Integrated BIM and Sustainability Curriculum

Wei Wu
Georgia Southern University
Statesboro, GA 30460
wwu@georgiasouthern.edu

Raja R.A. Issa Brittany Giel
University of Florida
Gainesville, FL 32611
{raymond-issa,b1357g} @ufl.edu

Abstract

Green building and sustainable construction have long been incorporated into the curriculum of construction management programs at both the undergraduate and graduate level. The Leadership in Energy and Environmental Design (LEED) green building rating system is an important topic in such curricula. Current LEED education for college students is typically constrained to fundamental theories found in textbooks and reference manuals. Due to a lack of practical experience, college students usually find it difficult to understand the rationales behind the LEED system, and of course, to conceive how a LEED project is delivered in the field. This paper discusses an innovative educational approach experimented with at Rinker School of Building Construction that facilitates sustainability education through its integration with building information modeling (BIM).

This BIM-for-LEED education model takes advantage of cutting-edge BIM authoring and analyzing tools to delineate critical design factors that contribute to the success of achieving LEED certification, using real LEED certified buildings on the campus of University of Florida (UF). Emphasis was placed on understanding design factors that were critical to contribute to the conformity to LEED certification, and the desired functionalities of the BIM solutions to achieve such compliance. Both lectures and labs are given to students to enrich their knowledge in computer aided sustainable design, and more importantly, hands-on modeling experience to expose the nuts and bolts of a LEED oriented design workflow. It was observed that at the end of the semester, the students had not only gained more in-depth understanding about sustainability and the LEED rating system, but also they had mastered solid skills to model LEED-compliant buildings. The advantages of using on-campus LEED projects is that the students could easily visit these buildings to identify the gaps between their design and the real projects and thus extend their understanding of sustainability and LEED from the design phase to project's construction, or even the operation and maintenance of the building.

Keywords

LEED, BIM, Education, Curriculum.

1. INTRODUCTION

The leadership in energy and environmental design (LEED) green building rating system has been consistently gaining popularity in the building industry since its debut in 1998 (LEED 1.0). Briefly speaking, the prevalence of LEED can be attributed to:

1. Strong marketing of the U.S. Green Building Council (USGBC) in terms of membership development and professional credentialing (LEED Accredited Professional, or LEED AP);
2. Endorsement of the government (e.g. Department of Energy Executive Order 13423);
3. Recognition of environmental, social and financial benefits in pursuit of LEED certification for building assets (Kats et al. 2003); and
4. College education and professional training oriented to building sustainability.

Education is important to sustain the momentum of LEED as a source of intellectual support. This is clearly observed in events such as a college career fair when the students approaching construction companies for an internship, the human resource managers tend to look at their resumes to see if they have qualifications such as being LEED APs. In recent years, the rise of perceived demands for LEED APs in construction companies' staffing has substantially impacted education in academic construction programs.

At Rinker School of Building Construction, there have been special workshops catered to such demands to provide intensive LEED training for both graduate and undergraduate students. They attend these workshops mostly to prepare for the LEED accreditation exam. Such workshops are in addition to existing curriculum at the Rinker School, which means it is unofficial and is optional. However, LEED training is regarded as beneficial to the students in many ways:

1. It helps students build appealing resumes and prepare them for a competitive job market;
2. It exposes students to fundamental principles and knowledge in green building design and construction that might be applicable to their future career;
3. Students who go through the training tend to be more resolute in their career planning, and demonstrate better leadership skills that are critical in their future roles as project managers.

So far, hundreds of undergraduate and graduate students have gone through the training and successfully attained their LEED qualification. Interestingly, follow-up conversations with these students find out that there are some unexpected issues in regard to the LEED accreditation and LEED training in general. A most frequent quote goes that "LEED AP does not bring me better chance in job hunting then why everyone is still striving on getting it?" Another typical comment is "Now it is actually rarer for someone to not have LEED accredited rather than having it."

To find out answers to these questions and comments, conversations have been conducted with recruiters during the Rinker School's career fair. A typical feedback is that companies would like to know whether students had LEED accreditation, but they would not be significantly affected by it in giving out internships or making job offers. They simply did not think that students' accreditation were well matched with corresponding LEED project experience, which is the true qualification appreciated by construction companies. In order to add value to the LEED education and accreditation, it is paramount that a more practical curriculum to be developed.

2. BACKGROUND

The LEED green building rating system was introduced to the UF campus as early as 2001, when the university adopted LEED criteria for the design and construction of all major new construction and renovation projects to deliver high performance and sustainable buildings (UF

2007). So far 19 campus buildings have achieved LEED certification, including the first LEED Platinum and LEED Gold certified buildings in the state of Florida. There are 26 more projects under way with the same goals.

Along the evolution of the LEED program at UF, there have been some significant milestones:

- In 2003, first LEED accredited professional on staff, first on University of Florida campus, and one of the first five in the state of Florida.
- In 2004, in-house LEED administration. Bahar Armaghani, LEED Accredited Professional, took on the responsibility of LEED administration and some LEED credit calculations for all UF projects.
- In 2005, it was determined that LEED certification can be obtained with no additional hard cost, and there was a need to take the next step.
- On January 2006, UF renewed its commitment to sustainable construction and delivering greener buildings by raising the bar and making SILVER the minimum LEED certification level for all its new construction and major renovation projects.
- In 2007, LEED Campus Standards were established for the whole UF main campus.
- In 2007, LEED-EB Portfolio Pilot program was started.
- In 2009, UF raised the minimum LEED certification level for all new construction and major renovation to GOLD.
- According to the latest data for 2009 from the U.S. Green Building Council, the University of Florida is the highest ranked campus for LEED project registrations (UF 2007).

The rich culture of building sustainability and deep engagement in LEED makes UF a strong candidate in green building and LEED education. The Rinker School of Building Construction as the oldest building construction management program in the country, is hosted in Rinker Hall, the first LEED Gold certified building in Florida and the AIA Committee on the Environment Green Project for 2005. Accommodating around 500 undergraduate students and 120 graduate students, Rinker Hall includes a mix of classrooms, teaching labs, construction labs, faculty and administrative offices, and student facilities. More importantly, as a green facility, it becomes a dynamic teaching tool to educate students about green buildings and LEED system.

3. BIM-FOR-LEED: THE COURSE CURRICULUM DESIGN

As BIM (building information model) adoption grows in the building industry, so does the use of BIM in educational curricula (Rundell 2005). A major driver in this trend is the partnership between software vendors and academic programs, for instance, Autodesk's free licenses for educational purposes.

Perceived benefits of integrating BIM in architecture, engineering and construction (AEC) curricula as identified by Rundell (2007) include:

- Purpose-built BIM solutions such as Revit help students learn holistic building design.
- BIM integrates conceptual design thinking with building technology, encouraging students to consider cost, constructability, environmental impact, and so forth.
- BIM also helps students learn about coordination and collaboration, giving students valuable knowledge regarding how building elements and systems interact, which in turn prepares them to interact with the people designing those systems.

In addition, as the climate change and environmental concerns are transforming the industry, college curricula have made corresponding adaptation to reflect the industrial trend. With powerful energy simulation and other environment-centric functionalities, BIM's potential in facilitating these adaptations is yet to be explored. Some well-known programs that have adopted such BIM facilitated green curricula include the Department of Architectural Engineering at Pennsylvania State University, School of Architecture at University of Southern California, School of Architecture at Georgia Institute of Technology, and the Savannah College of Art and Design (Rundell 2005, Rundell 2007).

The comparable initiative at the Rinker School is relatively new. Since 2007, the Rinker School has been experimenting with workshops to provide professional BIM training for local architects and contractors. As for the academic curriculum, BIM was first introduced to graduate level classes in Construction Information Systems and later to undergraduate prerequisite courses such as Graphical Communication and Print Reading. A huge momentum for sustainability oriented BIM integration in existing curriculum at the Rinker School came from its partnership with Autodesk. The joining of forces between Autodesk and the U.S. Green Building Council (USGBC) in November 2006 was perceived as a strong signal that BIM would be broadly implemented in the realm of green building and sustainable construction. This supposition was confirmed, as shown in Figure 1, in the results of the 2009 SmartMarket report published by McGraw-Hill Construction.

Combining existing academic resources, the original Construction Information Systems (BCN6787) class was restructured to highlight the dual themes of BIM and sustainability. The brand new curriculum was specially designed to accommodate the needs of addressing the integration of BIM and sustainability. The following paragraph subsections briefly explain the course curriculum design.

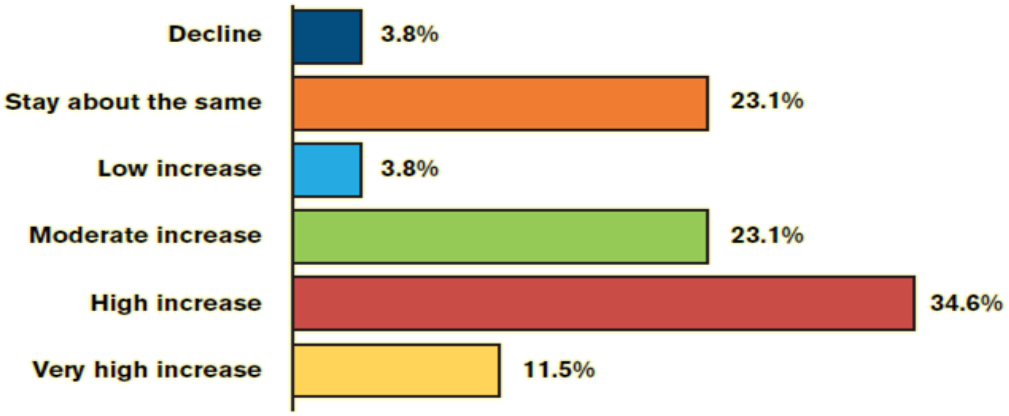

Figure 1: Expected growth in BIM use on LEED projects in the U.S. (Source: McGraw-Hill Construction 2009).

3.1 BIM Wiki

A BIM Wiki is useful in a classroom environment since it provides an open platform for students to communicate and collaborate, especially for group projects. It could also play an important role in knowledge management when used as an archive for course experience of students. This idea has been tested by existing BIM curriculum such as the one at PSU

(http://bim.wikispaces.com/). The wiki site at Rinker is still under construction, and currently opens only to faculty and students that directly engage in the Construction Information Systems class (Figure 2a). It is expected that in near future, the resources (Figure 2b) at this website will be accessible to the public.

(a) (b)

Figure 2: The Rinker School BIM wiki.

3.2 Lectures vs. Labs – Knowledge vs. Experience

As is common to any other curriculum in a construction management program, knowledge and experience are both critical for students to understand the essence of construction. Most students in this class had no previous exposure to BIM, which makes it necessary to teach them about the literature of BIM. Numerous resources have been consulted in this class, ranging from textbooks, industrial reports, whitepapers to live webinars and guest speakers, even training workshops from software vendors. Students were expected to gain a full spectrum of exposure to BIM at the end of the lecture series.

On the other hand, experience is equally important to students. It is unrealistic to put every single student into actual project delivery through collaboration with local construction companies. However, it is possible to simulate such a process. To achieve this goal, the class was broken down into 10 groups and each group was supplied with the complete project documents of a building on campus. Students' tasks include:

- Create the multi-disciplinary BIM model of the assigned project using the Revit BIM solution package, i.e. Revit Architecture, Revit Structure and Revit MEP;
- Conduct constructability review using clash detection tools such as Navisworks, and prepare the desired review reports;
- Perform the project planning and scheduling to create the 4-D BIM model by integrating the time/phasing information, using Microsoft Project or SureTrack with Navisworks;
- Perform quantity takeoff and estimating based on the multidisciplinary BIM model, and conduct cost analysis of the project to finalize the model into 5-D;

- Perform LEED strategy and compliance analysis for the projects and optimize the potential for LEED certification based on functionalities provided by the Revit BIM solution package, such as energy simulation, daylighting design, water consumption analysis, etc.

3.3 LEED Projects

As previously discussed, the advocacy of LEED at UF brings great opportunity to this class to enable comprehensive integration between BIM and LEED. All the nine projects assigned in this class came directly from the campus building portfolio, most of which (8 out of 9) were either LEED certified or are in the course of pursuing the LEED certification. The Genetics and Cancer Research Center is divided into halves and assigned to two groups due to its complexity and magnitude. A brief introduction of these projects is listed in Table 1. By going through the modeling process, students could have the opportunity to unveil the design factors that contribute to the building's success in LEED certification. Lucky for the student is that whenever they had any question about the building details, they could simply visit the building and find it out in person, which in reality extended their understanding of LEED buildings from design to the construction. With access to operation and maintenance data, they could also verify the LEED buildings' actual performance against their designed performance.

Table 1: Buildings used as term projects in the BIM-for-LEED curriculum

Project Name	Year	Area (SF)	LEED Certification	Highlighted Features
SW Stadium Expansion	2008	31,000 new + 28,200 renovation	Platinum	• Energy saving 35% • Reduced Indoor Water Use by 40%
Library West	2006	60,000 new + 117,000 renovation	Gold	• Increased insulation • Efficient lighting
Steinbrenner Band Building	2008	18,082	Gold	• SRI 90 roof • 100% Reclaimed Water for Irrigation
Graham Center at Pugh Hall	2007	45,000	Silver	• Recycled content • Light Pollution Reduction
Orthopedic Surgery and Sports Medicine Institute	2004	120,000	Certified	• Low-emitting materials • Auto-dimming
Genetics and Cancer Research Center	2006	286,700	Certified	• Ozone protection
Baseball Locker Room Facility	2007	15,000	Certified	• Water efficient landscaping
Nanoscale Research Facility	2007	52,000	Certified	• Regional materials • Ozone protection
Gerson Hall*	2004	33,000	N/A	N/A

*Gerson Hall was selected as a substitute for another LEED building for which project documents were not available.

4. BIM-FOR-LEED: THE COURSE OUTCOME

The trial for the brand new BIM-for-LEED curriculum spanned 13 weeks of the spring semester in the academic year of 2010. A total of 42 students were registered. The curriculum consisted of two major parts. Part I of lectures and labs were intensive in this curriculum in terms of the volume of knowledge reviewed and the modeling software solutions taught. Students were required to learn the Revit BIM solution package, i.e. Revit Architecture, Revit Structure and Revit MEP, as well as other BIM analyzing tools including Navisworks, EcoTect and Green Building Studio. Skills in other construction related software such as Microsoft Project or SureTrack were also desirable and were briefly introduced in the course. To reveal the cutting edge application of BIM in sustainability, guest lecturers from Autodesk and industry were invited into the classroom.

For Part II, students were broken down into 10 groups for the term project. Group membership was assigned using a rating of each member based on their undergraduate degree (construction, architecture, engineering, business); previous classes in BIM; and construction/design experience. Projects were assigned their complexity with the sophistication of the group members Each member in a project group was assigned with specific a role in the modeling process while same time needed communicating and collaborating with other members as a project team to come up with a complete project delivery package. The format and contents of the final project package were strictly predefined by the course instructors.

The term project was the most challenging part in this curriculum and took the students about 8 weeks to work on for a proportion of the real project scope. It is understandable that most of teams could not possibly finish all disciplines of the building model, but some of the groups simply went beyond expectation, which will be discussed further. Along the course of the term project, students were required to give periodic presentations about the progress of their work, the milestones achieved, difficulties encountered and solutions attained. At the end of the semester, all groups were required to prepare a comprehensive project summary presentation in a professional manner.

4.1 The Essence of LEED in the Curriculum

As emphasized previously, LEED is a key constituent of this curriculum. As a matter of fact, most students in this class were LEED APs. They had strong background knowledge about LEED but did not necessarily understand what a role of BIM could play in LEED projects. One of the major goals they intended to score in this class was to find out how BIM could facilitate LEED certification, and what could be different for these existing LEED buildings if BIM was implemented in the first place.

The Autodesk Sustainable Design Curriculum 2010 (Autodesk 2010) was used as reference. Important modules in this curriculum including conceptual solar and daylighting design, open view analysis, energy simulation and water consumption analysis were all directly or indirectly applicable to LEED.

The rationale behind the integration of BIM and LEED is illustrated in Figure 3. The rule of thumb is the match-up attained between certification requirements of the LEED rating system,

and the functionalities requirements of the BIM solutions. In the classroom setting, students were encouraged to conduct the match-up analysis for the project assigned to get a taste of strategizing LEED for the certification purpose, following the workflow depicted in Figure 4. The actual scorecard of these LEED buildings were available for references, which students used to evaluate the gaps between their idealized LEED strategies and the actual design approaches adopted in these buildings.

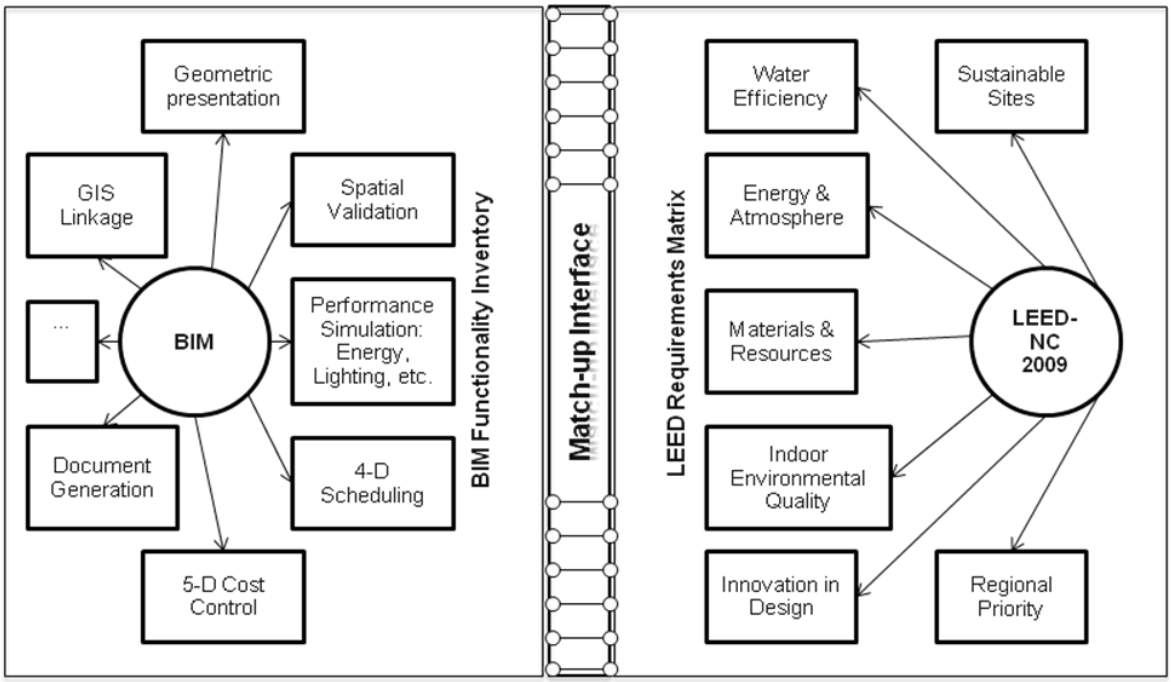

Figure 3: Generic rationale of BIM and LEED integration.

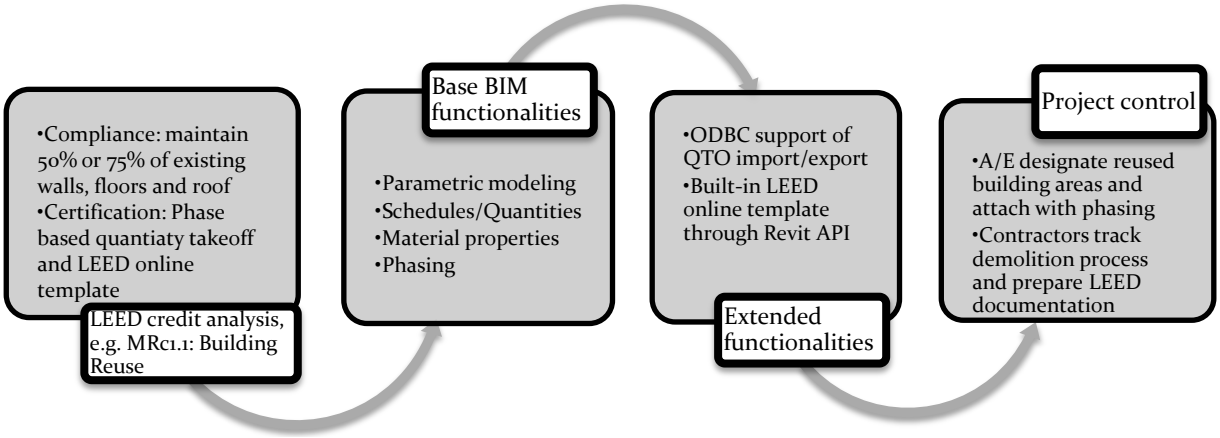

Figure 4: BIM and LEED integration process.

4.2 Selected Student Projects

The leap from generic building information modeling (modeling for fun) to project specific modeling (serious modeling) is substantial. The key is dedication to details, and the patience in repetitive working process. Some highly motivated individuals in this class demonstrated high quality of modeling skills and more importantly, deep understanding of the integration between BIM and sustainability. The following present some highlights of the students' work.

4.2.1 SW Stadium Expansion Project

The SW Stadium Expansion project is the first LEED Platinum project in the state of Florida. Major sustainable features of this project include:

- Green Roof on Weight Room
- Reduced Indoor Water Use by 40%
- 100% Reclaimed Water for Irrigation
- Dual-Flush Toilets & Other Low-Flow Fixtures
- 8 out of 10 Points for Energy Cost Savings over ASHRAE 90.1

Reflected in design, special care is needed in the landscaping, roof structure, plumbing system, efficient lighting, as well as Energy Management System (EMS) application in the HVAC system. Figure 5 is a rendered image created by students. As is shown, the irregular building shapes and the change of building elevations created substantial difficulty in the modeling process. In contrast, students enjoyed the exterior glazing design part, which was quite straightforward to model, and which made it relatively easy to achieve a satisfactory outcome. Figure 6 is a snapshot of the rendering of the exterior glazing.

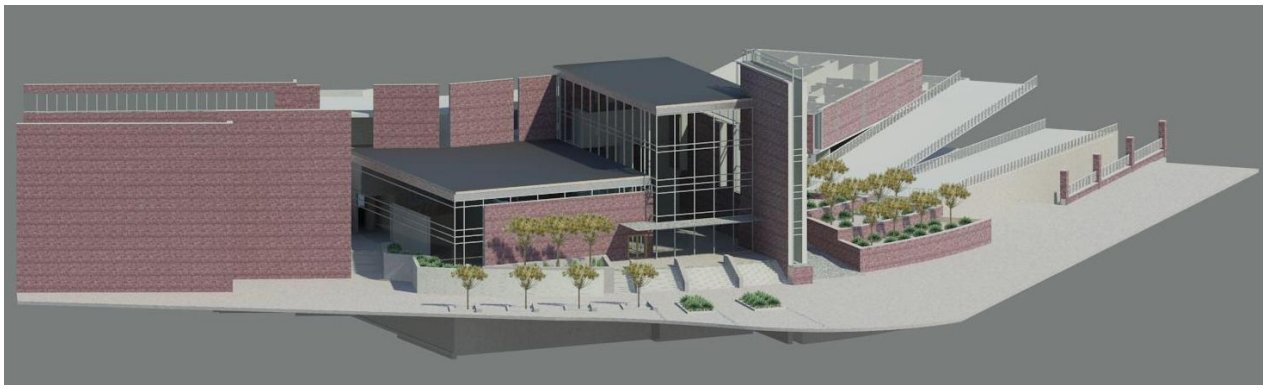

Figure 5: Rendering for SW Stadium Expansion (Image courtesy by Rhodes et al).

Figure 6: Exterior glazing rendering for SW Stadium Expansion (Image courtesy by Rhodes et al).

4.2.2 Genetics and Cancer Research Center

The Genetics and Cancer Research Center is a mega project of dual buildings (Figure 7) with a gross floor area of 286,700 sf. To better describe the magnitude and complexity of this building, some quick facts are listed below:

- 19,100 CY of concrete was installed for the building structure. Total weight of poured concrete was in excess of 77,000,000 lbs.
- The cast in place concrete contained over 3,800,000 lbs of reinforcing steel, which is 100% recycled material.
- Approximately 700,000 feet of wiring was used throughout the building.
- Over 1.2 million man hours were spent to build this building.

Figure 7. Aerial image of Genetics and Cancer Research Center (Image courtesy of Facility Planning and Construction, University of Florida).

To avoid overwhelming the students, this project was split between two groups, each with one of the dual buildings. Both groups demonstrated strong commitment to the level of details desired in this project. Figure 8a and Figure 8b are renderings from the two groups respectively.

(a) Group 1 Rendering

(b) Group 2 Rendering

Figure 8. Renderings for Genetics and Cancer Research Center buildings.

4.2.3 Summary

The final presentation of students' project was quite a success. Students shared their experience, excitement and frustration in this class. As required by the course instructors, each group kept a project log that recorded the learning process. Recommendations were also given by students to improve the curriculum in general. But most importantly, the students had consensus on these aspects:

- The modeling process forced them to revisit the LEED system and it turned out after this process, they became much more confident in their knowledge about LEED and sustainability;
- BIM seemed to be a natural fit for the LEED system considering the myriad functionalities built in current BIM solutions;
- Implementing BIM in LEED projects could vary significantly, heavily depending on the LEED strategy adopted by the project team;
- The BIM and LEED integration was not accomplished yet. Future development of more rigorous BIM functionalities is critical to reinforce this integration.

5. CONCLUSION

This paper presented an experimental curriculum that adopted a brand new approach to LEED education through integration of BIM. The course design process was delineated, and the course outcome was analyzed.

Although this BIM and sustainability integration in this curriculum proved to be beneficial to students as acknowledged by them, there were some drawbacks in the approach used. A major issue identified by the students was the volume of work. It seemed that the overall course goal was too big. Put another way, students became fatigued to learn so many pieces of different software in a single class within such a short period of time. Another contributing factor to this problem was the complexity and scope of the selected projects. Actual LEED projects were used, but the time allocated for the projects might have been too short considering that over 50% of these students were considered to have no or little BIM or 2D design software experience at the beginning of the class.

Project set up also needed a better configuration. The purpose of assigning roles to group members was to simulate a more realistic project delivery process. But it turned out that students complained a lot about such an arrangement since they were so much tied to their specific roles and lost the opportunities to get familiar with other disciplines.

Collaboration among the groups could be better if the BIM wiki was fully developed. The wiki site at the time was limited in both functionalities and flexibility to accommodate the needs of BIM facilitated LEED projects. All these feedbacks are expected to be incorporated into future improvement of this curriculum.

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