students were also encouraged to consult with other departments outside of our college, most notably with material science and biochemistry.

Our current environmental crisis led to a studio premise that it is not okay to maintain the status quo, but that we needed to fundamentally rethink the direction we are moving in as a design profession. This re-calibrating related to the structure of the design studio and the design proposals themselves. The speculation was whether city planning should continue to impose its will upon the land, or should it become yet another organism imbedded within a homeostatic ecosystem, like an emergent system which has been correlated with the concept of giving up control? Part of this process was determining how much should be designed and controlled in this potentially more dynamic, ecological model for humans and the environment (bottom-up versus top-down approaches).

The studio’s intent was to find ways of form-finding versus form-making: using natural and built infrastructure, systems and flows to create new planning strategies, relationships and building typologies. Projects needed to emphasize cycles and inter-connectivity. Pedagogical methods were a crucial part of the studio’s make-up, emphasizing digital agility and collaborative team-work. Recent advances in digital technology have helped us understand our environment at another level then we previously had known. Design proposals were critiqued against the move towards superficial formalism to an understanding of the systems and performative aspects of ecological systems. Speculating on whether this understanding can help us to develop a non-plan that allows for more adaptability, livability and change in our built environment. Ecological, inter-connected systems in the natural world have no separation of form, structure and material; they all act on one another and cannot be predicted by the analysis of any one separately or in a different context. Isn’t this how the design of our built environment should be, critically sensitive to its region and holistic? With the increasing specialization of professions and the academy it is imperative to get input from other areas of knowledge and experience to develop a more holistic design strategy.

ECOLOGICAL BACKGROUND
Inspiration from the natural world has been an important force in humanity’s design history. Charles Darwin’s theories in the late nineteenth century had a strong influence on Art Nouveau and the Arts and Crafts Movement. The concept of the organic was also central in the 20th century. Louis Sullivan, Frank Lloyd Wright and Le Corbusier all employed biological analogies. Generally the connection was fairly superficial, although Wright spoke of adaptability and several other core ecological concepts. In other fields Aldo Leopold, in the early twentieth century was a proponent of inter-disciplinary ecological design and author of the Land Ethic. He wrote, “When we see land as a community to which we belong, we may begin to see it with love and respect. There is no other way for land to survive the impact of mechanized man, nor for us to reap from it the esthetic harvest it is capable, under science, of contributing to culture. That land is a community is the basic concept of ecology, but that land is to be loved and respected is an extension of ethics.” (Leopold, 1949, p. viii).

Some scholars see his work as one of the first modern philosophies of sustainability. Developments in cybernetics, computation and science later in the century led prominent architectural theorists like Reyner Banham and Charles Jenks to predict that biologically-related architecture would be the next major movement. Jencks wrote in 1971, “When biology becomes the major metaphor of the 1980’s, the intuitive tradition will explode in a burst of biomorphic images suited to the individual and organic development” (Jencks, 1971, p. 99).

Hopefully we have learnt from the modernist tradition of ‘form follows function’ that making design too cut and dry tends to lead to alienating and cold environments. Most ecological systems are completely bottom-up systems, i.e. they are ‘designed’ through the balance organized internal and external environmental forces. Humans, being among the most complex natural organisms, have the ability to think and plan ahead, so one would assume that their built environments need to be a balance between top down (planned control) and these more natural, bottom up (self-organization) systems. Therefore designing for them should not be reductive, but should acknowledge that humans are different from plants and animals.

Most contemporary designed environments have emphasized the top down approach too much. In order for us to become more civilized we need to be less controlling of others and our environment (softer), realizing that in this time of rapid change we cannot plan for permanence or predictability in a way that past cultures have.

“Power itself must be abolished – and not solely in the refusal to be dominated, which is at the heart of all traditional struggles – but also, just as violently, in the refusal to dominate...Intelligence cannot, can never be in power because intelligence consists of this double refusal.” (Baudrillard, 2010, p. 47-8).

If we are to be at balance with natural systems we need to have less of a hierarchical attitude and focus more on a system of ethical, mutual respect for the entire environment. This ultimately leads to changes beyond traditional architecture’s scope, which would have to happen on multiple levels of society, including economics and politics. Trying to solve all of these issues is beyond the scope of this paper of course, but it is imperative to at least open the door to these larger ideas, particularly in an educational environment.
The Arts and Crafts Movement was in part a reaction against industrialization and the technological development of the world. However, the recent interest in natural systems is paralleling the development of technology and computation specifically. The need for computation to study and model this complexity is paramount. John Frazer, a pioneer in the use of computers in architecture has written that, “The modeling of these complex natural processes requires computers, and it is no coincidence that the development of computing has been significantly shaped by the building of computer models for simulating natural processes. Alan Turing, who played a key role in the development of the concept of the computer (the Turing Machine) was interested in morphology and the simulation of morphological processes by computer-based mathematical models... Von Neumann, the other key figure in the development of computing, set out explicitly to create a theory which would encompass both natural and artificial realities, starting with the premise that the basis of life was information.” (Frazer, 1995, p.13).

Generally technology today is not seen with the negative connotations that went along with the industrial revolution. Nicholas Negroponte, founder of MIT’s Media Lab, is a computer technology proponent and has stated, “I believe that computers have the potential for assuring a responsiveness, individually, and excitement in all aspects of living, to a degree hitherto unseen...the computer sciences, generally associated with elite and often oppressive authorities, can provide to everyone a quality of architecture approximated in indigenous architecture (architecture without architects).” (Negroponte, 1975, preface).

PEDAGOGICAL CONTENT

Even with the implications of our transforming world, much of our pedagogical methods for architectural design have remained unchanged since the introduction of studio culture in the Beaux Arts tradition. Nikos Salingaros, known for his work on urban theory has written that, “Architectural studios today are dominated by subjective, elitist, ideological, and master-apprentice models thatагgrandize invention over innovation, and radical individualism over collaborative processes.” (Preface in Salama, 2009, p. 13).

It is important to remember that studios are not a neutral environment so every attempt should be made to create as creative and interactive an environment as possible. John Dewey, an early proponent for experiential learning, wrote about the need for a democratic education where it was imperative for students to help shape their own program and context. As a result the program for the Future Cities studio was developed by the students, relating to the particular ethics and strategies of the groups research endeavors. For this particular studio emphasis was set out explicitly to create a theory which would encompass both natural and artificial realities, starting with the premise that the basis of life was information.” (Frazer, 1995, p.13).

The extreme climate in the desert was an obvious opportunity for students to address the idea of an ecological footprint and carry capacity. Density (the supportable population) became directly proportional to the amount of water and other available necessities in their given ecosystem. Students began by calculating the available resources in their given site (figure 1). They also evaluated standard norms of per-capita consumption evaluating these against potential (per-capita) improvements based on designs that encouraged less automobile usage and more developed attitudes to resource consumption generally.

In all cases there was a desire to increase density where appropriate and to protect the natural landscape from urban sprawl as much as possible, which is predominant in the Tucson area. They also needed to balance the obvious desire for density and collective experience, with the sense of individuality and freedom for which the desert southwest has become a symbol. Land use strategies were developed which generally related to the existing topographical and environmental conditions, in many cases pushing for more decentralized network strategies rather than the centralized schemes we have historically seen. These related in part to Yona Friedman’s plurality of utopias, “In this spirit, I propose to think of our autonomous and non-communicating Utopias – which can range from wandering tribes and settled villages all the way to great city states or regional ecologies – as so many islands, a Utopian archipelago, islands in the net, a constellation of discontinuous centers, themselves internally decentralized.” (Jameson, 2005, p. 221).
The positioning of main transportation routes and nodes became networks and attractor points that encouraged transit-oriented development. These attractor points/routes were created relatively easily in the digital parametric model. Most students worked in Grasshopper, the parametric plug-in for the 3-dimensional modeling tool Rhino, by Robert McNeel and Associates. Grasshopper is not just a stripped down version of Building Information Modeling (BIM), but allows a parametric design dialogue that is not the emphasis of all BIM tools. It also has a relatively graphic interface, which is generally useful to architecture students without a prior scripting background.

Parametric, geometrical, networks were also developed which linked programmatic distances with various transportation modes and systems, always encouraging more sustainable options. Students began to see these systems as inter-connected metabolic networks. They were also encouraged to see their system analyses as a series of dynamic flows and feedback loops rather than as static consumable objects. These dynamic systems by their very nature also needed the ability to adapt and change, bringing in 1970’s system theories of autopoiesis, the capacity of a system to self-regulate (figure 2).

FINDINGS - EXAMPLES

Obviously to use computational, morphological processes is a complex task indeed. There is a negotiation between the seen and unseen forces which need to be parameterized and added to the equation, hopefully in real time. Particular attention was given to what may be considered an arid regions most precious resource, water. Teams hypothesized in different ways about how future community boundaries, form and infrastructure could follow those of existing water sub-basins and flows within the larger existing watershed. Many groups clustered development around water run-off and catchment areas whereas others saved the areas where water naturally flowed for natural ecosystems and wildlife corridors, slowly grading to urban density with zones of agriculture or other non-built environments (figure 3). Through integrating water conservation systems at various scales (within the home, community gardens, and landscape), it was envisioned that citizens will embrace more sustainable water management practices in their everyday life, stimulating an educational paradigm shift, from the wasteful use of resources to using them in a more thoughtful way.
The following two student team examples show in more detail about how this was tackled to various levels of success. These groups were of particular interest as they also developed their schemes one step further than an urban plan, proposing specific materiality for dwellings which would rise out of advances in material systems related to their cycles and processes. Many of the common building materials used today are non-renewable and use an exorbitant amount of energy in their manufacturing processes. Michael Weinstock, Founder and Director of the Emergent Technologies Masters Programme at The Architectural Association has stated that, “form cannot be treated independently of material, even when the strongest architectural interest is in form-finding” (Kotnik and Weinstock, 2012, p. 106).

The first scheme, Reconvergence, an emergent city was an immediate response to specific desert conditions but could also be a prototype for any city faced with disappearing natural resources. In this emergent city, water is used and reused as a direct response to a disintegrating water table (figure 4).

Figure 4: Site analysis and design drawings relating to water issues. (Source: Tyler Jorgenson, Kevin Moore and Andre Rodrigue, B.Arch Graduates 2012)

The population within the emergent city is provided economic homeostasis through the emancipation of imported goods and services. As natural systems become a part of the community ritual, they provide energy and consumable goods, and can change according to the immediate demand of social implementations both actively and passively. The scheme proposed a relationship to desert calcification: where the contemporary means of groundwater desalination could help ‘grow’ the city form. Through the process of homogenous nucleation over time, the solids found in groundwater brine aggregate and solidify creating minimal surfaced limestone structures and habitable voids (figure 5 and 6).

Figure 5: Chemical breakdown of homogenous nucleation. (Source: Tyler Jorgenson, Kevin Moore and Andre Rodrigue, B.Arch Graduates 2012)

Figure 6: Physical modeling of minimal surfaces. (Source: Tyler Jorgenson, Kevin Moore and Andre Rodrigue, B.Arch Graduates 2012)

Dynamic differences in the aggregation of the metabolic dwelling machines [MDMs] provide for such human functions such as living, working, playing, learning and socializing. Therefore, programmatic elements that nurture these types of sociological behaviors differ and disperse based upon the density of the clusters. Each individual MDM unit is adaptable and can become any number of spaces to meet individual and community needs. By allowing amenities to fit within the clusters, each area of density will begin to have its own social identity. The porosity of each module also allows for access to exterior spaces linked to public areas and richer riparian landscapes shaped by the Filter Organism Homeostatic Landscape System [FOHLS] (figure 7).

Figure 7: Diagram showing dwelling machines and their relationship to the landscape systems. (Source: Tyler Jorgenson, Kevin Moore and Andre Rodrigue, B.Arch Graduates 2012)

The openness of cultural, community and economic areas allow for rich social interactions, where the community would manage socio-economic programs, thus fully engaging in all aspects of sustainability. Nature is introduced into the daily lives of citizens creating a strong ecological relationship amongst the people, the natural environment, and the systems facilitating this interaction. Positive ecological affect, is the product of people in the community caring for the environment due to an added understanding of ecology and the benefits that can be achieved by
designing for interaction amongst humans, habitation, and the environment. Author Richard Louv continually stresses this natural need especially in our increasingly informational age, “but electronic immersion without a force to balance it, creates the hole in the boat – draining our ability to pay attention, to think clearly, to be productive and creative. The best antidote to negative electronic information immersion will be an increase in the amount of natural information we receive. The more high-tech we become, the more nature we need.” (Louv, 2011, p.24).

The second group, team Arid Systemics based their scheme on the principle that in nature form and force are simply manifestations of material and energy flow, fundamental to its ability to capacitate life. The urban homeostasis was imagined as a literal manifestation of this human metabolic network that mediates between complex environmental biological processes and the indeterminate physical organizations of urban life. A series of rules were established based on precedents seen in nature. The basis for the management of energy in this system came from the precedent of the living machine, a system which effectively cycles waste through a series of anoxic, anaerobic and aerobic microbial and microbiological processes in order to extract clean water and support processes which produce various forms of energy; biofuel, agriculture and hydroponics (figure 8).

The main system that organizes the layout on the site is its water cycles. The system is shaped in order to catch rainfall and water runoff from the surface. The water is then cycled through the overall system flowing out from the center to the edges and back to the center in a series of feedback loops which also organize the water treatment processes. The appeal of this organization is the redundancy of scale and the repetition of feedback loops which organizes a series of dispersals of energy production and waste management processes within the overall system. The larger organization is driven by a series of cores, which extend out along major arterials into the landscape. These cores represent different scales within the organization of the system, and are the centroids of the potential expansion and contraction of the overall system. The scale and mode of lifestyle at these cores also produce a varying degree of regularity of program within clusters and also a varying degree of cluster type aggregations. The essential concept was that the volume of energy in the overall structure is consistent between the innermost and outermost rings.

They also developed a conceptual system of bonding specific molecules to plant roots, generating the growth of Biofilm, a polymeric conglomeration composed of extracellular DNA, proteins, and polysaccharides. The biofilm grows intelligently to begin to form a filament within a system of hydrostatic structuring (figure 9).
CONCLUSION
It was apparent that the balance of many issues became a key theme of the studio. This manifested itself on several levels, from the bottom-up verses top down planning principles, use of environmental resources and the reality of working methodologies in a quasi-hierarchical studio structure. The optimum result was usually a hybrid approach that acknowledged the complexity of the situation and was not too reductive. Obviously architecture itself cannot solve all of society’s problems, but as the eminent philosopher Michel Foucault has stated, “it can and does produce positive effects when the liberating intentions of the architect coincide with the real practice of people in the exercise of their freedom” (Rabinov, 1984, p. 246). We need to be engaged as educators to be part of the process of the future shaping of the world. Staying flexible and dynamic to changes in our profession and world, more akin to nature and natural models. It is imperative to start getting students to think and work this way too. Whether this is changing up the traditional solo-based designer methodologies or introducing them to other fields and disciplines.

Technically there are always developments to be made. It is imperative for architects to start using information and data in a smart way, and in multiple dimensions - the 4th dimension using time and energy. Simulation and analysis tools are developing daily, even though their interface (especially in a live way) is sometimes a digital challenge. This interface is crucial if we are to move beyond the green-washing that is the current general state of affairs and incorporate these principles in the earlier design stages. The studio started to address many key ecological concepts, but what is needed is a paradigm shift in thinking. William McDonough and Michael Braungart, authors of Cradle to Cradle, which gives an ecological approach to design, have written, “When one takes seriously that the concept of waste can be eliminated in the world of architecture, commerce, manufacturing, and transportation – indeed, in every sector of society – the purview of design shifts radically. Not only are we required to include the entire material world in our design considerations, we are asked to imagine materials in a whole new way.” (McDonough and Braungart, 2003).

At the end of the semester, feedback from students and peers indicated that the enormity of the design challenge was seen as a positive that was an engaging experience for all. (i.e. selecting and developing their own program on an urban scale). Part of the challenge pedagogically was the need to control and lead the studio, but not to the extent where I became dominating and stifled the students’ creativity. In our globalized world it is crucial to stimulate students to make further connections between themes and concepts like ecology, sustainability and parametric design, always encouraging them to work smarter, not harder. It is imperative to engage students in projects of this scale and complexity while they are in an educational environment, allowing them to be visionary and forward-thinking. These ways of thinking beyond the traditional box are becoming increasingly needed in our rapidly changing professional environment. Buckminster Fuller has eloquently stated, “Because politicians will not dare to stop pollicking, and because income-supported individuals will not risk loss of their incomes, and because the wage-earning world will not dare to drop its income-producing activity to promulgate the design-science achievement, it can only be undertaken by the more or less freelwheeling student world.” (Fuller, 1969, p. 291).

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Isomorphic City: A Customizable Future Scenario

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Keywords: Collective Intelligence, Parametric Urban Design, E-topias, Live Data, Programmable Matter.

Abstract
This paper discusses a future city design and research project for Tucson, Arizona, USA. The project, Isomorphic City, set in the year 2087 develops a truly customizable and ever-adapting computational approach to the existing built environment. Part of the challenge was to design digital methodologies that could simulate this scenario in as live a way as possible, incorporating real-time, live data into the equation, ranging from environmental criteria to social media information. Form was the result of inputted parameters versus the making of form in a traditional object-like fashion. The project anticipates a shift from simulating the urban condition with a rule-based set of criteria to a more human agent-based approach based on collective intelligence and social behaviour patterns.

1. INTRODUCTION
Making our urban environments sustainable, environmentally and socially, is a key design issue today. William Mitchell, in E-topia, wrote that, because of the digital revolution of bits, traditional urban models are no longer valid. He defined the new urban condition as “lean, green cities that work smarter, not harder. Their basic design principles may be boiled down to five points: 1. Dematerialization, 2. Demobilization, 3. Mass customization, 4. Intelligent operation and 5. Soft transformation” (Mitchell, 2000). Our current urban conditions are obviously a long way from these principles.

The following project, Isomorphic City, was an attempt to holistically incorporate Mitchell’s design criteria into a proposal which would anticipate what the future may hold, while researching and testing the latest available digital methodologies that can aid in this simulated process. The project was originally part of an undergraduate options architecture studio which had input from some graduate planning students in a related geodesign seminar led by Dr. Ryan Perkl of the University of Arizona. The project developed beyond the studio as an independent research course to allow more time to create live interfaces and make the digital model work in a way in which it had been originally hypothesized. An existing city, Tucson, Arizona, USA was chosen as the base urban condition. This existing city allowed the vision to incorporate real environmental and social media data. Tucson is currently facing several challenges that impede its ability to be truly sustainable. One is the large amount of urban sprawl which puts a social strain on the urban core and aggravates several environmental issues, in a place where several key resources, e.g. water, are already low. The existing extreme climate is also a condition that cannot be avoided in any future solution that attempts to be smart and green. These apparent negative existing criteria were seen as a positive to show how the city could be transformed and modeled in the future.

2. FUTURE VISION
Mitchell’s design principles are very pertinent today as they recognize the huge change that digital technologies have had on society. They are also relevant to environmental issues which are becoming more and more of a pressing concern. His criteria defined a model that is more akin to a dynamic, ecological model (like the natural world), which is alive and constantly changing and adapting. The history of this more dynamic approach to urban design is a topic in itself and not part of the scope of this paper. Of particular interest though, beyond Mitchell, were the ideas of Yona Friedman and the Metabolist movement, who saw the metropolis as a living organism. Some of their objectives were to create structures that could expand infinitely. For Isomorphic City part of the challenge was balancing this desire for a dynamic model with the growth constraints of the existing resources.

Conventional land use is rigid and lacks the ability to adapt and transform in the way that Mitchell deemed necessary. In Isomorphic City the proposed relationship of physical and digital space allows for a dynamic environment that could adapt to meet the direct needs of the inhabitants, in real-time, during the course of each day. Many dynamic/responsive systems incorporate sensors and are generally fairly technically complex in order to make parts that can adapt and change. For this particular scenario, set in the year 2087, programmable matter was utilized as the building block for the community, (digitally) creating form-finding aggregation (Figure 1).

Conversely, the more advanced areas of research, that of programmable matter, was utilized as the digital simulation process as we could be specific about a given set of environmental criteria and data. These digital methodologies, which were obviously set in the present, were seen as a tool to enable us to reach this smarter, greener vision faster. Certain applications are very applicable today, particularly the live linking of environmental and social data into a digital model.

With the complexity of both cities and sustainability, it was important not just to focus on digital tools in a reductionist, performative way. For true sustainability, environmental, social, economic and political issues are all interrelated. Students were encouraged to bring together all three of these concepts of sustainability in order to articulate a liveable community where the quality of life of the inhabitants is paramount. This meant that they needed to question the status quo of our current economic system, and to hypothesize and design alternative systems. These systems would hopefully inspire more equality and diversity, which seem necessary if future increased populations are going to survive cooperatively on this earth together in a positive fashion. This was obviously a cursory analysis, but is still a valid pedagogical tool to start understanding the inter-connectedness of all these issues.

In this particular scenario, it was anticipated that an incentive- and resource-based economy would emerge. The team hypothesized that the primary capital resource of the city would be programmable matter for use in housing, transportation, communication, and entertainment (Figure 2). The vision predicts that digital designers, programmers, developers, architects, and environmental experts would constitute the main demographic work force required to maintain the city (Figure 3).

Keywords: Collective Intelligence, Parametric Urban Design, E-topias, Live Data, Programmable Matter.
It was anticipated that programmable matter will become autonomous (create itself), yet designers and programmers will be needed to shape the matter, generate spaces and manifest the visions of the city inhabitants on a personal level. Food production, energy generation, water, and human waste management will be overseen by a workforce of environmental experts who will utilize haptic and health data, fed directly from city inhabitants, to optimize the efficiency of these resources. The hyper-advanced interface of programmable matter has the ability to reshape to accommodate water storage for future use, as well as generate power from every surface exposed to the sun through a skin of electrically super-conductive nanographene. Mitchell wrote that “If you want adaptability, generate power from every surface exposed to the sun.”

One of the keys to a successful city is having a diversity of programs and people. The proximity of home, work, and communal space in Isomorphic City allows for this, plus reduces commuting time. The project anticipates that, as internal combustion technology declines, a more advanced form of transportation will emerge with the utilization of automated programmable matter vehicles for transport (Figure 4).

Traditional streets take up space and damage the environment. Roads within the Isomorphic City will recalibrate and manifest as they are needed, and their matter will be repurposed when not in use. The digital plaza, which is the social and cultural centre of the city, allows for virtual and surrogate travel (Figure 5). This eliminates the need for long distance travel as local space is connected to long distance digital space—thus lowering the ecological footprint of residents.

Cities are among the most complex human-designed systems on the planet so it is imperative to study them in at least three or four dimensions to understand their complexity as much as possible. It is also important to study as many elements in a connected way so that one can see the issues more holistically. Most parametric design approaches use virtual data sources or simulated data. Live information sources such as direct input parameters are gaining more and more prominence as technology increases and designers seek faster and more performative solutions to their design criteria. Real-time input from the web or the environment can be integrated into the digital design model as part of the form finding process. This can be achieved as a live simulation to select models that “fit” best with the designer’s criteria or can be seen as a continuous stream that allows models or environments to adapt and change as the input alters. The project researched various digital methodologies and software applications in order to facilitate a live simulation process as possible.

In order to be socially sustainable it is necessary to incorporate input from individuals rather than rely on more rigid top-down approaches. Shin et al (2011) have claimed that the incorporation of direct participation of citizens, in this case via social networking data, creates a shift from rule-based simulation to a human agent-based approach.

3. DIGITAL METHODOLOGY

Live digital models can still be fairly complex and clunky because of the need usually to interface several platforms together. In this instance Rhino Grasshopper was selected as the main design interface, in part because of its NURBS-based logic, but also because of all the plug-ins, which are being developed daily, that allow this interface to connect with others in live ways (Figure 6).

Initially the existing city environment was developed with the ElK plug-in for Grasshopper. This plug-in has the ability to generate major map and topographical surfaces from OpenStreetMap.org. This is a fairly simple and fast generating tool, but with the drawback that the existing building fabric is not included. So, the preferred approach was to connect GIS data with the Finches plug-in developed by Nicholas de Monchaux at the University of Berkeley, California. This allowed for a much larger amount of existing city data to be incorporated into the digital model in a more dynamic fashion.

With regard to the social networking component of the project, it was noted that Salim et al (2010) referenced a project, Tweetform, that connected specific keywords and hashtags from Twitter accounts to a parametric model in Rhino. Since Isomorphic City was a more site-specific project concerned with environmental issues, there was the desire to incorporate geotag information from Twitter too. This would inform where the various social hotspots of the city were, in a live manner. Initially the project created a simulated data cloud with a script using the Locust plug-in for Grasshopper, created by Robert Cervellone. Locust generated a swarm-logic point cloud capable of control under various parametric behavioral criteria—e.g., avoid, seek, and alignment (Figure 7). The swarm points were studied for their association to human circulation patterns, and were later replaced by actual Twitter geotag data. The three dimensional form of the digital plaza and transportation networks were generated with the Geometry Gym plug-in created by Jon Mirtschin. The housing typologies within the vertical neighborhoods were generated from geotag points that were in closest proximity to one another, and were sorted into groups, metaphorically associated as people with similar interests. The individual unit sizes were determined based on an assortment of predetermined unit types, according to statistical family size data in Tucson collected from www.city-data.com. The units were generated according to the geotag points, and the Weaverbird plug-in for Grasshopper was used to generate a mesh that linked the housing units together in a minimal surface configuration (Figure 8).

Ultimately the initial Locust simulated data was replaced by live geotag data from Twitter accessed through the Mosquito plug in, created by Carlos Smuts of Studio Nu. A Diffuse Limited Aggregation System (DLA) was used to digitally generate a new street grid from this live geotag point cloud—in effect, to digitally generate a new flexible city grid. This simulated the way in which we anticipated the programmable matter would perform. DLA is an application derived from fractal geometry, by Witten and Sanders in 1981. Chen-Wei and Mao-Lin (2000) presented...
how DLA is appropriate to illustrate the distribution of urban space. In this example, a specific DLA script created by Daniel Piker (2010) was used to work with an adaptive boundary and gravitational pull to bring particles into a cluster. Specific Arc GIS information (e.g., water sources, key geographical information and infrastructure) was used for the boundary conditions (Figure 9). At the macro scale the DLA changed the grid and made the large environmental moves (e.g., agricultural zones near water sources) while at the micro scale it helped create the smaller housing communities and the digital plaza.

Climate data was linked into the Grasshopper model with the software program Ecotec by Autodesk via the GECO plug-in created by [uto], http://www.utos.blogspot.com.

4. FINDINGS

To get maximum potential from online data, the data generally needs to be refined and processed before it can be analysed or used in an effective way. This means that plug-ins or processing scripts need to be created. Although the number of Grasshopper plug-ins are increasing daily, it is imperative for designers and researchers to have the ability to customize these tools themselves. For architectural professional degrees, there always seems to be new tools that are vying for time in an ever increasingly crowded curriculum. This can be another reason to work more collaboratively with other disciplines. We have just started connecting with the computer science department on our campus in order to get more scripting knowledge and to find out how we can be smarter computationally with our model and possibly store future and past data.

Waste, as a concept, was created by human beings. In this future scenario, the thought and ideology of waste will be transformed. Resources, energy, and water use by the city inhabitants will be directly monitored and will limit potential population growth within areas of the city. Cities would grow more akin to historic cities in areas of maximum natural resources, but only to a size that can be supported—i.e., density is related to the area’s carrying capacity. This carrying capacity calculation determined the amount of water and other available necessities in the given ecosystem. The process for determining the specific carrying capacity of Tucson began by calculating the available resources in their given site. Then students evaluated standard norms of per-capita consumption evaluating these against potential (per-capita) improvements based on designs that encouraged less automobile usage and more developed attitudes to resource consumption generally. The future goal would be that city dwellers would have direct control over the programmatic function of their city, but the environment will set parameters that limit excessive and negligent use of resources, allowing the city and its inhabitants to become symbiotic within the natural ecosystem of the desert.

5. CONCLUSIONS / FUTURE DIRECTIONS

It was apparent that trying to realize William Mitchell’s criterion for an E-topia was a complex task on multiple levels. The project became a future vision set in the year 2087, incorporating future technologies, but was paradoxically digitally simulated with present day technologies. This leap of faith made sense: whether the specific predictions are realized or not, it is apparent that the push for live 4D digital models, with the ability to adapt, change and incorporate multiple levels of data, is paramount today. Only in this way will we be able to design and understand our built environment more effectively, on a large scale, with any sense of specificity to place.

To create this digital model, which would incorporate live, real-time data, was complex in terms of its methodology and had high requirements in terms of computational power. To continue this study more effectively we will need more computational support. The various plug-ins worked as described earlier, but these need to be refined and customized so that we can filter inputs to just get the information that we want. Apart from needing more geotag data we would want the ability to sort and store the information from social and climate databases so we can add more layers of information for this and future studies. We also plan to link to the live weather feed at the university so we can study the project over a year-long period. This would enable the model to update in a live way to the current weather conditions. Since the concept of carrying capacity was integral to this project, at some point it would be crucial to link this data more fluidly to the live model to ensure that the growth/limits of the city were thoroughly incorporated too.

The incorporation of social data and philosophies beyond the typical architectural realm was also a key step towards more balance between bottom-up and top-down design philosophies. Even though at times these were fairly superficial, it was an important part of the process in aiding the ability to think holistically and realize how interconnected everything is.

“A phenomenological model is tentative, malleable and always in flux, never attaining absolute isomorphism with the world. It is expressed, tested and revised in the creation or manipulation of entities in the world. Except in a utopia, which precludes creativity by refusing to differ from its description, this is the definitive aspect of the human condition...It is becoming increasingly necessary, and increasingly possible, for the form-maker to re-immers himself in the form-giving dialogue” (Frazer, 1995).
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Bio-logics: Critical Impact Approaches in Trans-disciplinary Urban Design for Arid Regions

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Abstract. In the late 1960’s American architect and author Buckminster Fuller wrote that our choices were utopia or oblivion. The spring 2012 architecture studio at the University of Arizona was an exercise in engaging students in the former. Students created trans-disciplinary proposals for urban communities in arid regions. The premise assumed that in our current environmental and socio-economic crisis we need to go beyond the role of designing single object-like buildings in a contextual vacuum; we have to relate and connect to specific local and global environmental forces. Students had to propose real sites, with real climatic conditions. It was not about utopia in a fantastical sense, but about the need to create a better reality for a specific extreme climate, where depleting resources are a commonplace. Through the studio’s design challenge was to balance this top-down way that other forms of life cannot. Part of the most complex structures in the natural world, have the ability to plan, think and design in a top down way down way that other forms of life cannot. Part of the studio’s design challenge was to balance this ability for top down planning with some bottom up strategies of self-organization that would encourage adaptability in a more dynamic, humane sense.

THEORETICAL BACKGROUND

Historically urban areas were created with a synergy between nature and humans (albeit mainly in terms of using nature’s resources in a very controlling way). With developments in technology and transportation the need to have this connection with nature has inevitably decreased. These new technologies had multi-scalar effects on the environment; resulting in non-walkable cities, natural resource exploitation and the abundant use of hermetically sealed buildings with the advent of air-conditioning. During the counter culture revolution of the 1960’s with the birth of what we know today as the environmental movement, architects and planners started re-emphasizing a connection to nature. The Metabolists were one such group whose proposals were based on an interest in the relationship with technology and nature, rather than seeing technology as the antithesis to nature, “The Metabolists announced an ambitious vision of accelerated urbanism and advanced technology existing in parallel with an untainted nature – a techno-utopia.” (Koolhaas and Ohbist, 2011, p.18) Rem Koolhaas has stated that this movement was, “the last that changed architecture including the social, cultural, economic and environmental.” (Koolhaas and Ohbist, 2011, p.18) Architectural historian Felicity Cott has written extensively on this period, and in her book, Architectures or Techno-utopia states that part of the failure of this movement was not in their desire for synergy between nature and technology, but that their designs created a “totalizing environmental control,” (Scott, 2007, p.1) which proved to be an “inner contradiction that could not be resolved.” (Banham, 1976, p.316) Even though they embraced the societal shift towards themes of diversity and egalitarian views, the infrastructure or projects they proposed were generally still static, top-down hierarchical designs with little to no ability for adaptation like there is in the natural world.

Tom Verebes, Associate Dean for Teaching and Learning at the University of Hong Kong, has labeled our current era, as an ‘Age of Indeterminacy’ where issues of uncertainty, complexity and emergence are embraced. Even though there is not one known absolute answer to the pressing issues facing us today there is a growing awareness of the positive impact that more bottom-up, organic and ‘softer’ forms of urbanism can have environmentally and socially. Some contemporary designers have tried to correct some of the authoritarian modernist planning assumptions, by reexamining past models. It is important to learn from the past, but not to be nostalgic about it; Verebes states that new urbanism and neotraditionalism are “ideologically bankrupt. Vernacular architecture can inform the mechanisms for formation of emergent, self-organized order, yet simplistic replication of its appearance is inadequate.” (Verebes, 2014, p. 89) He continues to states that, “The coherence of the traditional city is the result not of overall design but rather of smaller, local decisions which amalgamate to create a whole which exceeds the sum of its parts.” This relates to the definition of self-organization put forward by general systems theory and cybernetics in the mid-twentieth century. “Rather than seeking a cure for modern ills in traditionalism and preservation, can the grown and evolved urbanism of Marrakech or Isfahan be simulated and created?” (Verebes, 2014, p. 89)

Michael Weinstock, Director of the Emergent Technologies and Design Program at the Architectural Association, London, UK has written about the need to see Cities as energy flows and forces; as metabolisms that are networks, some of which are not neutral. Emergence as a contemporary bottom-up design concept for cities does not mean a lack of design, but instead draws parallels to growth patterns in nature. Weinstock states that, “Emergence requires the recognition of all the forms of the world not as singular and fixed bodies, but as complex energy and material systems that have a lifespan, exist as part of the environment of other active systems, and as one iteration of an endless series that proceeds by evolutionary development.”

Nature is the ultimate in performance-oriented design; the concepts of metabolism, self-organization and emergence are great role models for students to learn from. Humans being one of the most complex structures in the natural world, have the ability to plan, think and design in a top down way down way that other forms of life cannot. Part of the studio’s design challenge was to balance this ability for top down planning with some bottom up strategies of self-organization that would encourage adaptability in a more dynamic, humane sense.

PEDEGOICAL METHODOLOGY

So how can we encourage students to contemplate future scenarios in a more ecological and inter-connected way, without the heavy hand of master planning in a modernist sense? Multiple, interconnected issues need to be addressed and hypothesized. Sustainability goes beyond solely environmental goals, but also involves socio-political and economic issues. Manfredo Tafuri has argued that “it is useless to propose purely architectural alternatives.” (Tafuri, 1976, p. 181) There are varying degrees and arguments about how much architecture can solve these complex issues, but it is imperative for students to realize how interconnected politics, and socio-economic systems are and how they relate and affect our built environment. The hypothesis of the design studio was that we cannot design in a bubble; we have to relate to specific local and global environmental conditions, incorporating as much relevant data and information into the design equation as possible. We need to start seeing human communities as ecosystems which are richer with increased diversity, specific to a particular time and place. Students needed to define how we create a sense of community and diversity (in terms of age, race, choices and socio-economic terms), rather than adding to the cookie-cutter, separate enclaves which many of our planned ‘communities’ are creating today. Buckminster Fuller wrote, “All the attempts to establish Utopias were not only premature and misconceived, but they were also exclusive. Small groups of humanity withdrew from and forsook the welfare of the balance of humanity. Utopia must be, inherently, for all or none.” (Fuller, 1969, p.290)
Stan Allen has written about Michael Speaks’ concept of Design Intelligence, stating that “as in intelligence work, with immense quantities of information now simultaneously available, it is no longer access to information that counts, but the ability to process, organize and visualize information that is crucial.” (Allen, 2009, p. xviii)

The digital age has increased our access to larger and larger amounts of data; computation has become a vital tool in the process of editing this information. Various digital tools and platforms were explored in the studio setting to determine which ones would be most useful in modeling, mapping and processing some of the complex relationships that are present in urban environments today. “Working between the graphic character of the field, and the operative model of the information landscape, digital technologies make possible a new approach to cities and urbanism.” (Allen, 2009, p. 82)

Today technology does not have to be something that separates us from each other and nature, but can become a useful tool in the process of codifying all the complexity and data that is increasing daily in our lives and world. This studio class was really the students’ first opportunity to develop some of these methodologies as design tools. Parametric design is a crucial part of these methodologies as it is about relationships rather than just form finding in an abstract sense. Software analysis tools and plug-ins were additionally encouraged, which gave the students the ability to simulate their live digital models earlier and faster in their design process.

Additional pedagogical tools involved assigning relevant, critical texts and field trips. Many student’s backgrounds were from suburban contexts, so it was crucial to visit pedestrian-based urban environments (for some for the first time). We also had more local visits including a visit to a sewage water-treatment plant to understand the current processes that our used with our natural resources.

**BEYOND TYPICAL ARCHITECTURE**

Part of the design task was to look at these complex issues as holistically as possible. Due to the enormity of this task there is also an implied need for a collaborative effort across multiple disciplines in order to start dealing with these issues in a more integrated way. Although at the time there was no formal ability to collaborate due to curriculum constraints, there was a desire between faculty and the administration to make this happen on a more informal level. This desire was further encouraged and developed with the additional collaboration with The Two Worlds Community Foundation, headed by Vernon D. Swaback, an architect based in Scottsdale, Arizona, USA. The studio ultimately became a focused endeavor on an in-house competition called the Arizona Challenge 2.0 created by faculty members Susannah Dickinson and Dr. Ryan Perkl with The Two Worlds Community Foundation.

The specific studio comprised of eleven fourth year undergraduate architecture students who were given their first opportunity to work collaboratively on a design project and at an urban scale. This collaboration was between the architecture students themselves and six graduate planning students from Dr. Perkl’s Geo-design seminar class. Two of the planning students had a background in landscape architecture with another having a joint major in public health. Student teams met each week under joint instruction from both architecture and planning.

The competition design challenge given to students was to create a “purpose-centered community” focusing on the following eleven background issues called out in the competition text, “locational sequence, transportation, home maintenance, schools, employment, economics, housing, density, urban metabolism, telecommunication and vitality.” Rather than looking for the most perfect solution, the goal of the competition was to see a range of exploratory, dissimilar and exciting proposals that was not limited to existing codes or ordinances. Students focused on a site selection process which could best fit the team’s desired goals. The sole limitation on the site was that it should be large enough to explore and express some form of “custom community” within or adjacent to Tucson, Arizona.” The “rationale and ultimate site selection was part of the evaluation of the success of the design proposals.” (competition design hand-out)

To facilitate this site selection, students conducted a site suitability analysis, led by the planning students with their knowledge of geographic information system software methodologies (GIS). Students were able to select from various criteria, e.g. income disparity, wash proximity, hydric soils and access to transportation etc. They were then able to weight these selected criteria to visualize what would be the best sites for their proposals. This exercise was the beginning of a trans-disciplinary, digital collaboration which is a necessary next step for our design professions [Fig. 1]. Presently there is little to no interface between the GIS platforms, which are prevalent in the planning and landscape professions and the Building Information Modeling (BIM) software platforms that most architects use.

“It is obvious why the two systems need to interact: BIM provides physical and functional detail that is not typically available in GIS. GIS places facilities within an existing context...while BIM’s focus is much more specific within the facility context.” (Przybyla, 2010, p.15)

Additionally Architecture students were given a specific assignment to research digital design methodologies that could help in their design task beyond site selection. This assignment could vary in importance depending on the level of digital ability of the school and specific students. Unfortunately in most schools today there is still a general lack of emphasis in this area so it is crucial.
to make it a mandatory assignment to ensure that students develop their skills and see the connection with these methods, complex natural systems and design methodologies. Not that architecture and urban design needs to become a pure biological science, but they do need to embrace these more technical aspects if the profession intends to be a serious player in the future of our built environment. Below [Fig. 2] is an example of this digital assignment where students for the first time had a chance to explore natural growth algorithms, like cellular automata as a way of creating form based on a set of rules and relationships. The right hand drawing shows an example of students being able to control levels of adaptability and density related to inputs, which in real-life could be connections to natural features, public transportation and infrastructure etc.

Students also completed written narratives that addressed the competition’s six positioning questions and also calculated their design’s program statistics. These additional criteria are critical, particularly for the architecture students where design studios often avoid writing or quantitative methodologies.

Figure 2. Example of digital research into bottom-up methodologies; various plug-ins for McNeel’s Rhinoceros Grasshopper software.
(Source: Elizabeth Lorenz and Alex Zee, Graduates 2013)

**RESEARCH PROPOSALS**

Reyner Banham has noted that the desert is “an appropriate place for fantasies….In a landscape where nothing officially exists (otherwise it would not be ‘desert’), absolutely anything becomes thinkable, and may consequently happen.” (Banham, 1982, p.44) This sense of freedom and a seemingly tabula rasa for design possibilities needed to be balanced with the reality of depleting resources and extremities of climate that arid environments are known for. This particular desert location has more rainfall than most, but has high levels of evapotranspiration; its climate can evaporate eight times more water per year than is supplied by rain.” (Dimmitt, 2000, p.9) Most of the indigenous plants and animals have adapted to this environment over time. The Architecture School at the University of Arizona has historically seen this desert environment as a laboratory for the students to learn from, which this course intended to continue [Fig.3].

Apart from studying the specific climate, plants and wildlife, students were also encouraged to view the synergistic relationship between the elements; to understand for instance that plant spacing and density relates directly to the amount of water that is present and to start realizing that humans have a lot they can learn from these ecological concepts like carrying capacity. The ecological footprint (carry capacity calculation) determined the sustainable population that is directly proportional to the amount of water and other available essential parameters of growth + survival.

With global urbanization becoming the norm there is an obvious desire for increased density as part of any urban solution. Part of the pedagogical emphasis was communicating that density alone is not the sole answer; many of the most vertical cities in the world are struggling environmentally and socially. In this particular context the desire for increased density needed to be balanced with the sense of individuality and freedom for which the United States Desert Southwest has become a symbol. Diversity of living conditions and the ability to use communal resources were encouraged, including access to public transportation, while also giving options for more individual/private experiences too. True sustainability is a complex issue to calculate on a real level; we are continually increasing our understanding about the actual life-cycle costs and embodied energy of developing and building in the world. It is generally agreed, though, that as many passive strategies should be implemented first in any design scenario. Working at the urban scale it is...

Figure 3. Example of conceptual research into local, arid conditions specifically relating to hydrology; left; local plant life’s ability to optimize form based on water storage and availability; right; studies of water flow/catchment capabilities of various topographic conditions.
(Source: Rene Corella and Marco Juliani, Graduates 2013)

Figure 4. Example of parametric carrying capacity analysis.
(Source: Elizabeth Lorenz and Alex Zee, Graduates 2013)
imperative to strategize initial siting and orientation relative to available resources, particularly water and the sun and existing infrastructure, such as transportation. Tom Barker, Chair at OCAD, in Toronto, Canada has written that “Masdar in Abu Dhabi, which is a super-high-tech city for forty thousand people in the desert, but Masdar should never have been built in that location.” (Verebes, 2014, p.125)

With regards to the student proposals it was exciting to see the diversity of approaches with various levels of connections to existing neighborhoods and infrastructure. Some chose to re-vitalize suburban neighborhoods and big box stores, whereas others chose sites closer to downtown with more infill potential related to proximities to existing public transportation. All proposals contained varying levels of contemporary urban strategies relating to increased density, walkability and sustainability. What made the process more relevant was the attention to issues like adaptability and relating this specifically to the arid context through their digital methodology tools and adherence to natural systems. The first example shown in this article, 20 Minute City, comprised of students Meredith Abrams, Nada Asadullah and Anh Luc. They learned to understand the importance of diagramming their concepts, which were finalized in Fig. 5. It is imperative to diagram the issues (problems) in order to come out with the solution(s). Their solution attempted to look at these issues holistically and at multiple scales related to different transportation methodologies. The scheme increased density while maintaining the heights of the surrounding existing neighborhoods, by increasing height and building size towards the center of the scheme. They were also contextual to the historic parts of Tucson with their use of courtyard housing typologies. These traditional typologies were brought up to date by the use of stacking and twisting methodologies which responded to the intense sun and enabled more self-shading than traditional purely vertical walls can achieve. Some of the indigenous plants in the area, e.g. barrel cacti were also a precedent for this self-shading form. The team also showed inventive ways of maximizing an existing golf course for other uses, including algae farming and waste water treatment.

The second example shown, Desert Sponge, comprised of students Mitch Edwards, Elizabeth Lorenz and Alex Zee. They illustrated inventive techniques by which "community" could be cultivated with one of arid climate’s most precious resources, water. Water was a permeating theme in the analysis and ultimate design, enriching their view of sustainable arid communities of the future. The team hypothesized that future community boundaries in the city should follow those of existing water sub-basins within the larger existing watershed of the area rather than following superimposed orthogonal city grids that do not relate to topography or resources. These sub-basins were discovered through GIS overlays of the valley, realizing that it would take less energy to move water along its natural flow paths. The students projected that these basins would serve as communal water sources and would hopefully stimulate an educational paradigm shift, from the wasteful use of resources to using them in a more thoughtful way. This shift also occurred in a hypothetical communal effort to maintain agriculture and operate farmers’ markets. Without the previous GIS technologies and carrying capacities assignments this solution would never have materialized.

The selected basin had a wash running through the center, with a transit path in close proximity, with a mountain to the west. These factors contributed directly to the community layout [Fig. 6]. The amount of farmland needed to sustain the community and the amount of available water from the basin and surrounding mountain were calculated. Density of housing was focused around the transit hubs, allowing agricultural land and preserved desert to be further afield. A “flexible housing” strategy was incorporated into the proposal which allowed for a range of house sizes and types which had the potential to cluster; units could also fuse into one another to allow for growth and adaptability. The housing forms attempted to incorporate minimal surface geometries, which are more efficient for heating and cooling verses the standard cookie-cutter boxes that are predominant in the area. Their housing types focused on two main typologies; titled the ‘desert dwelling’ and the ‘succulent’, these varied from single units to multi-family housing with density increasing near transportation corridors. These students also anticipated how future development could be encouraged with our growing population trends and proposed changes to our current global resource allocations [Fig. 7].

The third example team, Recipro[city] comprised of students Daniel Aros and Brian Underwood. They focused on transforming an existing Automall and shopping center into a thriving live/work community, thus providing the opportunity to...
reduce time and money spent commuting. Students analyzed the existing conditions and discovered that approximately 80% of their 414 acre site comprised of impervious surface conditions, mainly in the form of roads, roofs and parking lots [Fig. 8]. Their site analysis also showed that there was little programmatic diversity in the neighborhood; very little housing was available for many of the minimum wage employees who worked there. The ability to have close proximity to places of employment or public transportation routes to those places of employment is crucial as it saves money, allows more time for social/family life and caring for one’s environment plus reduces traffic congestion and CO2 emissions.

Figure 7. Drawings showing various scales and types of housing relating to future demographic scenarios, also a scenario for the future city’s growth along major transit lines. (Source: Mitch Edwards, Elizabeth Lorenz and Alex Zee, Graduates 2013.)

Figure 8. Part of team Recipro[city]’s final presentation board showing the principal design concepts and the existing to proposed changed site relationships. (Source: Daniel Aros and Brian Underwood, Graduates 2013.)

The relationship or ‘reciprocal interaction’ between humans and the environment was a major emphasis of their scheme, encouraged by an ability to interact with nature in residents’ everyday life. Part of the design response to their site research led to a shift of using large areas of the site from impervious parking to more pervious natural landscape strategies. They realized that there was still a need for parking, but moved this into strategically located vertical elements verses the pervasive one story, horizontal options. Numerous paths were created which followed the natural topography of the land, preserving the natural permeable hydrology of the landscape to decrease surface run-off. A number of diverse architectural permeable hydrology of the landscape to decrease surface run-off. A number of diverse architectural

Figure 9. Part of team Recipro[city]’s final presentation board showing the housing and parking options, plus community connections/participation. (Source: Daniel Aros and Brian Underwood, Graduates 2013.)

CONCLUSION

The student teams made their final presentations and winners were chosen by a jury comprised of members from the competition creators, Jan Cervelli, Dean of the College of Architecture, Planning and Landscape Architecture (CAPLA) at the University of Arizona and community leaders including Arlan Colton, Pima County’s Planning Director. There was an additional dissemination event where the winning teams presented to a broader audience of faculty, students, community leaders and family and friends.

Feedback from all of those involved focused on the richness and diversity of projects. There was consensus on the value of this learning opportunity for students, where many ecological and social concepts were as interconnected as possible at the urban scale, for most students for the first time. Natural principles or biomimetics were understood to mean more than just using some form of natural system to help with the landscape portions of the design, but also related to issues of growth over time, carrying capacity, minimal surface enclosure and clustering, bottom-up urban strategies and adaptability. These complex issues need the ability for computation as a tool and as a design driver. It is also relevant to note the correlation between computational development and morphological design, with many key historical figures linking both interests. Students began to understand the relationship between the two and the need to coordinate across disciplines and software platforms as the semester progressed. Normally sites and programs are given to students up front in studio classes and students accept these in a very passive way; in this case the ability for students to fold this into their design process added more time, but was priceless to achieving the diversity of projects and commitment to design strategies, ethics and concepts. Some of the visions were utopian in a naïve sense, but the introduction of politics, land-use and social equity into the
sustainable design equation are important for students to start understanding.

Challenges during the semester were limited to minor personality conflicts which in some instances related to the different expectations from the different disciplines and the vertical mix of graduate and undergraduate students. When this ‘chemistry’ between students worked well it created projects which were well beyond what could have been achieved individually, but in a couple of instances this was not so successful so it added to the work load for all.

The focus on the official Challenge competition and need for end products sometimes can be at the expense of the time needed for pure research and other pedagogical needs, like focusing on digital integration. In future iterations, without the need for such explicit end products the hope would be that the bottom up strategies, digitally and design-wise would be emphasized to a larger extent. This balance between the need for goals and giving room for exploration, research and analysis is always a challenge relating to the instructor, course infrastructure and ultimately on the self-motivation of the students. Ideally the final design would be seen as just a snap-shot, not a conventional masterplan or as a piece of minimal infrastructure or framework to the potential life that could occur in real time with iterative opportunities for feedback by community participants.

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