

Innovation in Construction: New Course Development Within a Construction Management Curriculum

Mr. J. William White AIA, Indiana University Purdue University, Indianapolis

J. William White AIA is a lecturer with the Construction Engineering Management Technology program within the Purdue School of Engineering and Technology in Indianapolis. He is a registered architect who has more than 23 years of varied construction industry experience. Mr. White has undergraduate degrees from Indiana University and Ball State University and a masters degree from Purdue University Indianapolis. He is an active member of the American Institute of Architects and the Construction Specifications Institute. His professional interests include great architecture and all things related to construction innovation.

Mr. Veto Matthew Ray, Indiana University Purdue University, Indianapolis

Mr. Matt Ray is a lecturer for the Construction Engineering Management Technology Program offered through the Purdue School of Engineering and Technology at Indiana University Purdue University Indianapolis. He currently provides instruction for Soils and Foundations, Construction Cost and Bidding, Construction Project Cost and Production Control as well as managing the Certificate of Training in Asset Management. He is a graduate of Purdue School of Engineering and Technology receiving degrees in Construction Technology, Architectural Technology, and a Masters in Facility Management. His field experience includes residential construction and light commercial. He has been an architectural designer as well as a superintendent for single and multi-family construction projects. Mr. Ray worked as an engineering and design manager in the Building Component Manufacturing Industry for over fifteen years.

Dr. Dan D Koo P.E., Indiana University Purdue University, Indianapolis

Dr. Koo is an assistant professor in the department of engineering and technology at Indiana University and Purdue University Indianapolis (IUPUI). Dr. Koo is also a registered PE. Dr. Koo's research and professional activities are primarily focused on heavy civil infrastructure system, underground infrastructure system management and development, trenchless engineering, and sustainability. Dr. Koo received a Ph. D in Civil and Environmental Engineering and MS in Construction Management at Arizona State University in 2007 and 2003 respectively; and a BE degree in Civil Engineering in 1999.

Innovation in construction: New course development within a construction management curriculum

Every construction management program seeks to instill in its students and future graduates the skills necessary to be successful in the building construction industry. These skills are well known and highly regarded. Students should excel in their capacity to solve problems, manage challenges, communicate well, lead a team, and be familiar with the everyday technologies associated with building construction, to name just a few. However one skill that appears underserved – at the undergraduate level, at least – is the skill to innovate. One program sought to correct this deficiency through the development of an undergraduate course, Innovation in Construction. This paper describes the development of that course, including a brief literature review, resources, course goals, objectives and assignments.

Literature review

The U.S. construction industry has long been saddled with a reputation as being resistant to innovation. Countless scholarly papers and articles in the popular press have identified this trait and bemoaned its effects on both the construction industry and the country as a whole. Respected construction researcher E. Sarah Slaughter acknowledged in her study on construction innovation that the “...generally accepted perception of the construction industry views innovation as a rare occurrence.”¹ This view is supported by industry journals as Engineering News Record editorialized in 2003 that innovation within the building industry is nothing less than a paradox, noting that while construction is complex and demands considerable technological sophistication, “... a construction team may do everything it can not to innovate...”² Similarly, a committee within the Construction Industry Institute (CII), a research institute dedicated to the advancement of the construction business, acknowledged that “The construction industry is characterized by its slow adoption of innovations.”³ In another report which studied the correlation between technology adoption and productivity gains, the CII noted that unlike the communication industry which “...leverages innovation on a continuing basis... the construction industry lags in this regard and underutilizes advances in technology.”⁴

To further illustrate this innovation / productivity disconnect, Stanford University Professor Emeritus Paul Teicholz presented an analysis of construction productivity compared to productivity within nonfarm industries. Teicholz noted that construction productivity has been stagnant to slightly declining since 1964 while nonfarm industries have been increasing annually at 3.06%.⁵ The disparity builds between the two sectors until 2012 when the index value of nonfarm productivity is more than 2-1/2 times greater than the construction index value. In identifying five possible causes for the construction industry’s dismal performance, Teicholz noted two – procurement based on competition rather than collaboration and data presented on paper documents – that imply a traditional (read “non-innovative”) way of doing business. Also, Teicholz’s proposed solutions involved “better use of data with BIM and IPD” and “greater use of off-site fabrication and modular construction”⁵ all of which command greater reliance on innovative technologies.

The industry's reluctance to adopt innovation manifests itself in the popular press as well. Wall Street Journal columnist James Hagerty, in his review of LePatner's book, *Broken Buildings, Busted Budgets* quoted Ara Hovanian, one of the country's largest homebuilders as he described the construction industry as "...200 years of tradition unhampered by progress".⁶

The problem thus presents itself: construction as an industry is reluctant to engage in the considerable benefits of innovation. Given the profound effect this has on the industry, it appears there is a legitimate need to instill a greater appreciation of innovation within construction management graduates. The Innovation in Construction course was created to address this need.

Course Development

In developing the course, a few common threads began to emerge which would eventually serve as its foundation. The first dealt with the terminology. Simply, what is "innovation"? Many dictionaries define the term simply as "anything new". Clearly this is vague to the point of being meaningless. It is therefore not uncommon for the scholarly author to define innovation in the beginning of the work. Slaughter cited Freeman when she offered a definition which is pragmatic and easy to apply. She identified four characteristics which are common to many definitions. Specifically an innovation must be new / novel to the institution (in this case, the construction industry), it must be non-trivial, it can apply to a process, product or system and perhaps most importantly, it must be *used*.¹ It is important to note that an innovation does not have to be new to the world, just new to the industry that adopts it.

Another common thread involved trying to answer the most fundamental of questions, "why?" While there are some contrarian studies that support the premise that construction really is innovative and that it's unfairly maligned, (reference Slaughter, *Builders as Sources of Construction Innovation*⁷) the vast majority of researchers remain firmly in the non-innovative camp. Because of its pervasiveness, it seemed necessary to consider the source: the industry itself and the people within it. Do razor-thin profit margins, cut-throat competition, life safety liabilities and a fragmented industry conspire to make building professionals so conservative that innovation becomes simply a needless risk? What kinds of people – and types of companies – are attracted to innovation? Where is innovation built into the "cost of doing business"? Does "if it ain't broke, don't fix it" accurately portray the industry's attitude?

A third common thread appeals to the more fundamental nature of innovation. That is, innovation can be a genuinely exhilarating topic. When considering new processes, materials, tools and products, it's difficult not to get excited about the possibilities. Therefore the course should incorporate the innovations themselves and not pursue a singularly academic approach. Indeed the current construction related innovations of our day, such as increasingly paperless job sites, augmented virtual reality, radio frequency identification technology, 3D printers and nano-materials all offer tantalizing new possibilities which have a strong student appeal.

From this foundation, the goals and outcomes of the course became clear:

- Provide the student with a critical eye towards inherent problems embedded within the construction industry. At the successful conclusion of this course, a student will be able

to recognize anti-innovation bias and take steps to mitigate its influence on the decision making process.

- Enable the student to define innovation and distinguish it from simple novelty. With this capability students will be able to identify legitimate innovation, recognize it for the value it offers to the construction industry and be more inclined to implement it within a construction project.
- Evaluate innovations by utilizing a risk benefit analysis-like approach. With this approach, students can make a reasoned decision as to the value an innovation offers when compared to the risks it may incur.

Course Development

Numerous sources were utilized in the development of this course. The works of key researchers and authors were reviewed to develop both a general perception of innovation and how it is specifically addressed within the construction industry. Everett Rogers *The Diffusion of Innovation*⁸ and E. Sarah Slaughter's many construction studies were instrumental in this regard. In identifying the types of individuals and companies which tend to be attracted to innovation, Nam and Tatum's work, *Leaders and Champions for Construction Innovation*⁹ was referenced.

Although research on innovation and its application within construction was plentiful, documentation which chronicled undergraduate construction-based innovation courses at other institutions was difficult to find. "Construction-based" is the operative term here. The vast majority of text books, courses and educational opportunities are associated with innovation as it relates to product development. One notable exception was a course designed by renowned construction industry researchers C. H. Nam and C. B. Tatum. Nam and Tatum published their development and implementation of a construction innovation class for civil engineering students at Stanford University.⁹ They approached the topic from two perspectives. First, the course involved analyzing innovation fundamentals, specifically the process of innovation, including theories, human interaction, cultural influences, and governmental policies. Second, the course studied innovation using case studies. Using case studies students consider how innovation was – or wasn't – properly applied. In reviewing this course, while it did address the fundamentals of innovation and their application to the construction industry, it didn't appear to incorporate the technologies themselves. Conversely, case study review was a component which our course, *Construction in Innovation*, lacked – probably to its detriment.

A somewhat unusual reference source which became required reading is Barry LePatner's *Broken Buildings, Busted Budgets*.¹⁰ The author presents an unflattering portrait of construction, much of it stereotypical but still of value nonetheless. The premise of the book is that the construction industry is substantially dysfunctional and that radical corrections are required to correct it. Written as it is by a construction attorney whose targeted reader appears to be the neophyte building owner, the book presents a perspective the construction management student rarely encounters in his/her academic career. While this viewpoint alone offers value for in-class discussion, the real value is the author's identification of the industry's problems. LePatner addresses the challenges of traditional roles, contractual inadequacies, prefabrication failures, labor challenges, federal labor laws, and yes, its storied reluctance to adopt innovation. Because of its critical nature the book is used to challenge the construction student to either agree

with the author’s observations or develop a rational counter-argument as to how the critique is unfounded or at least unwarranted. Later in the semester the student is encouraged to correlate an innovation discussed in class with the failings identified by LePatner. In this way it is possible to illustrate that a construction industry “failure” can be mitigated or even corrected through the use of innovation.

The 16 week semester for the Innovation in Construction course is divided into three parts or areas of concentration: 1) Importance and Impediments (6 weeks); 2) Innovation and Technologies (6 weeks); and 3) Management (4 weeks). Areas of course concentration and associated assignments appear in Table 1.

Table 1. Construction Innovation Course Development: Topics and Assignments.

<u>1) Importance and Impediments</u>	
1) Top 10 Innovations	Students write a report identifying the top 10 innovations since 1900, considering human impact, disruption to status quo, and effect on other technologies.
2) Review: “Restoring the American Dream...”	Watch the PBS video and respond to questions pertaining its main premise, the value innovation plays in determining a nation’s wealth, characteristics of a good innovator, explanation of specific terms, e.g., 20% Time, efficient failing, DARPA.
3) <i>Broken Buildings, Busted Budgets</i> summary questions	This book is read over the course of the first 6 weeks. Students read the book, submit a series of written responses to questions and participate in class discussions.
4) Mock Innovation Jury Evaluation	Students must evaluate and rate a variety of construction innovations as submitted to the NOVA Awards. The rating requires assessment of each innovation utilizing established rating criteria found within a study authored by E. Sarah Slaughter. All evaluations are compiled to determine the class awards and then compared to the results of the actual competition.
<u>2) Innovation and Technologies</u>	
5) Construction Innovation Technology Report	The student selects three products, processes or procedures which qualify as construction innovations. Over the course of a few weeks, the student researches the topics utilizing reputable industry sources and prepares an in-class oral / video presentation of his/her findings. Students are provided with a specific list of items to include in the presentation and the topics which must be addressed. Topics are submitted for instructor approval.
<u>3) Management</u>	
6) Innovative Company Research and Report	The student must research and identify construction companies which appear to possess the traits of an innovative company as determined by interviews, company web sites, job portfolios, etc. While this is a written report, students report their findings and share their results with the class.

1) Importance and Impediments

Part 1 addresses the nature of innovation itself. Here its definition is considered collectively and will be set for the rest of the semester. Additionally, in the first assignment of the semester students are challenged to identify their own top 10 list of the greatest innovations of the 20th Century. Following the assignment the class compares their lists with a fairly comprehensive list, the *Chronology of Key Innovations, 1400 – 2000*¹¹. Invariably the students' first attempts tend to be narrowly focused – it's uncanny how many appliances appear on their top 10 lists. In contrast, Johnson's list serves to broaden the students' understanding of what constitutes a legitimate innovation. It includes innovations ranging from double-entry accounting to the flush toilet to the smallpox vaccine to special relativity.

The student is also presented with key components of Rogers' *Diffusion of Innovation*. Rogers' concepts are instrumental in assisting the student in grasping how innovation is adopted thereby gaining a greater understanding of why or why not innovation is incorporated within the construction business model. It's often a revelation that Rogers originally coined the term "early adopter", a term used so commonly in popular media. Also, the student is presented with concepts identified in Slaughter's study, "Models of Construction Innovation"¹. The models are helpful in evaluating innovation along a meaningful scale / continuum, ranging from the minor (incremental) to the profound (radical / disruptive). The "Slaughter Scale" as it becomes known in the class, is helpful in evaluating real world innovations and also aids in correlating innovations with their likelihood of being adopted (courtesy of Rogers' diffusion theories).

In another assignment, students' capabilities in distinguishing the quality of innovation are further enhanced by acting as judges in a real world construction innovation competition. The relative merits of a given product or process are evaluated and ranked with numerical scores. The assignment utilizes the materials provided by the NOVA Awards as administered by the Construction Industry Forum (CIF)¹². Winners and losers within the class are determined by the scores awarded by the students. Importantly, besides for simply awarding a numerical value, students are also asked to provide a rationale for their scores. The CIF offers an excellent source of materials as it provides the actual documentation submitted by each contestant and then provides the results of the year's competition. Students are confronted with the same challenges the actual competition judges had to address, not the least of which is comparing a broad array of different products, materials and systems and then assigning them numerical scores.

To gain a greater understanding of the importance of innovation on a global scale, another assignment requires students to review and report on a documentary originally presented on PBS, *Restoring the American Dream: How To Innovate* hosted by Fareed Zakaria¹³. The video presents a compelling argument as it describes the importance innovation has on the welfare of humanity and global living standards. Zakaria interviews a number of renowned innovators as it makes the case that innovation is crucial to world development. It also underscores the importance of the United States retaining its leadership role as a global innovator. The importance of this documentary is its emphasis of innovation as being universally important and not just a narrowly focused concern of one particular industry.

2) Innovations & Technologies

This portion of the course addresses real-world innovations that are making an appearance within the construction industry. Recent topics included innovative management strategies (e.g., integrated project development, Lean Construction), electronic / digital devices (e.g., tablets, virtual construction, RFID capabilities, paperless construction sites), industrialization (e.g., modular construction, pre-fabrication), infrastructure (e.g., trenchless technology), and materials (e.g., carbon fiber, nano-materials). At the beginning of this section students are assigned to create a presentation upon the construction technology of their choice. The assignment requires both written and presented materials. The presentation portion is considered particularly beneficial as it shares each student's research with the entire class.

In-class content was supplemented with a lecture by a world renowned expert on tunnel boring and underground pipe installation. His experience was particularly well suited for the class as he was involved in the development of an innovative product not available within the United States. His first-hand experience underscored the difficulty associated with the development of an innovative product within building industry.

Obviously this portion of the course must be updated regularly so that the innovations being presented are current – that is, are still considered innovative. The selection itself can present something of a dilemma worthy of a class discussion. For example, building information modeling (BIM) was once on the topic list but now, given the years of BIM in the marketplace, it can no longer be considered a legitimate innovation. This can pose a conundrum to students who may already be working in the industry and know their particular employer has never encountered BIM technology. In fact, this challenge recalls an in-class exchange between the instructor and a student when the instructor questioned the relevance of fax machines. The student reminded the instructor that faxing remained the exclusive form of bid communication where he was employed. This is the real test of the definition of “innovation”. Is something innovative because it's new to you or new to the marketplace?

Besides for the many trade journals and professional organization publications, there are a number of sources that are dedicated almost exclusively to innovation including:

- Construction Innovation Forum (www.cif.org)
- Fiatech (www.fiatech.org)
- ConstrucTech Magazine (www.constructech.com)
- Jetson Green (www.jetsongreen.com)
- Construction Innovation (Canada) (<http://www.nrc-cnrc.gc.ca/ci-ic/>)

3) Management

There is a strong relationship between a company's culture / work environment and the positive attributes of innovation. In their literature review, Powl and Skitmore cited a number of studies supporting their observation that “Work environments that support and encourage creativity and innovation have been associated with increased productivity in general...”^{14(p42)} For innovation to flourish, these authors observed that companies must walk a fine line between “tightly defined systems... that ensure the efficient delivery of products...” with “... the freedom... to encourage

creativity and innovation...”^{15(p42)} The challenge for the construction management student is to identify the management tools that promote innovation. Additionally – given that this class is 400 level and typically occupied by soon-to-be-graduating seniors – identifying companies that adhere to an innovative management philosophy was particularly timely.

This was accomplished in two ways: identify the common management characteristics of successful innovative companies and consider the personality types of individuals who may be more receptive to innovation.

When considering company characteristics, two key resources were used. The first was a report issued on behalf of the Australian Cooperative Research Centre for Construction Innovation, *Being the Best: Talking with highly innovative contractors*¹⁶. The authors interviewed 20 Australian construction firms that were generally well regarded as being innovative. Four topic areas were considered: employee policies (e.g., staff suggestion schemes, mistake management / tolerance, incentives), company culture / procedures (e.g., networking, implementation), government policies (e.g., employment initiatives, regulation environment), and the role of clients (e.g., desirable characteristics, contract language, strong supporter). The report presented its findings in a very practical way so that students could easily relate to the points and make comparisons to their own employment experiences.

The second resource is a scholarly article which described the concept of an innovation “champion”. Nam and Tatum⁹ reviewed 10 construction projects to discern what company organization variables promoted innovative construction solutions. Their study considered company policies which hindered and constrained (e.g., excessive bureaucracy, isolated top management and inappropriate incentives) as well as encouraged and supported innovation (e.g., a small, “flat” organization, supportive atmosphere and a strong market orientation).

Not surprisingly, Nam and Tatum’s research meshed quite well with the BRITE report. Both of these sources were helpful as students were each assigned a construction company to research. The goal was to determine if the company could qualify as being genuinely innovative. While students were unable to ascertain internal policies, they could deduce the company’s philosophy by evaluating cues as presented on each company’s web site. Cues could include the types of construction projects that were promoted, employee programs, the amount of space dedicated to new / innovative technologies on the web site and the sophistication of the web site itself.

From the company level the course topics drill down to innovative groups, closely followed by consideration of the innovative individual. Group composition, communication methods, frequency of spontaneous meeting, and random interactions modeled similar to an urban environment were topics of discussion. Drilling down to a more personal level, the course spends one week discussing individual personality traits. The students are directed to take a “personality test” that is freely available on the Internet. Based on their score, they can ascertain if their personal approach is receptive to innovative tools or processes. It is important to note that, regardless of the personality type identified, the superior team make-up consists of a variety of individuals with different strengths and perspectives. Thus, even though the “test” may indicate an individual is not necessarily prone to innovative creativity, everyone can make a contribution to innovative progress.

Conclusion

Recognizing the construction industry's notorious reluctance to adopt innovation, an undergraduate course was developed in an attempt to instill within construction management students a heightened awareness of innovation and the role it can play in advancing the construction industry. The authors presented a brief literature review which documented the industry's seeming aversion to innovation. The development of the course was outlined followed by a detailed course organization and content. The organization of the course attempted to address the concept from the very broad – identifying what innovation is – to the very specific – innovative materials and technologies being utilized in the industry today. The course concluded with an analysis of the types of people that are most likely to innovate and the types of company cultures which encourage innovation to flourish.

References

1. Slaughter ES. Models of Construction Innovation. *Journal of Construction Engineering and Management*. 1998;124(3):226.
2. Innovation is a paradox for construction teams. *ENR: Engineering News-Record*. 2003:128-128.
3. Institute CI. *Leveraging technology to improve construction productivity*. Austin, TX: University of Texas at Austin; 2008:52.
4. Hass C, Passwaters J. *Accelerating Innovation Adoption in the Construction Industry*. Austin, TX: Construction Industry Institute; 2008:3. Available at: <http://www.construction-institute.org/scriptcontent/break.cfm?section=break>. Accessed September 12, 2012.
5. Teicholz P. Labor-Productivity Declines in the Construction Industry: AECbytes Viewpoint #67. *AECbytes Viewpoint*. 2013. Available at: http://www.aecbytes.com/viewpoint/2013/issue_67.html. Accessed November 18, 2013.
6. Hagerty JR. Getting Hammered - WSJ.com. *The Wall Street Journal*. 2007. Available at: <http://online.wsj.com/news/articles/SB119681431154013727>. Accessed December 30, 2013.
7. Slaughter ES. Builders as Sources of Construction Innovation. *JCEM*. 1993;119:532-549.
8. Rogers EM. *Diffusion of Innovation*. 5th ed. New York: Free Press; 2003.
9. Nam CH, Tatum CB. Case Method to Educate Innovation Champions in Construction. In: *Preparing for Construction in the 21st Century; Proceedings of Construction '91*. Cambridge, MA: ASCE; 1991:484-489.
10. LePatner, Barry B. *Broken Buildings, Busted Budgets: How to Fix America's Trillion-Dollar Construction Industry*. Chicago, IL: University of Chicago Press; 2007.
11. Johnson S. *Where Good Ideas Come From: The Natural History of Innovation*. New York: Riverhead Books; 2010.
12. Construction Innovation Forum: NOVA Award. *NOVA Award*. 2013. Available at: <http://www.cif.org/nova-award.php>. Accessed December 30, 2013.

13. Zakaria F. "Restoring the American Dream – How to Innovate" – Global Public Square - CNN.com Blogs. *CNN World: Global Public Square*. 2011. Available at: <http://globalpublicsquare.blogs.cnn.com/2011/06/14/watch-gps-special-restoring-the-american-dream-how-to-innovate/>. Accessed August 29, 2012.
14. Powl A, Skitmore M. Factors hindering the performance of construction project managers. *Construction Innovation*. 2005;5:41-51. doi:10.1108/14714170510815168.
15. Powl A, Skitmore M. Factors hindering the performance of construction project managers. *Construction Innovation*. 2005;5:41-51.
16. BRITE Project. *Being the Best: Talking with highly innovative contractors*. Brisbane, Australia: Cooperative Research Centre for Construction Innovation; 2007:26.