

Teaching Vegetative Roofing Systems: An Industry and Academic Collaboration

Rodolfo Valdes-Vasquez, Ph.D. and
Jonathan W. Elliott, Ph.D.
Colorado State University
Fort Collins, CO

Scott Kawulok
B&M Roofing of Colorado, Inc.
Frederick,, CO

Leveraging relationships with industry to produce current, and real-world learning activities offers students the opportunity to explore the benefits and challenges of sustainable technology and practice. This study reports the results of implementing a three-week vegetative roofing teaching module comprised of three phases; 1) an industry-expert lecture, 2) multiple case study analysis and 3) an in-class student presentation (cohort one) or a student-led debate and defense of student's green roof system selection (cohort two). Specifically, the teaching module was designed to expose students to green roofing system installation requirements, their benefits and disadvantages as well as green roof application-specific project management considerations. In total, 46 students (n = 20 presentation format, n = 26 debate format) completed the vegetative roofing teaching module and survey. Student ranked the case study research and analysis phase as the most effective classroom intervention for increasing their knowledge of vegetative roofing systems. T-test results revealed that student completing the debate reported statistically higher effectiveness ($p = 0.019$) and increased green-roof knowledge ($p = 0.022$) resultant the teaching module than did those in the presentation format. The roofing industry expert's perspective is presented. Study implications and areas of further research are discussed.

Key Words: Vegetative Roof, Construction Management, Case Study, Active Learning, Sustainability

Introduction

Vegetative roofing systems, also known as green roofs, eco-roofs or roof gardens, support plant life while creating an impervious layer that directs water away from a building envelope. Vegetative roofs have been utilized since the fifth century for their aesthetic and thermal insulation value (Osmundson, 1999). However, green roofing system installation has expanded in the 20th century as a method to commingle human-built infrastructure with limited urban green space (Berardi et al. 2014). For example, in the U.S., green roof installations increased from 5.6 million to 6.4 Million square feet (8.4%) between 2012 and 2013 (Green Roofs for Healthy Cities, 2014).

Vegetative roofs can be very complex, requiring effective design and construction collaboration from various disciplines including, but not limited to, architecture, engineering, construction management, and horticulture. Thus, understanding multi-disciplinary concepts and applying such knowledge through real-world case study is important in educational programs such as engineering and construction management (CM). Sankar et al. (2008) posit that analyzing case studies is an effective approach to promote students learning through real-world experiences and enhance students' cognitive skills. Several university engineering programs have utilized green roofing-based teaching modules to convey real-world issues and facilitate multi-disciplinary problem solving (Taleghani et al., 2014). Despite the presence of green roof education in undergraduate and graduate engineering programs, implementation in construction programs was found limited.

Sustainable technologies and practices are rapidly changing and construction students entering the industry face the challenge of keeping up with these dynamic systems. Consequently, construction educators must be intentional and proactive in teaching changing technologies and practices through proven pedagogical methods. Effective education for sustainable development requires students to consider not only the benefits to the built environment, but also understand the processes and challenges of implementing environmentally friendly systems while navigating the reality of stakeholder budgets, technical constraints, climate considerations, and community interests. To convey

these sustainable building complexities, one approach is for educators to partner with construction industry members to capitalize on conveying case studies that emphasize sustainable design and construction practices.
This study describes the implementation and results of a vegetative roof teaching module where student reviewed, analyzed and evaluated two vegetative roof case study projects. In addition, in-class learning activities (e.g. expert industry presentation, student presentations and debates) were included in the teaching module to provide student with context and expose them to green roofing practice. The study was conducted over two academic years in a 400-level Sustainable Design and Construction course at a major U.S. university. The purpose of the study was to gain construction students post-intervention input regarding the effectiveness of the green roofing teaching module. Also, the study aimed to explore student perceptions regarding differing deliverable approaches; e.g. a student-led presentation or debate.

Background

Vegetative Roofing System

Vegetative roofs have been utilized since the fifth century for their aesthetic and thermal insulation value (Osmundson, 1999). However, green roofing system installation has expanded in the twentieth century as a method to commingle human-built infrastructure with limited urban green space (Berardi et al., 2014). While a variety of technologies related to green roofs have been implemented in the last two decades, a typical vegetative roof assembly consists of four main components: 1) a waterproofing membranes and filter membranes, 2) drainage films, 3) a growing medium, and 4) a landscape materials. The efficiency of green roofs varies given the use and configuration of different component materials (Saadatian et al., 2013). In addition, green roofs can be constructed using multiple individual components or modules to create a system or as a combination of turn-key, pre-cultivated, blankets (Berardi et al., 2014).

In North America, green roof installations increased from 5.58 million to 6.42 Million square feet (8.4%) between 2012 and 2013 (Green Roofs for Healthy Cities, 2014). Vegetative roofing research has mirrored the proliferation of green roof installation, notably increasing in the past ten years. It is clear that specific-expertise, from multiple disciplines, is required to successfully execute a vegetative roofing installation. From the project management perspective, vegetative roofing design and construction considerations should be addressed properly, and in a timely manner, to ensure the project success and owner acceptance. Since construction office and field personnel coordinate multiple stakeholder interest and construction trades to meet owner expectations, it is critical that CM students are exposed to, and understand, vegetative roof design and construction practice in light of the systems potentials and drawbacks.

Teaching Vegetative Roof Systems in U.S. Academic Programs

Academic programs that incorporate practical learning components are effective in generating student enthusiasm and increasing the retention of core concepts through real-world experiences (Tener 1996). Literature review revealed no vegetative-roof courses or teaching modules specifically tailored to CM students; however, other disciplines have tested green-roof specific curricula. An initial example, housed in Penn State University's horticulture program, was found in the Eco-Roof and Green Technologies course. The intent of this course was to increase horticulture student's understanding of green technology fundamentals including the design of roof media and its functions (Center for Green Roof Research 2016). Carleton College implemented an Eco-House construction class that allowed students to design and build a green roof as an independent study under the supervision of college and facilities management staff (Savanick et. al 2008). The roof was used as a teaching aid for a prairie plant identification class and was the subject of student-led campus tours. Despite the project's successes, the independent study approach would likely prove difficult to implement in other context, particularly, larger undergraduate courses.

Real-world exposure to professional practice and problem solving has been cited as a primary benefit of industry and university teaching partnerships (Ahmed et al. 2014). An exemplary course, offered by the Department of Environmental Engineering at Norwich University, leveraged hands-on instruction in several sustainable technologies, including green roofs, to promote student learning and community outreach. During the class, undergraduates worked with students and teachers at a local elementary school to develop, design, and estimate the

cost of a green roof system while navigating project specific parameters including the school's budget and design requirements (Kulkarni 2014).

The University of Michigan's Civil Environmental Engineering Department and the Business School collaborated to implement a Green Roof design and construction course that requires students to produce technical and cost proposals, engineering specifications and calculations, and a net-present value analysis over 40 years with a breakdown of construction costs and the expected payback period. The course was designed to demonstrate the evolution of projects with students producing a design report for the construction of a green roof on existing buildings (Adriaens et al. 2007). The students reported that the course provided them with valuable academic and professional experience. However, some students reported that their exposure to regulatory issues was inadequate (Adriaens et al. 2007) indicating that the course was perhaps too broad, preventing students from applying specialized knowledge in construction management.

Experts have identified a need for the teaching and learning of environmentally sustainable systems within construction-related academic disciplines (Pearce et al. 2013). Since construction office and field personnel coordinate multiple stakeholder interest and construction trades to meet owner expectations, it is critical that construction students are exposed to, and understand, vegetative roof design and construction practice in light of each systems' potentials and drawbacks. While other fields, such as architecture, engineering and business, have experimented with green-roof teaching interventions, a review of literature revealed no CM-specific vegetative roofing courses or teaching modules. Thus, this study seeks to build on the findings of research from other disciplines by developing and implementing an industry-informed vegetative roofing teaching module within CM. The teaching module contained both structured and unstructured learning activities and hinged on student analysis of two commercial building vegetative roofing case studies.

Implementation of the Vegetative Roof Teaching Module and Survey

The vegetative roof teaching module was developed through a faculty and roofing-industry collaboration and was designed for a three-week implementation period. The teaching module comprised of three learning phases: 1) a vegetative roofing presentation provided by a roofing industry expert, 2) a group assignment in which students reviewed, analyze and evaluated two green roof case studies and 3) either a group presentation (Fall 2014) or debate (Fall 2015) discussing their results. These learning activities were administered in a 400-level Sustainable Design and Construction course among two independent groups of students during Fall 2014 (N1 = 27) and Fall 2015 (N2 = 29) semesters.

A total of 56 potential participants were part of the course, including 55 students majoring in construction management and one from interior design. The student sample includes 51 upper-level undergraduates (13 juniors and 38 seniors) and five graduate students. Students completed a post-intervention survey in both academic years. Participant responses from both student cohorts were analyzed in aggregate. In addition, a comparative analysis between the two cohorts, given the group presentation or debate options, was conducted to assess the effectiveness of the teaching module delivery method.

Vegetative Roofing Teaching Module Phases

Phase 1: An industry expert in roofing systems provided a guest lecture. The industry representative, a member of the Roofing Industry Alliance for Progress, discussed the evolution of vegetative roofing, its definition, system types and examples as well as the advantage and drawbacks of implementation. The presentation was designed in conjunction with the faculty member teaching the course to achieve the following learning objectives. After the presentation student shall be able to:

- Recognize why studying vegetative roofing is important for their professional career
- Define baseline concepts concerning vegetative roof systems
- Analyze the differences between types of vegetative roof systems
- Explain the benefits and drawbacks of a vegetative roof system
- Describe the major components of a vegetative roof system

After covering the vegetative roofing materials and system, the industry expert discussed CM-specific considerations during the green roof design and construction phases (Table 1). The presentation was covered in approximately 50 minutes. Subsequently, the industry member participated in a question and answer session with the students. After the guest speaker presentation, the instructor gave students a brief overview of the case study assignment. Participants were assigned to work in groups of four to five students. The assigned groups were similar to a previous mid-term group project to minimize the challenges of building a new understanding of team dynamics.

Table 1
Examples of Project Managing Considerations for Vegetative Roof System Implementation

Project Phase	Managing Considerations
Design	• Obtain advice from trusted manufacturers, designers, and contractors • Find out the "why's" associated with the vegetative roof • Ensure costs of install and maintenance are understood by O.A.C team
Pre-Construction	• Ensure that bids can be evaluated apples to apples and contain all the specified components required. Also, consider the following: – Identify specified material – Look for the warranty requirements (is overburden included or not?) – Identify test requirements (water test/flood test/EVFM testing) – Select roof contractor as early in the process as possible – Check for any exclusions
Construction	• Ensure proper planning prior to forming hard schedule such as conducting interviews and "pull planning" if needed to ensure proper sequence • Make sure timeline is appropriate by understanding submittal, approval and procurement requirements • Document and follow through with the O.A.C. team, regarding questions and/or constructability problems
Closeout	• Ensure contractor furnishes owner with required closeout documents, especially the warranty documents • Ensure contractor/manufacturer has supplied detailed instructions on O&M related items • If there are problems have a plan and a realistic approach

Phase 2: During this phase student specifically analyzed two case studies included the Sun-Root Solar Garden Roof (Breuning, Tryba, & Miller 2013) and the Soka Bau Administrative Complex (Ngan 2004). The objective of this assignment was to expose students to the overarching concepts, design considerations, and constructability factors involved with two vegetative roof system cases. Using the industry case studies as a guide, students recommended materials, construction methods, and other technical considerations to build a similar roof in a different environmental setting. Student groups submitted formal reports of their case finding. Papers were limited to 3-4, single-spaced, pages or approximately 2000 words. The inclusion of graphics was acceptable and did not count towards the page limit. Students were required to determine the best green roofing selection for a residential or commercial building given the information provided two case studies. Students were given two weeks to complete the report after it was assigned and strongly encouraged to conduct their own research to support their answers to the open-ended questions. Most importantly, the students were asked to provide a recommendation as to which system might be better suited for a residential versus commercial projects. Specific report deliverables included the following tasks:

1) Summarize the highlights of the two green roofing installation methods

2) Compare and contrast significant differences and/or similarities between systems

3) Discuss the pros and cons of one or both systems

Phase 3: As previously described, students presented their findings in a class session by using a 5-minute presentation (Fall 2014) or debate format (Fall 2015). The presentation required students to discuss their finding in a lecture format followed by a 3-minute Q/A session. For the debate, students discuss the main case study findings, took a position, and defended their green roof selection. After the argument was made and the debate discussion concluded, groups were given 3 minutes to respond to peer comments and 2 minutes for a closing statement. The instructor provided a rubric to inform students of the timing and process of the debate sessions similar to those found in previous studies (Kennedy 2007; Doody and Condon 2012).

Student feedback Survey

A post-intervention survey was created to seek student feedback about the implementation of the vegetative roofing teaching module. Students reported their level of agreement with the following statements on a 5-point Likert scale (-2 = "Strongly Disagree" to 2 = "Strongly Agree")

- Energy conservation is very important for future generations
- A vegetative roof system is a key part of the process of designing an energy efficient building
- Being familiar with vegetative roof systems is a critical skill to possess in the modern construction industry
- This assignment was effective in exposing me to the benefits or drawbacks of vegetative roof systems

Next, students were asked to rank the effectiveness of the implemented learning activities in increasing their knowledge of vegetative roof systems on a 5-point Likert scale (1 = "Least Effective" to 5 = "Most Effective"):

- Guest speaker presentation: Vegetative and "Green" Roofing.
- Reading the Case Studies related to the group assignment
- Comparing the Case Studies as homework
- Presenting (fall 2014) or debating (fall 2015) their results with the class and industry
- Conducting their own research about vegetative roofing

Finally, students were asked to indicate their level of agreement regarding the implemented learning activities (indicated above) increasing their knowledge of vegetative roof systems. Students' level of agreement was recorded on a 5-point Likert scale (-2 = "Strongly Disagree" to 2 = "Strongly Agree"). The survey included two open-ended questions (e.g. "was there another activity in class that increased your knowledge of vegetative roof systems?" and "if you would like to elaborate on any of the topics covered in the previous questions, please write them down.") to solicit students comments about the teaching module. Based on the requested feedback from fall 2014, it was decided to maintain the assignment in full, but change the final learning activity to a debate instead of a group presentation.

Results and Discussion

Student Responses

Forty-six students completed usable surveys yielding a response rate of 82%. As previously described, the group of students in 2014 completed a presentation of their case study results while students in 2015 led an interactive in-class debate and provided supporting argument for their green roofing system selection. Students from both semesters reported their level of agreement (5-point Likert Scale; -2 = "Strongly Disagree" to 2 = "Strongly Agree") with the following statements: "energy conservation is very important for future generations", "a vegetative roof system is a key part of the process of designing an energy efficient building," and "being familiar with vegetative roof systems is a critical skill to possess in the modern construction industry". Independent samples t-test indicated no significant ($p < 0.05$) difference in the level of agreement with these statements between the groups of students. This finding provides assurance that the presentation and debate groups were not statistically distinguishable based on their perceptions of the importance of energy conservation in general, or specific to green roofing systems within the domain of energy efficient building design.

Results revealed that while six students reported a "neutral" level of the agreement, 23 student's "agreed" and 17 "strongly agreed" that the green roofing case study teaching module was effective in exposing them to the benefits of vegetative roofing systems. The mean rank (1 = "Least Effective" to 5 = "Most Effective") for the different content delivery methods were calculated. Mean ranks revealed that "Reading the two case studies related to the assignment" ($M = 3.35$) was regarded as the most effective classroom intervention, followed by the "industry-expert green roofing lecture" ($M = 3.24$). For increasing student knowledge of vegetative roofing systems, students ranked the presentation

(M = 1.79) and debate deliverables (M = 2.09) as the least effective interventions. Participants were aggregated based on the presentation and debate format and compared to investigate differences in students' perceptions of the teaching module given the different deliverables. Students from both semesters reported their level of agreement on a 5-point Likert Scale (-2 = "Strongly Disagree" to 2 = "Strongly Agree") with the statement "this assignment was effective in exposing me to the benefits of vegetative roof systems".

Independent sample t-test results (Table 2) showed that students who led the debate defending their green roofing decision (n_2 = 26, M = 1.50) reported a significantly higher level of agreement [t (44) = 2.43, p = 0.019] that the case study teaching module was effective in exposing them to green roof benefits than did student who completed the group presentation (n_1 = 20, M = 1.04). The effect size (d = 0.72) was typical according to Cohen (1988) and Morgan et al. (2007).

Table 2
Independent samples t-test: Teaching Module Effectiveness of Exposing Student to the Benefit of Vegetative Roofing Systems given Assignment Format (Presentation vs. Debate)

Variable	N	M [95% CI]	SD	t	df	p
Effectiveness: Benefits				2.43	44	0.019
Presentation (fall 2014)	20	1.04 [0.75, 1.33]	0.72			
Debate (fall 2015)	26	1.50 [1.26, 1.74]	0.51			

Students also reported their level of agreement on a 5-point Likert Scale (-2 = "Strongly Disagree" to 2 = "Strongly Agree") with the statement "The instructional activities increased your knowledge of vegetative roofing systems". Again, an independent sample t-test was conducted to examine mean differences in students' level of agreement given the deliverable format; student presentation versus student-led debate. Results (Table 3) revealed that students who led a debate and defended their green roof decision (n_2 = 26, M = 0.75) reported significantly a higher level of perceived increased knowledge of green roof benefits [t (44) = 2.37, p = 0.022] than student who completed the group presentation (n_1 = 20, M = -0.04). It was noted that students who completed the presentation reported a mean score of -0.04. Practically, this result shows that, on average, the presentation group disagreed with the statement that the green roofing module was effective in increasing their understanding on green roofing system while the debate group reported a score of 0.75 indicating agreement. The effect size (d = 0.71) was typical according to Cohen (1988) and Morgan et al. (2007).

Table 3
Independent samples t-test: Perception of Increased Understanding of Vegetative Roofing Systems given Assignment Format (Presentation vs. Debate)

Variable	N	M [95% CI]	SD	t	df	p
Increased Understanding				2.37	44	0.022
Presentation (fall 2014)	20	-0.04 [0.75, 1.33]	1.15			
Debate (fall 2015)	26	.75 [1.26, 1.74]	1.07			

Analysis of mean ranks revealed that the presentation and in-class debate activities were ranked as the least effective classroom interventions. However, it should be noted that the debate format (M = 2.09) was ranked higher regarding increasing student knowledge of vegetative roofing systems than the presentation (M = 1.79). These results, although not statistically significant, align with previous pedagogical studies that indicate in-class debates play an important role in mastering the content covered in class as well as engaging students with the content (Kennedy 2007; Carroll 2014; Kegley 2014). Continued study of the impact of debate formats in CM classroom interventions represents an opportunity for further research.

Industry Perspective

The collaborative teaching module presented in this paper demonstrates that industry outreach to construction programs actually provides several advantages for industry experts who take the time to engage with CM program partnerships. The industry expert was able to use this type of outreach to hone and refine their presentation skills and to better understand the teaching aspects inherent in his daily activities as a specialty contractor. In addition, helping with this module allowed him to share detailed information about specific systems and the professionalism and management required in their respective trades. Overall, industry outreach to construction programs provides students with a taste of what it will be like to work with similar professionals when they eventually graduate and seek employment within the construction industry.

Roofing, and specifically vegetative systems, carries with it a host of terms, nomenclature, and technical expression that relate to products and also means and methods concerning installation techniques. These aspects of a specific industry sector might be somewhat confusing and unknown to the majority of CM students. Thus, the act of creating a lecture, organizing one's thoughts, and crafting the assignment for students who may have had little to no exposure to these concepts encourages the industry leader to carefully think through the knowledge he/she possesses and to communicate it effectively as previously discussed and portrayed in Table 1. It is a slightly different process, and a dissimilar setting, to be lecturing to a group of upper-level students when compared to working with a design team and/or client, but the teaching aspects of the endeavor are similar in many ways. The academic teaching partnerships allow the industry expert to learn applicable skills for use in their day-to-day activities. Presenting material to the student translates to teaching their business associates and clients their green-roof specific expertise which leads to more effective contractor and client communication. This outreach can enlighten students' appreciation for how premier contractors approach projects, the market, and work with other trades and design professionals when applying sustainable technologies and practices.

Conclusions

Vegetative roofing is considered a sub-specialty within roofing specialty contractor and is a relevant system of sustainable building science. Due to its relatively recent resurgence within the US roofing market, these types of roofs are mostly accomplished by roofing contractors who are experienced and knowledgeable. Teaching CM students about this vegetative roofing system helps them to form their expectations about the level of knowledge and competence they should expect and demand from this roof system and its contractors. The exposure of CM students to industry experts and real-world case studies can give them a baseline knowledge and experience that is otherwise only attainable after graduation and once they are in the workforce. Overall, students agree that both the industry-driven lecture and the case study analysis approach were effective in exposing them to the benefits of vegetative roofing systems. In addition, students ranked the comparison of the two case studies as the most effective classroom intervention for increasing their knowledge of vegetative roofing systems. This pedagogical approach demonstrates that industry outreach and collaboration with construction programs is a worthwhile endeavor. Student surveys revealed that the vegetative roofing module was a meaningful and rich experience. Students who participated in the debate format reported significantly higher levels of perceived increased exposure and understanding of vegetative roofing systems than did those who presented their findings to their peers in a traditional format. Further research should focus on exploring the impact of student-led debates and presentations on the increase of content-specific knowledge.

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