Project-Based Learning: Interdisciplinary Collaboration of Bio-façades in Urban Environment

Interdisciplinary collaboration has gained more importance in both academia and practice as a result of increasing demand on environmental agenda and building energy efficiency. Many building projects show the need for architects, engineers and building scientists with integrated backgrounds that span different disciplines. This integrated and collaborative design approach will prepare students to think critically in emerging design situations and real world problems. While it is clear that we do not currently integrate the important subjects of design, engineering, materials science, and fabrication/construction in architectural design, the advantage of doing so is apparent.

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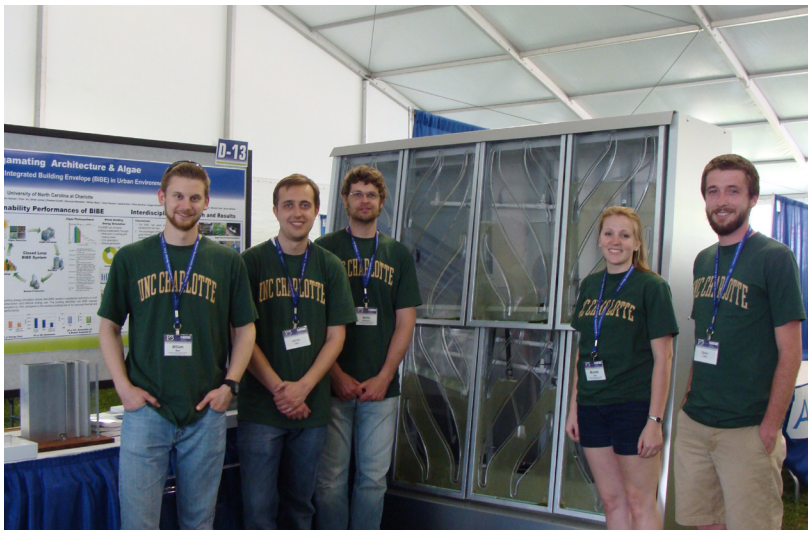
INTRODUCTION

The paper was developed based on an interdisciplinary class offered in the School of Architecture at the University of North Carolina at Charlotte in 2013 Spring term. Representing three colleges and four departments at UNC Charlotte, all 24 students (17 architects, 2 biologists, 2 mechanical engineers, and 3 construction managers) came together to work on a P3 project to develop an algae-integrated façade system - Bio-façades. P3 stands for People, Prosperity and the Planet, and Environmental Protection Agency (EPA) sponsored a P3 research grant to develop a sustainable façade project at UNCC, which can enhance the sustainability of built environment and "benefit people, promote prosperity and protect the planet".

The course deliverables were structured to produce the final project to meet course requirements and to participate in Expo and competition for the Phase 2 Award in Washington D.C. (Figure 1). The students worked in teams representing their main departmental discipline under faculty guidance from the participating departments and were given specific tasks to investigate in the context of the overall project. Students worked within a set framework of pedagogical strategies and expected outcomes, and their progress, including work production and pedagogical goals, was monitored through weekly meetings, workshops, lab sessions, and design reviews.

PROJECT DESCRIPTION: BIO-FAÇADE SYSTEM

The construction and operation of buildings significantly contributes to resource depletion and greenhouse gas emissions. A challenge for the building design and



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construction industries and building owners is to meet sustainability goals in reducing energy consumption and pollutant emissions while providing healthier indoor and outdoor environments. The University of North Carolina at Charlotte participated in the P3 competition in 2013 and adopted an interdisciplinary teamwork as a pedagogical method to teach sustainable building practice. The P3 Award is a national college competition sponsored by EPA and focuses on designing solutions for a sustainable future in five categories - water, energy, agriculture, built environment, and materials and chemicals. We proposed a bio-façade system as an innovative facade material to enhance building sustainability and carried out a feasibility study and the system development in collaboration with four departments – ARCH, BIO, CM, and ME. The bio-façade project was an entry project to compete the P3 Award aiming to benefit people, prosperity and the planet by improving sustainability and air quality in the built environment.

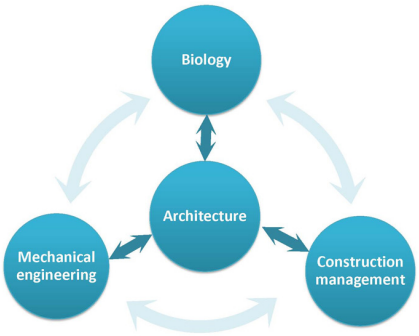
A sustainable building with bio-façades require a high interdisciplinary approach consisting of architecture, engineering, urban planning, biology, material science to maximize the integration of environmental resources surrounding a building and minimize environmental impacts associated with operating a building. The results of our feasibility study and design development showed great sustainability potential from the bio-façade system. Preliminary data showed that this bio-façade system can provide a cost-effective, environmentally-friendly, sustainable, and aesthetically pleasing alternative to glass facades. Advantages of the bio-façade system include good thermal performance, improved daylight transmission, and impact resistant. Further, the algae-growing area of bio-façades modulates solar gains over the entire year and has thermal mass potential for passive heating in winter months. Bio-façades are expected to reduce greenhouse gas emissions as a result of photosynthesis and even has future potential for producing a renewable energy fuel stock in the form of biofuel or biomass.

Specifically in line with the P3 goals (People, Prosperity and the Planet), further bio-façades are expected to benefit people and the planet by reducing concentrations of CO2 in outdoor and indoor environments and promote prosperity by developing local economies through its manufacturing and fabrication. Because algae can grow in different climates and locations, bio-façade has the potential to create a wide variety of jobs, from research to engineering, construction to farming, and manufacturing to marketing. In addition, bio-façades will produce renewable

Figure 1 UNCC interdisciplinary team[1] for 2013 P3 competition in Washington DC.

energy fuel stock and, consequently, protect the planet by lessening the need to extract and combust non-renewable energy resources. Algae can grow in different climates and locations and has the potential to create a wide variety of jobs, from research to engineering, construction to farming, and manufacturing to marketing.

Three industrial partners (i.e., Reynolds Polymer Technology Inc. in Grand Junction, CO; Optima Engineering in Charlotte, NC; and Front Inc. in NYC) were involved on this P3 project, providing in-kind consultation to the student groups on system development, fabrication, and operation of a bio-façade system. Optima Engineering particularly assisted students with specifying distribution systems, controller and pumps for air and water.



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INTERDISCIPLINARY COLLABORATION THROUGH ARCH, BIO, CM, AND ME FIELDS

This paper tests the promise that interdisciplinary teamwork produces more comprehensive outcomes for a sustainable building project. This research project observed the Spring 2013 offering of this three credit course. The class consisted of four departments with various backgrounds - ARCH, BIO, ME, and CM. Participating students were part of a senior capstone courses that bridge biology and engineering which collaborated with senior and Master students from the Architecture department. The course offered lectures on how to design and develop an bio-façade system while estimating performances in the areas of structure, environment, and sustainable energy potential. The course focused on teaching sustainable façade practices through lectures, lab work and a semester-long team project. The semester-long project was served as a P3 competition project to be presented in Washington DC and to compete for the P3 2 Award.

The teaching plan to offer a course in preparation of the P3 competition seek to develop and extend curriculums in the area of the Building Technology at the undergraduate and graduate levels, focusing on innovative facade system characterization, performance assessment, and its real world applications. With the vital and growing role played by building façades in building sustainability, it is imperative to conduct an interdisciplinary collaboration to complete the P3 project. Architecture students were divided into three groups and given primary role in sustainable building practice and façade design. They took a leadership role in developing an bio-façade system while coordinating information with BIO, ME, and CM students. The biology students had closely worked with ARCH and ME students to select appropriate algae strain, cultivate selected algae and carried out laboratory work in measuring cell counts and estimating biofuel and CO2 absorption rate. The ME students had cross collaboration with ARCH and CM to specify bio-façade operation systems and mechanical equipment. The CM team coordinated case-study building information and energy performance measures of the algae façade with ARCH and ME students and carried out whole building energy simulation and building life cycle cost analysis. We held weekly meetings and milestone presentations with each team to discuss group work, monitor progress, and appreciate individual roles and contributions to the P3 project. Each team was given specific tasks to investigate in the context of the entire project, including the following:

- Architectural applications
- Performance assessment of thermal, daylighting and structural integrity
- Life cycle assessment & cost analysis
- Assembly development and prototyping
- Algae strain selection and algae growing environment optimization
- Lab work to check growth rate, O2 generation, and CO2 reduction.

Figure 2: Interdisciplinary collaboration, *twenty-four students and seven faculties drawn from four departments involved in the bio-façade research during 2012-2013.*

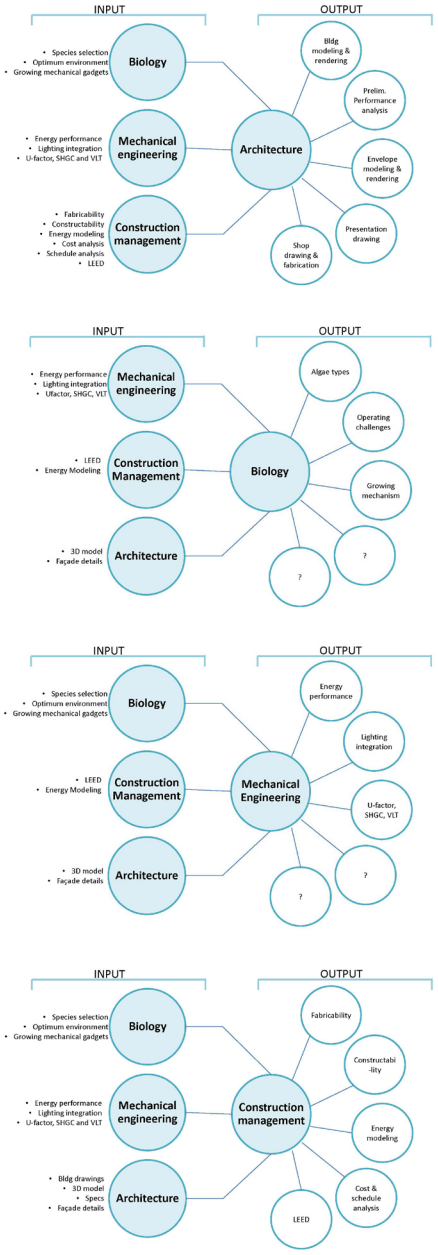

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Figure 3: Interdisciplinary collaboration, *deliverables and action items from each department - ARCH, BIO, ME, CM from top to bottom image.*

Figure 2 shows interdisciplinary teams consisting of four departments at UNCC and explains the relationship between each department. The Architecture students played a major role in coordinating project information with BIO, ME, and CM. Each ARCH, BIO, ME, and CM teams compiled own data, exchanged knowlege and produced a progress report as part of course deliverables.

PEDAGOGICAL OUTCOMES

The P3 project linked two significant future directions for building technology; innovative building material and sustainable systems engineering. It further proved that investigation on innovative facade materials and sustainable systems engineering thinking infused into traditional architecture studies to invigorate and carry the profession forward. Through the P3 project, not only are links developed within architecture department such as building design, structural calculation, and environmental performance, but also facilitated between architecture department and other fields. The students from four departments experienced the excitement of the link between research in an advanced building system and real-world needs for contemporary sustainable buildings. Team members who had previous experience on a group project or interdisciplinary collaboration with other classes, showed more proactive project communication than team members with no previous experience. A higher level of project communication resulted in strong trust and knowledge sharing between team members, leading to better process and final presentation.

Student learning outcomes was primarily assessed with observation and reviews during the semester and the final project presentation. Because non-architecture students had a time conflict with architecture students on regular class schedule, there were several group meetings outside the class to keep track of information exchange with other groups and reliance they placed on other group members. The faculty advisors also tracked the communication density between group members in terms of its nature and scope of information. During the final presentation, the student and team performance were assessed by the depth of central research inquiry, interdisciplinary exploration and the quality of final project presentation.

The architecture students primarily focused on delivering bio-façade system details, carrying out preliminary performance analysis, fabricating visual and performance mock-ups and producing analytical renderings that demonstrate different applications of bio-façades in built environment. The primary deliverables from the biology students consisted of a scientific report and laboratory measurements. The scientific report contained literature review on suitable algae strain selection and state-of-the art technology in algae-based biodiesel production as well as opportunities and challenges associated with energy generation potential and CO2 reduction and O2 supply from bio-façades in the built environment. The lab measurement included algae cell count in order to estimate algae growth rate in bio-façade invironment. The CM students used the P3 project as their senior capstone course in Sustainable Systems Engineering, produced data of energy conservation and renewable energy potential from bio-façades along with life cycle cost analysis using literature review and a whole energy building simulation. The students from Mechanical Engineering focused on executing a bio-façade operation system including distribution pipes, controller and pump equipment.

The P3 project carried out at UNCC was pedagogically successful in that we addressed our project goals and research inquires during the project schedule and received encouraging outcomes and results. From the very beginning of the

project, we knew that the involvement of the campus community, including faculty, staff, and students from different disciplines, was essential to the success of our P3 project, and we have been pleased to see this enthusiasm across all sectors. Our students have been very excited to participate in this P3 project, and as a result, the quality of the work has been highly rated by the teaching faculty and co-advisors. Our industry partners were very supportive through sharing their professional expertise and in-kind consultation with the class.

CONCLUSIONS

While it is clear that we do not currently link well the important subjects of sustainable design, building technology, bio-technology, applied mechanics, materials science and manufacturing, interdisciplinary education is imperative, and the various paths to be taken in the future remain to be discovered. In order to achieve an optimal linkage between these subjects in the training of undergraduate and graduate students, our collaborative P3 project involved faculty and students from disciplines including architecture, biology, and mechanical and civil engineering. Representing three colleges and four departments at UNC Charlotte, all 24 students (17 architects, 2 biologists, 2 mechanical engineers, and 3 construction managers) came together to work on a P3 project to develop a bio-façade system, focusing on innovative facade system and sustainable performance assessment. Our overarching pedagogical goal was to give students a multidisciplinary experience in problem solving on a research project through integrating innovative technology into a broad spectrum of solutions.

The P3 project was an exciting opportunity to direct our coursework towards sustainable design pedagogy within the collaborating departments of Architecture, Biology, Mechanical Engineering, and Construction Management. Students from each of the above four departments successfully delivered fundamental research in environmentally responsible design and developed a bio-façade system for real world application. This project was highly relevant since it encompassed all the mentioned disciplines as well as others that became involved as the project unfolds, in relation to its technical, environmental, materials, fabrication, cost, and building life cycle assessment. In addition, as part of our initiative to engage with the departments of Mechanical Engineering and Construction Management, integrating interdisciplinary studio-based learning into engineering, we foresee this P3 project becoming the bedrock for how we proceed with future initiates in architectural education and sustainable built environment.

ENDNOTE

1. The 2013 UNCC P3 was supported by EPA Grant Number: SU835322. The title of the project was “Beyond Green: Bio-reactor Integrated Building Envelope (BIBE) in Urban Environment”. The Project abstract can be downloaded from http://www.epa.gov/ncer/p3/project_websites/2013/su835322.html.