(Geo)Design with Data (and Nature too)

Ming-Chun Lee

Abstract

This paper describes an urban design studio course conducted in the spring of 2014. Students in this studio explored the future of North Carolina coastal cities in light of rising global sea levels. Through the use of innovative mapping techniques, the class studied the impacts of changing coastal patterns and the opportunities that cities may have to both address climate change and to strengthen urban form. Geodesign using GIS and other visual media enabled students to focus on urban morphology, development patterns, and environmental characteristics in order to identify new interventions that can support a new set of relationships between urbanity and nature.

M.-C. Lee
School of Architecture, University of North Carolina at Charlotte
Charlotte, NC 28223, USA
Email: ming-chun.lee@uncc.edu

1. Introduction

This paper documents both the theoretical framework and its operational aspects of an urban design studio course with a special focus on the concept of Geodesign in an interdisciplinary setting in the School of Architecture at the University of North Carolina at Charlotte.

This semester-long design studio course, offered in the spring semester of 2014, combined two classes together with a total of 26 students from a graduate-level program in urban design and an undergraduate-level program in architecture. Students in this studio, in close consultation with the urban design and planning staff of the City of Wilmington Planning Department, worked on a real-world project to explore the future of North Carolina coastal cities in light of rising global sea levels.

This paper first outlines the underlying three-pillar Geodesign principles that served as the theoretical foundation of the course. It then explains how these principles were further put to use in the development of the operational framework of the course, including the rationales behind the design of all the learning modules used in the studio. To conclude, the paper briefly discusses the outcome of the course using the feedbacks received from the participating students and also offers some thoughts for potential next steps to carry out this effort further into the future.

2. The Geodesign Framework

2.1 Design Thinking

Geographic Information System (GIS) has been a driving force for promoting environmental understanding and decision making since it emerged in the 1970s. Design is a process for arranging physical elements in such a way as to best accomplish a particular purpose. Geodesign brings GIS into the process of designing human built environments. It integrates geographic information science with design, resulting in a systematic method for spatial planning and decision making.

Carl Steinitz of Harvard University defines Geodesign as "changing geography by design." In this definition, the emphasis is on the active role of Geodesign to shape our surroundings to our desired uses. The desire to change geography considers broader-scale plans beyond individual buildings for a better understanding of the influence of and consequence for the native landscape. Wikipedia describes Geodesign as a set of techniques and enabling technologies for planning built and natural environments in an integrated process, including project conceptualization, design specification, stakeholder participation and collaboration, design creation, simulation, and evaluation. Perhaps the most agreed-upon definition of Geodesign would be in a quote from Michael Flaxman where he states "Geodesign is a design and planning method which tightly couples the creation of design proposals with impact simulations informed by geographic contexts, systems thinking, and digital technology" (Steinitz, 2013, pp 12). Geodesign is the merging of geography and design through computers, in particular, through geospatial technologies such as GIS. It requires an interdisciplinary and collaborative approach to solving humans' pressing issues in relation to changing our human-made as well as natural environments.

Conceptually, Geodesign builds upon the traditional design approach of sketching an idea, evaluating it, and redrawing the design (Albert & Vargas-Moreno, 2012). Design, the process of creating or modifying some aspect of physical or man-made environments, is about intent or purpose requiring imagination (McElvaney, 2012a). It often requires the creation of a sketch or model, followed by an iterative process of rapid re-design and evaluation of alternatives in order to reach the desired result. What makes Geodesign unique however is the exploitation of modern computer technology to provide rapid, simulation-based feedback on different design proposals.

2.2 Geography as Context

Geography is about place and processes, human-made or natural, across both space and time. It seeks to organize, understand, and describe the world (McElvaney, 2012b). Geodesign is design in geographic space, which gives the designers the context they need to actually conduct Geodesign, "ensuring that our designs consider everything that supports or inhibits life" (Miller, 2008).

Geography, or the geoscape according to Bill Miller, gives us a new canvas for understanding, moving beyond traditional mapping for navigation and location, towards using all forms of geospatial information for active designing and decision-making (Artz, 2012). If geography is the set of processes that operate on or near the earth's surface together with the entities, physical structures or forms, that result from such processes, then Geodesign is concerned with manipulating those entities and intervening in these processes to achieve specific objectives with its implied emphasis on the geographic domain (Miller, 2012).

2.3 Design with Nature

Design that considers geography has been going on since humans started designing. Ancient cultures built settlements in close proximity to water and with good natural barriers for defenses to the wilds (McElvaney, 2012b). In his book *Design with Nature*, landscape architect Ian McHarg already advocated a framework for design that helps humans achieve synergy with nature. In his view, design and planning that consider both environmental and social values in the context of both space and time help ensure a natural balance. Geodesign enables designers to think about geospatial data as a part of a creative decision-making process and to translate geographic analysis into built forms. This eventually results in designs that more closely follow natural systems (Zeiger, 2010). This benefits both people and nature and provides a more synergistic coexistence (Artz, 2012).

2.4 Technological Perspective: The Role of GIS

To follow Geodesign is to recognize it as not appearing from nowhere, but alongside with longstanding endeavors to embedding geospatial technologies into several established professions (Wilson, 2014). It is the current manifestation of a long-standing practice of planning, designing, implementing and evaluating changes to our built and physical environments, transformed by modern computer tools (Ervin, 2011).

As part of a broader techno-scientific endeavor (Wilson, 2014), Geodesign facilitates evidence-based design (McElvaney, 2012a & 2012b). It enhances traditional environmental planning and design activities with the power of computers, offering ready access to information, simulations, and impact analyses to provide more effective and more responsible integration of scientific knowledge into the design of alternative futures. Building on McHarg’s map-overlay technique, GIS has extended its analytical capabilities to perform the calculation of hazards, risk, sensitivity, capacity, proximity, accessibility, and other analytics to inform design decisions. Most importantly, the impacts of those designs on the environment can be measured and weighed as part of the design (Dangermond & Artz, 2012; McElvaney, 2012b).

2.5 Social Perspective: Collaboration and Inter-discipline

Geodesign aims to generate desired outcomes that go beyond individual building/structure projects to incorporate effects of the broader landscape. This vision for broader change relies on a joined effort that requires inputs both from general clients who are affected by the design and from the designers in such fields as landscape architecture, environmental science, engineering, urban planning, political science, and community development. The success of Geodesign depends heavily on an interdisciplinary and collaborative approach that is inclusive of all of the various actors in the design/planning process (Steinitz, 2013). In this regard, design and plan quality is increased by informed professional and public deliberation through a deeper involvement of multiple stakeholders.

From the socio-political perspective, Geodesign facilitates value-based design (McElvaney, 2012b). Through its participatory and collaborative approach supported by modern geospatial technologies with communication and information-sharing capabilities, human values, often qualitative or based on personal views that arise from differences in culture, religion, class, education, politics, or age, can be injected into the design/planning process.

2.6 The Three Elements of Geodesign

Geodesign, by its very nature, is a way of thinking, framing, and implementing the design of human settlements. Any discussion about its underlying constructs therefore has to be grounded into the ways in which design (as a process) is conceptualized. In this regard, Geodesign, as a framework or method of design, has three fundamental elements that tie closely to the three common conceptions of design. These three elements further serve as the foundational pillars to support the deployment of Geodesign.

2.6.1 Element 1: Evaluation

Conception 1: Design as an iterative feedback loop of concept generation, performance evaluation, and design refinement

According to Michael Flaxman of MIT, Geodesign is a design and planning method which tightly couples the creation of design proposals with impact assessments informed by geographic contexts. Jack Dangermond also argues that Geodesign unites the art and creativity of design with the power and science of geospatial technology. Geodesign can produce more informed, “databased” design options and decisions. It enables designers to sketch alternative design scenarios and quickly get feedback on performance and suitability by comparing the design proposal to the massive geospatial databases behind GIS. “Geodesign links design to science and science to design” (Artz, 2010). It gives the designer the power to do science-based design.

2.6.2 Element 2: Visualization

Conception 2: Design as spatial thinking relying on seeing in our mind's eye what the intended outcome could be

Design at a geographic scale implies a sensible effort to create something that is functionally efficient, aesthetically pleasing, and environmentally sound. The design process is essential in considering the way in which functionality, aesthetics, and constraints are managed in the intended outcome(s). It requires an ability, in its creators—the designers, to generate mental images of the “designed thing” in their minds’ eye; an ability to mentally see design, both the process and the product, in a conscious way before it eventually becomes realized.

Furthermore, geographic concepts such as similarity, quantity, hierarchy, proximity, and relatedness among large numbers of objects of study that diverge over space and time can be effectively represented graphically to support spatial thinking. Geodesign, with its cartographic and graphical capabilities, allows designers to visualize selected impacts in real-time during design. Visualization with Geodesign develops a variety of combinations of layout, symbolism, and interaction according to data, task, and purposes, which enable data analysts to mutually integrate such relationships effectively, understand spatial processes, and eventually generate knowledge that supports the design process.

2.6.3 Element 3: Collaboration

Conception 3: Design as a participatory process requiring an inclusive, communicative, and interdisciplinary approach to information sharing and public deliberation

Geodesign involves the modeling of desired outcomes that goes beyond individual building/structure plans to incorporate the design of the broader landscape. This purview for broader change relies on a joined effort that requires inputs from such fields as landscape architecture, environmental science, engineering, urban planning, political science, and community development. In order for Geodesign to truly take off, it must take an interdisciplinary approach that is inclusive of all of the various parts in the design/planning process. The practice of Geodesign therefore needs to be promoted in each individual discipline.

Geodesign from the practice perspective emphasizes collaboration and cross-disciplinary cooperation towards the best and most sustainable design that takes into account livability, the environmental impacts, and efficiency. In this regard, design and plan quality is increased by informed professional and public deliberation through a deeper involvement of multiple actors (designers, planners, or stakeholders). In order to subjectively increase the kinds of stakeholder engagement and social learning needed to go from plans to successful community-supported implementations, various means for individuals to communicate, share data, and design collectively is crucial to this Geodesign approach.

3. The Studio

3.1 Introduction and Context

In the spring of 2014, the School of Architecture at the University of North Carolina at Charlotte launched its first “SuperStudio” aimed at addressing critical research questions through interdisciplinary design exploration. Under the direction of Dr. Ming-Chun Lee and Dr. Jose Gamez, the SuperStudio explored the use of innovative mapping techniques and the impacts of changing coastal patterns in order to identify opportunities that cities may have to both address climate change and to strengthen urban form. The SuperStudio brought together advanced undergraduate architecture and intermediate level graduate urban design students and charged them with the task of exploring the future of North Carolina coastal cities in light of rising global sea levels.

With Allen Davis, an urban designer with the City of Wilmington, serving as our primary contact, the studio focused upon key areas within the city in an effort to compliment on-going comprehensive planning activities. Our SuperStudio explored sea-level rise data and the context of the North Carolina coast as well as Wilmington’s urban morphology, development patterns, and environmental characteristics in order to identify a new set of relationships between urbanity and nature.

GIS, Geodesign and other visual media provided the means through which specific design interventions were measured and visualized. GIS-based analytical tools enabled design students to map and evaluate the potential impacts of rising sea levels, changing coastal patterns and the projected reach of future storm surges. Geodesign tools, such as map overlay, imagery processing, and 3D visualizations, enabled comparison between different urban design and development scenarios by measuring their physical, environmental, social, and fiscal impacts on the targeted areas. The combined research and design efforts of our SuperStudio identified various ways by which not only the City of Wilmington can begin to address the impacts of climate change but also opportunities that cities throughout the region may address to strengthen urban infrastructures.

3.2 Geodesign Process

Under the Geodesign framework, this studio course aimed to provide students with practical skills for analyzing complex phenomena (economic, environmental, and social) in a metropolitan area. Students explored the functionality of GIS as an effective tool for analyzing complex spatial relationships within human-made environments and further refining their design/planning solutions based on knowledge learned from spatial analysis processes. In addition, students also investigated new ways to better integrate GIS with other digital visualization programs for effective presentations and communication—a useful skill for forging better working relationships with clients/community.

The three fundamental elements of the Geodesign framework served as the underlying principles for the development of the course content and the delivery of all the GIS learning modules.

3.2.1 Element 1: Evaluation

Design as an iterative feedback loop of concept generation, performance evaluation, and design refinement

According to Matt Ball, editor-in-chief of GeoWorld magazine, Geodesign is a software-enabled framework for the design of human built environments (Ball, 2010). With GIS as its core operational unit, Geodesign enables a systematic approach to understanding and managing earth issues by allowing designers to inventory, analyze, and display large, complex spatial datasets.

This studio course was designed mainly based on the notion that Geodesign is a design and planning method which tightly couples the creation of design proposals with impact assessments and performance evaluation informed by geographic contexts and spatial information. In this regard, Geodesign is informed by science and logic.

David Cowen described GIS as a decision-support system involving the integration of spatially referenced data in a problem solving environment. He further specified a typical 4-stage workflow approach for a GIS project, which starts with (1) identifying project objectives, (2) creating a project database, (3) analyzing the data, and then finally (4) presenting the analysis results (Cowen, 1988). This SuperStudio further expanded on Cowen's simple model and adopted Carl Steinitz's six-stage model of landscape change that enables design of alternative futures. Steinitz's model has been broadly recognized by researchers and practitioners in this newly emerging field as the theoretical base for the Geodesign method (Dangermond, 2009; Steinitz, 2011). These six modeling stages are framed by a set of critical questions that designers ask themselves. The first three questions describe the world as it is and assess its condition (the assessment process). The last three questions describe the world as it could be and evaluate proposed design alternatives and their impacts (the intervention process). See Fig. 1.

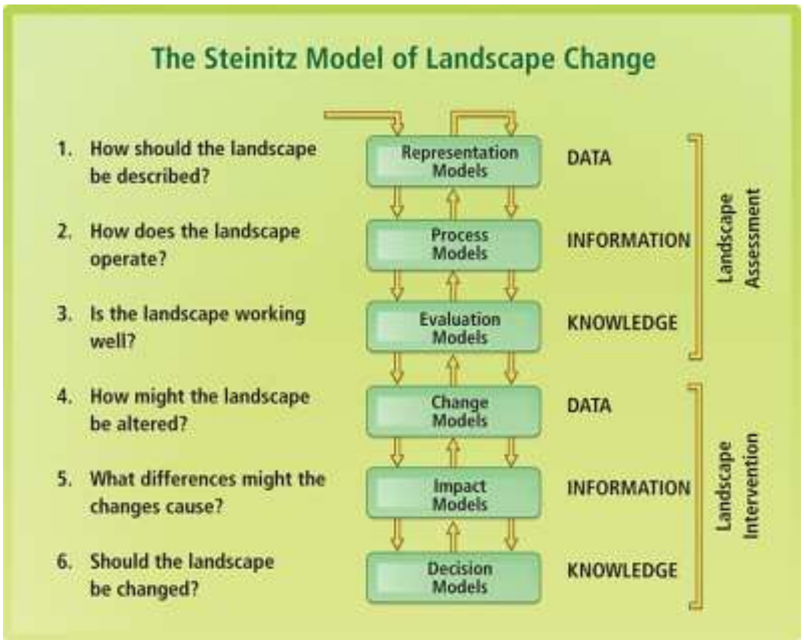
3.2.1.1 Landscape Assessment

The first question, "how should the landscape be described," consists of abstracting landscape (geography) into a series of inventory data layers. The second question, "how does the landscape operate," requires combining geospatial data and the use of spatial analysis techniques to describe landscape processes and predict how spatial phenomena and processes might change over time. The third question, "is the landscape working well," involves the creation of composite maps that combine a number of dissimilar things in a way that reveals areas that may be more favorable than others for certain activities. From Steinitz's point of view, the assessment process consists of examining existing conditions and determining whether the current conditions are operating well or not.

3.2.1.2 Landscape Intervention

Once the assessment is complete, the landscape intervention process begins. The fourth question, "how might the landscape be altered," involves the sketching of design alternatives directly onto a geospatially referenced data layer. The fifth question, "what differences might the changes cause," is answered by the quick evaluation of the impacts of those potential changes. Finally, the sixth question, "should the landscape be changed," integrates considerations of policies and values into the decision process. The information produced by these intervention models is used to help designers and decision makers weigh the pros and cons of each decision factor so they can weigh alternative solutions and make the most informed decision possible.

Fig. 1. Carl Steinitz's six-stage model of landscape change (Steinitz, 2011). (Image source: www.esri.com)



3.2.1.3 Studio Learning Modules

The learning modules were then designed in a way that they closely followed the sequence of these six modeling stages of Steinitz's nuanced GIS project workflow. A brief summary of the organization of all the learning modules is listed below:

(1) Representation model: ***How should the landscape be described?***

Learning modules for this stage focus on building GIS database, linking external data such as demographic data from Census, attribute-based operation, imagery registering, and 3D representation. This studio began the project by engaging in a series of collaborative research and analysis exercises aimed identifying issues impacting North Carolina's coastal cities in light of rising sea levels. Data were gathered through online resources, such as data files provided by the City of Wilmington, and through site visits to the city.

(2) Process model: ***How does the landscape operate?***

Learning modules for this stage include: map overlay (vector-based), map algebra (raster-based), network analysis. Students working in teams examined patterns in the urban and natural environments found in the City of Wilmington.

(3) Evaluation model: ***Is the landscape working well?***

Learning modules for this stage focus on setting up measures for design performance assessment based on metrics of judgment, community value, design intent, and goals/objectives. This assessment phase involved the participation of a diverse set of subject matter experts from the city who were involved in defining issues, metrics, and the proper method of analysis. A set of common values/goals was identified, including (1) protecting existing communities from rising sea levels; (2) rebuilding communities in areas susceptible to future rises in sea levels; (3) addressing valuable public shoreline infrastructure.

(4) Change model: ***How might the landscape be altered?***

Learning modules for this stage focus on building scenarios with editing in ArcGIS.

(5) Impact model: ***What differences might the changes cause?***

Learning modules for this stage focus on testing scenarios based on indicators, measurements, and performance assessment.

(6) Decision model: ***Should the landscape be changed?***

Learning modules for this stage focus on finalizing criteria for decision-making, producing outcomes, and presenting outputs.

3.2.2 Element 2: Visualization

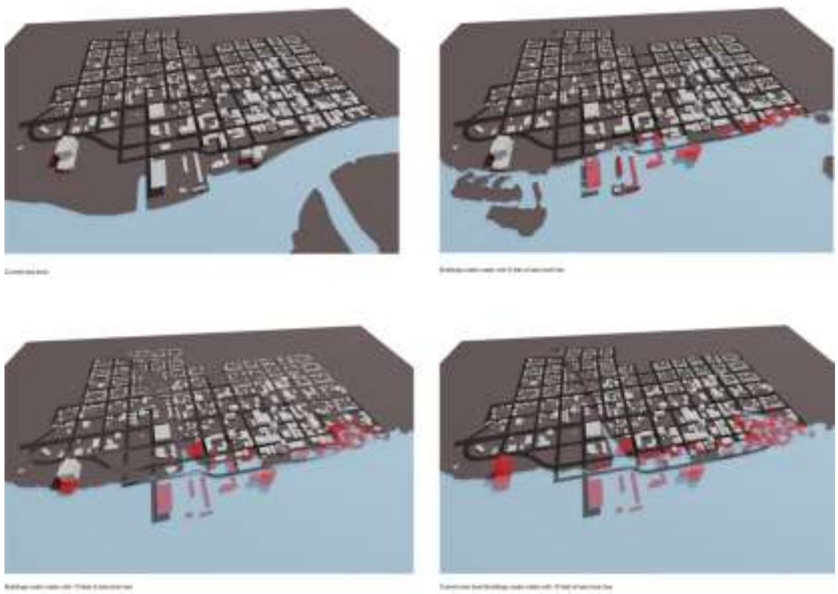
Design as spatial thinking relying on seeing in our mind's eye what the intended outcome could be

The land planning and environmental design process is a series of activities requiring the visualization of diverse site information. In land planning and design, graphic symbols are used alone and in combination to convey information about the characteristics of the site and the spatial organization and articulation of the proposed development. Qualities of specific attributes of the site can also be expressed graphically. Mapping and diagramming are an effective way to simplify and communicate important project information. Effective maps, diagrams, and other graphics can simplify reality, and reveal significant patterns and processes.

Robinson and Petchenik (1976) defined a map as a “graphic representation of the milieu.” The term milieu suggests much more than the flat, static maps that we are familiar with. It presents a challenge to step beyond the comfortable reach of two dimensional (2D) representations to higher dimensions of visualization. The introduction of 3D graphics into architecture, planning, and engineering has fostered new expectations and advanced new ways of explorations in those fields.

In addition to offering the fundamental knowledge of the traditional cartography and graphical representations of the real world and teaching students the skills of producing and utilizing 2D graphics, this course also incorporated 3D visualization tools into the learning modules. These included ArcGIS 3D Analyst extension, SketchUp 3D modeling program, and Google Earth.

Fig. 2. A series of 3D models showing the potential impact of sea level rise to Downtown Wilmington.



One special emphasis is put on the inter-operationality among and integration of these tools. Students explored various ways to transfer geo-referenced data between different programs. For example, students learned how to import GIS layers from ArcGIS to SketchUp and later created 3D massing to render the built form of an urban area at various geographic scales.

The visualization process that was incorporated in the studio project was comprised of:

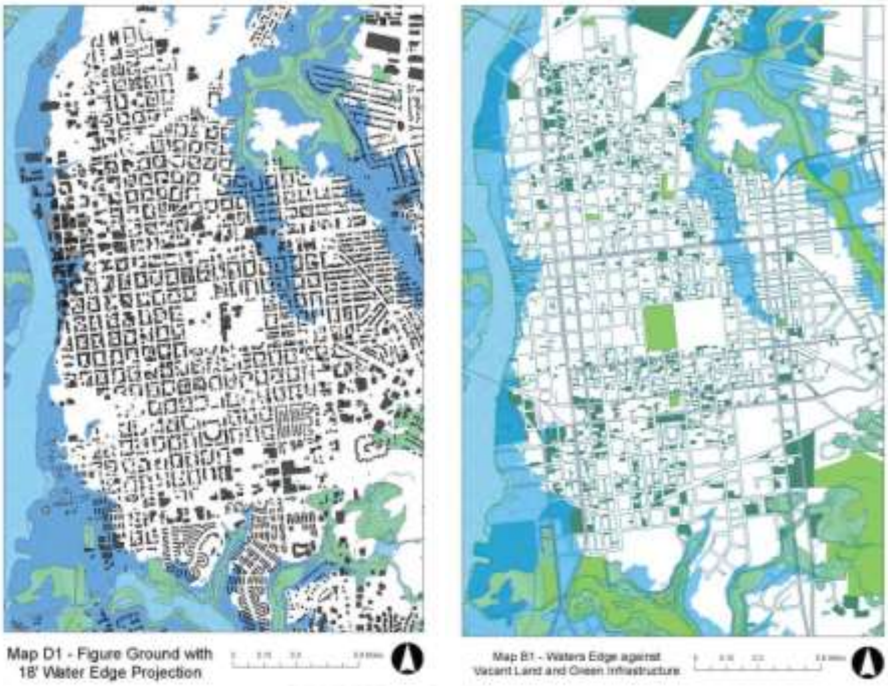
- An overall graphic analysis of the urban form of both the city at large and the key zone study areas.
- An overall graphic analysis of the “blue” and “green prints” of the existing city and its natural systems (present).
- An overall graphic analysis of the historic, current and projected coast/water edge conditions of the city.
- An overall graphic analysis of areas prone to urban flooding due to past development patterns.
- Development of a topographic map of the city.
- Documentation of major infrastructure, utilities, roadways, etc.
- Identification of “communities” or sub-areas of local place, identity, use and urban pattern.
- “Ripe and firm” analysis (using GIS, land-use information, and information gathered following the site visit) that delineated:
    - Properties that are “firm” (i.e. in good condition and not threatened by sea level rise).
    - Properties that are “ripe” for development of redevelopment (on account of their poor condition, vacancy, and/or threat from sea level rise).
    - Properties have potential for “green” redevelopment under certain conditions (maybe due to underutilization of property in key locations and relationship to sea level rise exposure or climate change related challenges).
- A figure/ground analysis and block and/or landscape typologies, existing infrastructures systems (street/transport, open space, etc.).
- Design alternatives at larger scales in order to fully articulate and illustrate design intent and spatial character.

3.2.3 Element 3: Collaboration

Design as a participatory process requiring an inclusive, communicative, and interdisciplinary approach to information sharing and public deliberation

Architectural and urban design solutions are richer when end users are involved early on in the design process, making for better buildings and community spaces. Participatory design has been called upon in response to the demand to have the voices heard and ideas taken from those who involved in the process. It is not a new phenomenon and is well established in community design and development. Participatory GIS (PGIS) is an emergent practice in its own right. The practice is the result of a spontaneous merger of participatory design methods with geographic information technologies.

Fig. 3. A series of maps showing projected coast/water edge conditions of the city.



This course, built upon an interdisciplinary knowledge base with students coming from different design programs, encouraged collaboration among students themselves and between the client (City of Wilmington) and the class.

In addition to the typical ways of communication through site visits to the city or meetings for project reviews on campus, various digital channels were deployed to serve this particular purpose of encouraging collaboration. First of all, a remote file sharing server on campus was utilized for all students to share GIS datasets and other files needed for their projects, such as scanned map images, photos, satellite imageries, and other graphics and written materials.

To share materials and exchange information with the client, ArcGIS Online, ESRI's free cloud-based geospatial content management system for storing and managing maps, data, and other geospatial information, was put to use. A learning module was designed to provide students with an overview of the functionality of the ArcGIS Online system.

Fig. 4. Various development scenarios responding to the site condition in relation to sea level rise.

4. A Preliminary Discussion of the Course Outcome

This SuperStudio resulted in 8 sub-area master plans and 20 individual site design projects, including a number of selected sites in urban areas such as Downtown Wilmington and those in more rural/suburban settings near City's coastal lines. Project reports and other materials produced by the students, including maps and drawings, were shared with the City of Wilmington Planning Department after the conclusion of the studio.

At the end of semester, students were asked informally to reflect on this Geodesign framework based on their semester-long first-hand experiences with the concept. In general, they offered positive comments and regarded Geodesign as "an invaluable tool for designers." One of the students argued that "the use of GIS and its plug-ins coupled with other related software such as SketchUp and Google Earth resulted in a better analysis and visualization of the site leading to a more informed design decision." He went on to point out that “understanding the client’s and community needs can give us more programs that are tied up to the different attributes of the sites as well as the program requirements of the client.” However, students were also concerned with some fundamental limitations embedded in the concept due to its analytical and technical nature. One student pointed out that “GIS tools and plug-ins were able to answer most of the design questions posed in order to analyze the site as well as to evaluate the design proposal using the available metrics from the plug-ins results. However, the result of the analysis was not fully conclusive because there are other factors that were not considered in the model analysis.” Another student also argued that “Goedesign is an alternative way in planning and designing leading to a more informed design decision. However, this process fell short in terms of the ability to create actual planar and sectional representation drawings. There is still a need to work on other software such as CAD and Adobe programs to further visualize the design.”

5. Some Thoughts for the Next Class

Goedesign offers alternative ways of planning and design resulting in more informed design decision-making. However, any design/planning practice, on one hand, requires broad knowledge including theory, techniques, and tools; on the other hand, it also requires attentions to be paid to intention, purposes, and contexts. Each person’s Geodesign method therefore must vary depending on his/her initial intent, and so do the tools he/she decides to use. To be successful at Geodesign, an individual must be capable of utilizing a variety of tools (evaluation, visualization, collaboration) in order to analyze design problems and model solutions in many different ways. Because design scenarios are unique, it may be ideal to use different tools for different types of analysis for each scenario. An ideal setting for teaching/learning this particular Geodesign method therefore should be established with the following two important actions: (1) employing a variety of software packages that can be integrated in various ways in response to different design proposals and scenarios at various geographic scales; (2) exploring theories and processes that can better involve stakeholders in the selection of appropriate metrics/measures for evaluation and efficient channels for communication and collaboration.

References

Albert, C. & Vargas-Moreno, J.C. (2012). Testing GeoDesign in Landscape Planning: First Results. Digital Landscape Architecture conference, May 31, 2012. http://193.25.34.143/landschaftsinformatik/fileadmin/user_upload/_temp_/2012/Proceedings/Buhmann_2012_25_Albert_Vargas-Moreno.pdf (accessed February 1, 2015).

Artz, M. (2010). Changing Geography by Design: Selected Readings in Geodesign, Esri. http://www.esri.com/library/ebooks/geodesign.pdf (accessed February 1, 2015).

Artz, M. (2012). The Geoscape: A New Canvas for Understanding. Esri Insider blog, July 30, 2012. http://blogs.esri.com/esri/esri-insider/2012/07/30/the-geoscape-a-new-canvas-for-understanding/ (accessed March 8, 2014).

Ball, M. (2010). Is GeoDesign an activity, a practice or a software-enabled modeling approach? Spatial Sustain blog, 12 March 2010.

Cowens, J.D. (1988). GIS versus CAD versus DBMS: What are the Differences? *Photogrammetric Engineering & Remote Sensing*. Vol. 54, No. 11, pp. 1551-1555.

Dangermond, J. (2009). GIS: Designing Our Future. Redlands, California: *ArcNews*, Summer 2009.

Dangermond, J. & Artz, M. (2012). *Understanding Earth*. Redlands, California: ESRI Press.

Ervin, S. (2011). A System for GeoDesign. In Buhmann et al. (Eds.), Proceedings Digital Landscape Architecture 2011, Anhalt University of Applied Sciences. Berlin/Offenbach, Wichmann, pp 145-154.

Flaxman, M. (2009). Fundamental Issues in GeoDesign. Digital Landscape Architecture. http://193.25.34.143/landschaftsinformatik/fileadmin/user_upload/_temp_/2009/2009_Proceedings/406_flaxman-2009-jun03-abstract-n.pdf (accessed March 8, 2014).

Flaxman, M. (2010). GeoDesign: Fundamental Principles. GeoDesign Summit 2010, Redlands, California, January 6-8, 2010. http://www.geodesignsummit.com/videos/day-one.html (accessed February 1, 2015).

McElvaney, S. (2012a). Geodesign: A Primer. *Imaging Notes*, Winter 2012, 27(1). http://www.imagingnotes.com/go/article_freeJ.php?mp_id=296 (accessed March 8, 2014).

McElvaney, S. (2012b). *Geodesign: Case Studies in Regional and Urban Planning.* Redlands, California: ESRI Press.

Miller, W. R. (2008). Geo-spatial Design, position statement, Specialist Meeting on Spatial Concepts in GIS and Design, UC Santa Barbara, Santa Barbara, California, December 15-16, 2008. http://ncgia.ucsb.edu/projects/scdg/ (accessed March 26, 2014).

Miller, W. R. (2012). Introducing Geodesign: The Concept. Esri Working Paper. http://www.esri.com/library/whitepapers/pdfs/introducing-geodesign.pdf (accessed March 26, 2014).

Robinson, A.H., & Petchenik, B.B. (1976). *The nature of maps*. Chicago, Illinois: University of Chicago Press.

Steinitz, C. (2011). A Framework for GeoDesign. GeoDesign Summit 2011, Redlands, California, January 6-7, 2011. http://www.geodesignsummit.com/videos/day-one.html (accessed March 8, 2014).

Steinitz, C. (2013). *A Framework for Geodesign: Changing Geography by Design.* Redlands, California: *Esri Press.*

Wilson, M.W. (2014). On the criticality of mapping practices: Geodesign as critical GIS? Landscape and Urban Planning, in press, DOI: 10.1016/j.landurbplan.2013.12.017.

http://dx.doi.org/10.1016/j.landurbplan.2013.12.017 (accessed June 18, 2014).

Zeiger, M. (2010). Meet the Geodesigner. *Architect*, March 2010. Available at http://www.architectmagazine.com/technology/meet-the-geodesigner.aspx (accessed June 18, 2014).