

A Comparison of Two Inquiry-based Construction Management Curricula

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This paper describes the theory base and developmental history of two U.S. construction management programs that have implemented inquiry-based curricula. Supported by research literature and the requirements of professional thinking seen in contemporary industry practices, both programs centered their curricula on five- and six-credit problem solving coursework that follows the model of traditional professional education where subject content is engaged through integrative problem solving and critical thinking. This comparison describes these curriculum development efforts and identifies the common pedagogical foundations and challenges shared by both programs.

Key Words: Integrated curriculum, interdisciplinary curriculum, construction management education, curriculum design.

Introduction

Over the past decade, two university construction management programs at California Polytechnic State University at San Luis Obispo and Mississippi State University implemented completely new curricula in response to perceived shortcomings of existing course structures. Working independently, these programs ultimately adopted curricula that shared many common components based on a common belief that an inquiry-based pedagogy represented a significant opportunity to better prepare today's construction management students for the contemporary challenges facing the profession. These two programs represented two very different geographical regions of the country serving a varied student base and a different construction market. Cal Poly was replacing a curriculum in a department nearly forty years old, and Mississippi State was designing a curriculum for a newly approved program of study. Both looked at some literature and critiques of existing construction management curricula to conclude that a different approach to teaching—not just different curricular content—was necessary to educate the professional leaders of tomorrow. The intentions of this comparison between the two programs are to describe these curriculum development efforts and identify common pedagogical foundations and challenges. Subsequently, the outcomes of the comparison are the basis for an initial model of professional inquiry-based education that is used to construct an agenda for further research in inquiry-based construction education applications (Monson & Hauck, 2012).

Many construction management faculty have heard similar requests from industry advisory board members and other members of the industry: "I'm not as concerned about what content you are teaching your students as I am that you are preparing innovative problem solvers who can think, communicate, and lead after they graduate." Faculty have addressed some of these critiques by adding a technical writing course or a module on leadership or a capstone experience to "bring it all together." But, by and large, our curricula are content driven, not process driven. This emphasis is understandable—measuring outcomes related to "developing critical thinkers" is much harder than measuring whether all graduates can complete a forward and backward pass on a CPM schedule. Ultimately, mastering the content is necessary, but can the more complicated thinking skills be developed within a curriculum without a conscious effort to do so?

In order to accomplish this, both of the programs in this comparison determined that they must not only cover the content, they must also change the way in which it was taught to develop the integrative, problem-solving, thinking skills that were lacking in traditional approaches to construction education. Both turned to the research on problem-based and inquiry-based education to suggest ways to restructure existing coursework to address these more

complicated outcomes. Fortunately, other professions have dealt with these issues before and much could be learned from them. The result was two new curriculums similar in many ways, but unique to the environment in which they exist. Some models and examples from each might be adopted by other programs seeking to address similar issues.

Literature Review

While there has been a long history of educators advancing the concept of integrated learning in undergraduate education, there has been much less success in its implementation. Whether called problem-based, inquiry-based, synergistic, or integrated, each of these approaches to teaching emphasizes the process of learning over the content of instruction. In 1973, the *Dictionary of Education* defined the concept of integrated curriculum as "a curriculum organization which cuts across subject-matter lines to focus upon comprehensive life problems or broad based areas of study that brings together various segments of the curriculum into meaningful association" (Good, 159). In 1993, Bonds, Cox, and Gantt-Bonds qualified the instructional aspects of integrated curricula as "synergistic teaching," saying that "[s]ynergistic teaching does more than integrate; it presents content and skills in such a manner that nearly all learning takes on new dimensions, meaning and relevance because a connection is discerned between skills and content that transcends curriculum lines" (254). However, a decade later, Fink saw that little had changed regarding integrated approaches to undergraduate instruction. He observed that "the majority of college teachers do not seem to have learning goals that go much beyond an understand-and-remember type of learning. . . . [S]itting in many courses gives one the feeling that teachers are doing an information dump" (2003, xi). Lacking evidence of necessary changes in undergraduate instruction, the American Association of Colleges and Universities and The Carnegie Foundation for the Advancement of Teaching argued for the wider implementation of integrated learning as a point of institutional policy. Their 2004 "Statement on Integrative Learning" said that "integrative learning is central to personal success, social responsibility, and civic engagement in today's global society" and that "integrative learning . . . should be a cornerstone of a twenty-first-century education" (Huber & Hutchings, 2004, 13).

The questions about integrated learning seen by AACU and Carnegie were also evident in construction education. AbouRizk and Sawhney (1994) and Bertz and Baker (1996) suggested that the instructional methods used in a majority of construction engineering and management programs rely, for the most part, on unlinked and independent courses that convey knowledge in a fragmented fashion. Often students neither retain nor are able to utilize or synthesize knowledge acquired in previous courses, and traditional teaching methods are often not fully capable of providing students with the skills necessary to solve real world problems encountered in construction. Beliveau and Peter (2002) challenged the disjunction between subject content and thinking skills in construction education by conceptualizing the potentials of problem solving through the educational theory of constructivism. Their model argues for the integration of experience, theory, experimentation, and reflection through inquiry-based coursework that would connect student learning to the professional thinking skills required of practice.

More recently, several colleges of engineering have been experimenting with curriculum changes designed to cut across subject matter boundaries. The Departments of Mechanical and Civil Engineering at the University of Maryland have developed an integrated statics and strength of materials curriculum that uses an inquiry-based emphasis on design problems. Traditionally, statics and strength of materials has been taught separately. Bruck, et. al. (2004) noted that although this approach has proven to be effective in providing students' understanding of basic principles in mechanics, it has been less than effective in providing students with an understanding of the relationship between the two subjects and their importance in designing structures. This observation prompted the two departments to seamlessly integrate the two courses together. Bruck, et. al. (2004) suggests that this integrated approach better prepares students to apply mechanics principles in the design solutions to engineering problems. The new courses are being delivered in new interactive, multimedia "studios."

There are an increasing number of construction management programs in the country that are starting to adopt elements of an integrated curriculum and inquiry-based learning. One early example was the vertical and horizontal integration model initiated at Virginia Polytechnic Institute and State University in the mid 1990's. This model provided vertical integration by way of a common lab for freshmen, sophomore, and junior students and horizontal integration by assuring that all information in service courses (engineering, communications, math, business, etc.) related directly to skills being developed in the construction program's major courses. Mills, Auchy, and Beliveau (1996) identified several opportunities and benefits derived from inquiry activities in a fully integrated curriculum. Students learn by teaching each other in the team-driven lab, and the reinforcement of technical knowledge is

developed in addition to the student improving in leadership and teambuilding skills. There is also a more effective utilization of faculty, equipment, and facilities. Most importantly, integrated curriculums concentrate student time on competency development which fosters a continual need for evaluation of the curriculum's relevancy.

The outcomes of the integrated construction management curriculum implemented at Cal Poly have been studied in more recent years. Hauck and Jackson (2005) discussed the early pilot studies on which this curriculum was based and analyzed the implementation issues that needed to be addressed to accomplish a successful transition. Montoya, et. al. (2009) studied early "lessons learned" in the pilot study of these courses and addressed such questions as individual versus group learning in these settings, the appropriate sequencing and content of these courses, the appropriate role for industry professionals in the classroom, and the assessment of student performance in this mode of teaching compared with conventional approaches. Kelting and Hauck (2010) looked at the impact of this approach to project-based learning on coursework in residential construction. This was followed by a study conducted by Kelting (2011) that examined the components of the course that were perceived by students to have contributed the most to their learning. Similarly, Barlow (2011) studied the delivery of a jobsite management course integrating multiple subject areas into a single lab course. Looking at interdisciplinary education across multiple design and construction professions, Starzyk and McDonald (2010) and Starzyk, et. al. (2011) described the successful attempts to combine teams of students from different disciplines in a studio environment in which the students responded to a design-build RFP using an actual client with a real design project. These ongoing research projects have resulted in continuing changes to the implemented curriculums.

Integrated Curriculum Rationale and Design at Cal Poly

As Cal Poly starting planning for its new facility in 2001, discussions among faculty, students, alumni, and industry partners began about designing a completely new curriculum to be conducted in the new building. Academic programs build new buildings perhaps every fifty years, so participants wrestled with the question, "What will the profession of construction be like in 2050?" Only then could they ask, "What is the best curricular model to prepare those professional constructors in fifty years?" Only then could the question be addressed, "What physical spaces are needed to support that curriculum model?"

While the specifics of this industry cannot be discerned fifty years in advance, certain trends can be identified. Constructors will need to be prepared for multiple changes in job assignments and perhaps companies during their careers, so specializing in just one area will not support that flexibility. Collaboration will be the key to successful projects, so future constructors will need to master the ability to solve multiple problems at once that cut across boundaries of expertise and responsibility (FMI, 2000). Working in a complex profession, constructors will need to realize that, for most of these problems, there will not be a single solution, but instead many possible approaches and strategies—some more applicable than others.

Increasingly, it became clear that current approaches to a segmented curriculum—in which content is divided into relatively small amounts, taught in a format encouraging limited student participation, and then referenced at best tangentially as the student continues to advance through the curriculum—would not support this view of the future of the constructor profession. Just as constructors in practice are called on to deal with methods, contracts, estimating, scheduling, personnel, and subcontractor issues simultaneously and creatively, construction students need to learn all of these aspects in an integrated rather than sequential fashion. Traditional curricula tend to concentrate these aspects into separate "subjects" to be taught and mastered one at a time. In fact, numerous curriculum reviews are conducted to minimize "overlap" between the subjects for the sake of "efficiency." But, this specialization and separation of knowledge does not describe the work of the successful constructor. Just as practitioners must cut across these boundaries, the integrated curriculum proposed for Cal Poly sought to cut through these "silos" of subject areas to expose students to these specialized tools again and again in a project oriented environment. Pilot studies of the courses in the proposed new curriculum—that would soon replace seventy-five percent of the existing coursework—began in 2005 and the entire new curriculum was implemented in 2009.

An Integrated CM Curriculum Model

Under the new model, construction management is taught as a series of labs integrating the various construction management courses into an active, applied learning experience. The integrated curriculum for construction management at Cal Poly is centered on seven project based labs as follows:

- Fundamentals of Construction Management
- Heavy Civil Construction Management
- Residential Construction Management
- Commercial Building Construction Management
- Specialty Contracting Construction Management
- Jobsite Construction Management
- Interdisciplinary Project Management

Each of these courses is based on a model of five or six quarter-hours of lab credit for a total of fifteen to sixteen contact hours per week. These courses replaced all of the traditional coursework in estimating, scheduling, contracts, methods, and materials as this content was presented in the context of the assignments in each of these integrated labs. Similar to a studio in an architecture curriculum, each of these CM labs is taught in a dedicated space filled with models, samples, contracts, marketing documents, specifications, estimating guides, computer references, and other tools appropriate to that market sector and available to students in that class all day. Each lab is coordinated by a single faculty member, but at times employs a team teaching approach to insure that all aspects of a traditional subject area are mastered incrementally throughout the seven course sequence. Most labs are similar in that a real, complex industry-based problem is presented at the beginning of the term—usually by industry representatives—and the students spend approximately nine weeks developing the budget, schedule, project management plan, and other documents required to present their solution. At the end of the term, industry representatives and other faculty and students return to hear and critique the student presentations. Each cycle in this process continues to spiral upward through the various content areas of the curriculum at a higher level as the students continue the practice of their profession and apply what worked in the past to new problems. In other words, they will be exposed to estimating, scheduling, contracts, methods, materials, and other areas seven times at an ever increasing level of complexity. These subject areas are taught in the context of real problem solving rather than as stand alone courses.

The first of these seven courses is a "tool belt" course covering the fundamentals of contract documents—including drawings, specifications, and Building Information Modeling (BIM)—and an introduction to basic quantity take-off and planning tools. This course lays the groundwork for the series of labs in each of the three major sectors of the construction market: heavy civil, residential, and commercial building. These courses begin the project based instruction of the integrated curriculum in which students deepen their understanding and application of methods, estimating, scheduling, cost control, contracts, and other aspects of the existing curriculum. By the end of their third year of studies at the latest, students have been exposed to these areas of study four times and may have participated in up to six months of industry internships.

Following this foundation, students repeat a similar process in labs emphasizing three areas that are becoming increasingly important to professionals in this industry. The first emphasizes a problem presented by an industry leader in the specialty contracting community. Whether eventually employed by a subcontractor or a general contractor, graduates must be more familiar with methods used in this segment of the industry and the unique personnel and equipment utilization issues faced by specialty contractors. The next course provides an in depth introduction to problems related to jobsite management such as project administration, productivity measurement and improvement, workforce management, subcontractor coordination, safety, jobsite utilization, temporary structures, formwork, and project layout. The role of the modern project superintendent is changing rapidly with the need for computer literacy, better communication skills, and understanding of the contemporary workforce. Increasingly, graduates are being asked to apply the principles of lean construction (Howell & Ballard, 1997) by considering a career in jobsite management. The last course of the sequence emphasizes the concepts of integrated project services and alternative project delivery systems through an interdisciplinary experience with other students in the College of Architecture and Environmental Design. Teams of students in this course are now made up of majors from construction management, architecture, architectural (structural) engineering, and sometimes landscape architecture. Under the direction of faculty from each of these departments, up to fifteen five-student,

interdisciplinary teams prepare the schematic design, structural analysis, budget, and schedule in response to an RPF for a design-build project with actual clients (Starzyk, et. al., 2011). This provides a culminating experience for the CM integrated curriculum and helps to prepare students to collaborate with these other professionals early in their careers.

Studio-Based Curriculum Rationale and Design at Mississippi State

The Building Construction Science program at Mississippi State University was launched in 2007 as a brand new curriculum in a college with existing and well-established design programs in the built environment—architecture and interior design—as well as the fine arts and graphic design. The University already had a number of other programs serving the construction industry. These included a construction and land development program in the business college, a construction engineering program in civil engineering, and a landscape contracting program in landscape architecture. But there was no comprehensive curriculum in construction management that engaged the breadth of twenty-first century construction or addressed the potentials of integrated design-construct practice.

Representatives from the state's construction industry and Mississippi State's architecture program first met to discuss the idea of a new construction program in fall of 1999, and a planning group comprised of academics and construction professionals was assembled to research industry needs and to develop potential curriculum content and pedagogy. As with the research done by Cal Poly in its integrated CM curriculum, the very same questions, trends, and contemporary developments in construction practice were seen by the planning group at Mississippi State. It was clear that construction graduates will face an increasingly complex industry where the skills of multivariate problem solving, communication, and the development of new and flexible expertise would be demanded. The planning group visited four recognized and well-established construction schools and surveyed a number of others to research curriculum content and pedagogic methods. Leaders at each school reported that—if they could start up a brand new program—they would question the instructional pedagogy of the lecture course model upon which their curriculums depended. These schools were seeing the same trends in the integration of construction skills and knowledge, and were facing the same struggles against subject area silos, faculty specialization, and the inherent difficulties of integrating construction content within the traditional three-credit lecture course structure of the university. Among the most important finds by the planning group was the clear need that construction students be prepared through the length of their educations for deeply integrated collaboration with the design professions.

Because the new Mississippi State construction program would be located in a college that taught exclusively through the studio-based learning model, it became clear that developing a curriculum focused around problem-solving courses would be a way to leverage the capacities of the college as well as work toward reimagining construction education to fit the requirements of twenty-first century practice. The planning group ultimately proposed to build the new construction curriculum around a series of six semester-long problem-solving studios that would begin in the sophomore year. These courses were modeled on the inquiry-based learning pedagogy of the studio system of architectural education. The planning group understood that establishing an identical credit hour structure and meeting time to the new program's construction studios meant that future integrated practice coursework was possible with the architecture and interior design programs.

A "Thinking Constructor" Curriculum Model

Based in the iterative model of studio instruction, the construction studio sequence was devised holistically to introduce and then develop construction skills and knowledge through repeated engagement with more and more complex problems. The standard of this kind of professional education is seen in architecture, medicine, and law (Schön, 1987). From the very beginning of studies in these professions, students are engaged in discipline-specific methods of problem solving through which discipline-specific content is introduced and mastered. In the manner of professional education, the design of the Mississippi State construction studio curriculum tried to avoid separations based upon *types of content* and instead tried to conceptualize the interrelationships of *types of thinking*. The desired outcome of the curriculum was a "thinking constructor": a person whose capacities of critical thinking were foundational to their skills in construction content and application. To this end, the initial broad outlines of the construction studios were established:

- Construction Studio I: Introduction to the construction process; general building materials, systems, and types of construction; architectural drawings and details; and the collaborative building professions.
- Construction Studio 2: Introduction to site assessment, development of design and construction of building envelope and finish systems.
- Construction Studio 3: Introduction to principles of building costs and estimating, introduction to scheduling, sequencing, construction safety. Problems emphasize concepts of budget and construction management in building systems.
- Construction Studio 4: Development of principles of financing, cost estimating, scheduling and sequencing; introduction to digital design and fabrication. Problems emphasize applied knowledge of budget within construction management.
- Construction Studio 5: Development of basic principles of project management, project delivery models, contracts; construction site planning, staging, and implementation principles; introduction to construction financing and cash flow management.
- Construction Studio 6: Development of principles of project management, project delivery models, contracts; construction site planning, staging, and implementation principles; integration of construction financing and cash flow management.

Each construction studio course is six credit hours and meets for twelve contact hours per week—Monday, Wednesday, and Friday afternoons from 1:00-5:00 pm. Within each studio course, more advanced construction content is introduced through the reapplication and further development of previously engaged skills and knowledge. Beyond the studio courses, the three-credit support courses for the new curriculum were comprised of existing courses within the colleges of architecture and design, engineering, and business. Like Cal Poly's lab curriculum, the Mississippi State construction studio courses replace all of the traditional classes in estimating, scheduling, contracts, management, and construction materials and methods. Faculty generally are assigned to teach studios individually, but there is frequent team-teaching, collaborative participation in project reviews, and sharing of instructional resources. Construction professionals from industry are frequent guest lecturers and provide critiques for student projects in the accessible environment of the studio.

Construction studio projects are defined by faculty to suit their skills, interests, and research initiatives. The basis for studio projects is methodologic; students must propose solutions to a problem, critique those potential solutions, and then iterate the propositions (Monson, 2011). Broad content outlines are specified for each studio, but the exact nature and definition of the projects are not. This allows faculty to develop projects that build off of their current research, take advantage of real building or management projects in industry or the community. Many times, projects will address what appear at first to be impossible problems: an unbuildable site, an unworkable crashed schedule, or a building that must be constructed to resist tornadic winds. Since there is no simple or obvious solution to such problems, two contradictory learning paths appear; students research the problem as a shared activity while at the same time develop their own conclusions through their individual effort toward a solution. As normative practices and existing content resources are challenged by the invention of a new solution, the classroom discussions between these two learning paths are some of the most productive ways of developing professional thinking. A studio project usually fails if it leads students to similar solutions or inhibits the collective understanding engendered by collaborative research and resource management. In these characteristics, the construction studio problems are the antithesis of the graded, testable, deductive assignments that typify undergraduate construction education.

Content outcomes are established for each studio level. As part of a new program, these outcomes have been subject to ongoing assessment and evaluation. This work has been guided by the development of a vocabulary of thinking typologies, where the discipline's method of thinking in relationship to content is conceptualized. While most mature professions are characterized by how they think, construction education has yet to build upon the cognitive consistencies within and across construction practices. When realized as habits of mind, things like "sequence," "performance," "optimization," "visualization," "dependency" can be seen as foundations of method for construction as a discipline. The development of this typology has been especially useful in the ongoing dialogue with architecture faculty as the two programs develop a year-long integrated "building tectonics studio" where students from both disciplines would learn about building materials, assemblies, and sequences. Like law and medicine, architecture's history as a profession—with a profession's uniquely discursive form of education—has encouraged its methods of thinking to become consistent arcs across its disciplinary content. These forms of thinking are in turn used as a cognitive structure that runs through architecture curriculums. The discussions about

the integrated practice studio have demanded that the thinking typologies of construction education be illuminated so that the new collaborative courses can be built with equitable attention to thinking skills. A structure of thinking typologies offers consistent methodologic threads upon which construction content can be engaged.

Conclusions

As inquiry-based construction management education has been realized at Cal Poly and Mississippi State, the descriptive comparison of its application at both programs offers an important perspective for the evolution of construction education.

Both programs have created curricula that are centered on lab/studio coursework. This type of holistic problem-solving coursework is the single most characteristic feature, one with which the programs have become thoroughly identified. When students are asked where most of their time is spent, or what class is hardest, or in what classroom environment they believe they learn the most, invariably the answer is the lab or studio. While the collection of this data is still a necessary line of research, both programs have the same anecdotal impressions about the impact of their inquiry curriculums. The short experience of lab/studio instruction at Cal Poly and Mississippi State shows that an inquiry curriculum with its high interaction among students, faculty, and experienced industry practitioners provides for a very rich learning environment, and that this is recognized as very beneficial by students.

Both programs have integrated subject content through the activities of inquiry, problem solving, critical thinking, and reflection. Supported by theory and the literature, this kind of integration should lead to evidence of superior learning outcomes when eventually measured by research. Both Cal Poly and Mississippi State have anecdotally seen that combining content and skill sets with problem solving and critical thinking provides students with better success at learning and transfer of knowledge to new contexts. What has been seen to be problematic is the struggle to learn the subject content traditional to construction education—and required by accrediting bodies—while still having the time to learn how to think. This conflict between the breadth of subject content and depth of critical thinking skills is a significant challenge for faculty and the discipline. Hopefully, further research may suggest that the seminal "reflection-in-action" approach suggested by Schön (1987)—where content is engaged through iterative, critical thinking—is the most appropriate methodology for educating professional practitioners.

Perhaps most importantly, both programs have questioned the normative model of undergraduate construction education by engaging the realities of twenty-first century professional practice. As the discipline of construction continues to build its professional status and the challenges of integrated practice become more evident, construction education will need to learn more from these types of integrated, inquiry-based, and critical thinking curriculums.

The experiences of Cal Poly and Mississippi State speak directly to these instructional research challenges. While each program is continuing to evolve as its curriculum matures, this comparison provides an initial set of research and development issues. Specifically, these include questions of student learning outcomes, the development of construction content and skill sets, curricula and curriculum development and its required instructional facilities, faculty development, and program accreditation. The comparison between the two programs has provided a better understanding of these challenges so that lines of scholarly research can be established (Monson & Hauck, 2012). Faculty and administrators at Cal Poly and Mississippi State are forging ahead on these plans for collaborative research work in conjunction with academic and industry groups, which hopefully will encourage continued classroom, faculty, and institutional development. Without these efforts, the wider adoption of inquiry-based learning in construction education will lag behind its full potential.

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