

Concepts of inquiry, constructivist learning, and the potentials of studio in construction education

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While many of the contemporary changes in construction education should be recognized and commended, there are substantive issues as yet unresolved as to how inquiry-based learning pedagogies are best applied in the classroom. This question is not raised from problems seen in student learning outcomes, but from a close comparison of the concepts behind inquiry-based construction education to the best practices of constructivist learning. The potential limitations of how inquiry-based learning has been applied to date can be seen through a conceptualization of the practices of instructors in the classroom, the relationship of subject content to those practices, and how those relationships fulfill the characteristics of constructivist learning. These issues are examined through a comparison to the familiar studio pedagogy of architectural education.

Key Words: inquiry-based learning, constructivist learning, studio, pedagogy, construction education, architectural education

Introduction

In the nearly twenty-five years that have passed since the famous 1986 Neal Report criticized undergraduate STEM education in the United States, nearly all of the engineering and science disciplines have made shifts toward active, research-based, and problem-based student learning (Atman &Turns, 2001; NAE, 2002; Pew Science Program in Undergraduate Education, 1998; Project Kaleidoscope, 1991; Rothman & Narum, 2000). Parallel to these developments, the Accreditation Board for Engineering and Technology's (ABET) outcomes-based accreditation initiative known as EC2000 called for demonstrations of student ability to apply practical knowledge: to work in multi-disciplinary teams; to formulate and solve ambiguous problems; to communicate effectively; and to use the techniques, skills, and tools necessary for disciplinary practice. Since these important professional skills are nearly impossible to engage in the traditional lecture classroom context, EC2000 essentially mandated problem-based coursework components in engineering curricula.

At the same time as these developments in engineering, similar student learning outcomes were recognized as problems for undergraduate construction education. In 1982, the Business Roundtable published a report titled "Management Education and Academic Relations," and its top two highest priority recommendations for undergraduate construction education were improvements in the practice-based skills of written and oral communication and management decision making. In a 1995 study of construction experts, Stephen Mead and Gay Gehrig found that construction education should increase "people skills" by "develop[ing] specific courses . . . which will help professionals develop and strengthen these key skills." Among the ideas suggested for improvement were the expansion of role-playing and simulations, requiring students to present their work, doing more collaborative team projects for the development of leadership and management skills, and placing more emphasis on professional abilities in communication and writing (1995, not paginated). All of these studies in construction pointed to the very same pedagogical impetus found in engineering and the sciences; undergraduate education should be improved through the application of active, problem-based learning.

Collectively, the instructional methods that depend on inductive and abductive teaching and learning can be described by the term "inquiry-based" pedagogies. The term "inquiry" refers the general characteristic of student-directed questioning and problem solving shared among these pedagogies. All forms of inquiry-based learning can be characterized as *constructivist* methods of learning. Constructivist pedagogies are student-centered; they work by reflectively connecting new learning to existing cognitive structures; they are dependent upon discursive, socialized instructional environments; and they are dependent upon collaborative and cooperative learning between students and with teachers and other disciplinary masters (Bruner, 1961; Dewey, 1997; Piaget, 1972; Prince & Felder, 2006; Vygotsky, 1978).

In construction education, inquiry-based learning includes design projects, capstone projects, integrated curricula, project- and problem-based learning, and inter-disciplinary group work. Inquiry-based learning has driven many new applications in construction management programs (Abdelhamid, 2003; Beliveau & Peter, 2002a, 2002b; Gier & Hurd, 2004; Lucko, 2006; Montoya, et. al., 2009; Scott & Fortune, 2009; Sirotiak, & Walters, 2009). Most construction programs have instituted various forms of inquiry-based coursework and anecdotally have seen improvements in student outcomes. However, it is evident that these changes have almost uniformly been implemented within the existing paradigm of the traditional classroom. That is to say, the application of inquiry-based methods has taken place by adding problem-based assignments within the normative structure of the three-credit lecture course. Within this paradigm, the instructor still acts as the source of knowledge for students, assignments tend toward a prescriptive adherence to outlined course content, the focus remains on individual student accountability, and students have little real responsibility for the learning of their peers (Buch & Wolff, 2000). Even so, many building construction programs have come to believe that their curriculums are "problem-based," and that they have satisfactorily progressed toward the larger benefits of inquiry-based learning pedagogies.

But, can this be true without challenging the paradigm of the traditional three-credit lecture course? Can it be true if teaching methods have not been radically rethought? If inquiry-based problems are simplified in ways that conform to the norms of the classroom rather than of practice, how do students learn the difficulty of applying content in a professional context? When inquiry-based problems are assigned episodically rather than holistically, how do students develop skills of knowledge transfer from problem to problem? And where is the consistency in fostering professional thinking and action? When inquiry-based problems are reduced in variables and scope to become "testable" and "measurable" for the classroom, how do students understand the complexities of disciplinary problem-solving in the real world?

Pedagogical questions: How is inquiry-based learning applied?

While many of the contemporary changes in construction education should be recognized and commended, there are substantive issues as yet unresolved as to how inquiry-based learning pedagogies are best applied in the classroom. This question is not raised from problems seen in student learning outcomes—a study which has yet to be done—but from a close comparison of the concepts behind inquiry-based construction education to the best practices of constructivist learning. The potential limitations of how inquiry-based learning has been applied to date can be seen through a conceptualization of the practices of instructors in the classroom, the relationship of subject content to those practices, and how those relationships fulfill the characteristics of constructivist learning. These issues are examined through a comparison to the familiar studio pedagogy of architectural education.

Conceptualization of instructional practices: Facilitation versus mastery

The use of inquiry-based learning ranges from instructor facilitated methods through integrated curriculum projects to the engagement of real-world problems as they occur in the field. As a continuum, these classroom practices move from "teacher-facilitator"—where instructional methods are *separated from* subject content—to "teacher-master"—where problems are engaged through the *practice of* subject content. As we will see, the instructional methods of teacher-facilitator have less disciplinary efficacy than the instructional methods of teacher-master.

In non-professional disciplines with little history of education through practical application, inquiry-based learning has developed by using instructional methods separate from subject content. This means that inquiry in the classroom is applied through external instruments of logic and thinking that are not found in the practice of the subject content in its discipline. These facilitation instruments are designed for the classroom rather than the subject content, and this separation is parallel to the general division of subject content from pedagogical practices in undergraduate education and education scholarship (Schön, 1983). One of the earliest and perhaps most characteristic of these facilitation methods was the problem-based learning "panel system" devised by Barrows and Myers: an overtly scripted sequence of classroom activities organized by the categories of "ideas," "facts," "learning issues," and "action plan" and recorded on large boards, sheets of paper, or whiteboards (1993). Subsequently, Barbara Duch outlined the general models of problem-based learning appropriate for undergraduate education as the "medical school model," "facilitator model," "peer-tutor model," and "large-class model" (2001). Realizing some of the limitations of these prescriptive applications, Cindy Hmelo-Silver broadened the potential value of facilitated methods by redefining them as a more general problem-solving strategies that included evaluative activities that looped back to earlier assumptions so they could be reconsidered (2004).

While inquiry-based learning in construction education is not premised on the application of these kinds of facilitation methods, they do typify the larger context of undergraduate education as it has struggled to implement active, problem-based learning. This kind of separation between subject content from pedagogical practices appears artificial from the perspective of professional disciplines that have a long history of problem-based pedagogies. The studio pedagogy of architectural education is one key example; the master/apprentice environment of the design studio makes no distinction between the instructional methods of teachers and the content that is central to architectural practice. In both realms, the process is holistically called "design." Even though architectural education has used the studio pedagogy for well over 150 years, the best new applications of inquiry-based learning in construction education demonstrate the very same master/apprentice process of problem-solving because both arise from *the practice of content within their discipline*.

It is this indelible relationship of subject content knowledge to instructional classroom practice that is best represented by master/apprentice pedagogies and the centrality of *design thinking* within them. In the disciplines of building construction and architecture, design has typically referred to the particular skills and responsibilities of the architect or engineer. However, in the last decade, "design thinking" has emerged as a powerful interdisciplinary concept that generalizes the activities of ambiguous, multivariate problem-solving (Martin, 2009). When diagrammatically compared to the problem-based learning facilitation panel system [Figure 1a] and Hmelo-Silver's problem-based learning reformulation [Figure 1b], the process of design thinking [Figure 1c] shows a cyclical and iterative pattern of fully integrated learning activities (Messarovic, 1964; Watts, 1966). What is most striking about

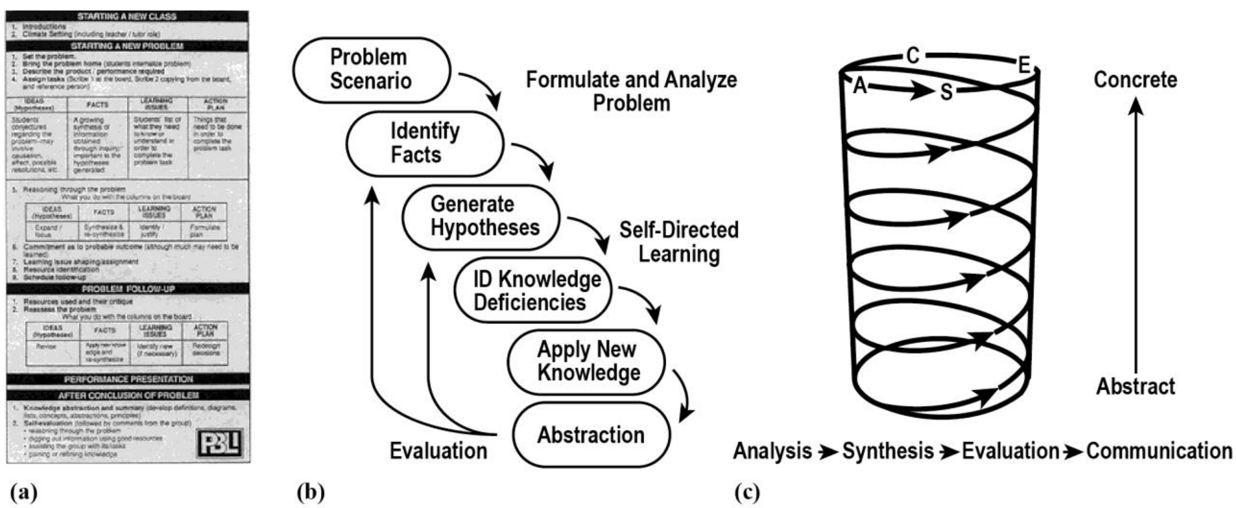

Figure 1: (a) Problem-based learning panel system; (b) problem-based learning reformulation; (c) design thinking.

the design thinking diagram is its potential to explain the relation of instruction to subject content. Given the seamless and iterative connections between the activities of "analysis," "synthesis," "evaluation," and "communication," there is no *separation* implied between instructional practices and subject content. They are completely integrated with one another in the person of the teacher-master. To pursue inquiry-based instruction through design thinking necessitates the integration of subject content and pedagogical practices.

Subject content, instructional practices, and realizing constructivist learning

Until the development of undergraduate degree programs, construction had historically been taught through the apprenticeship system with teacher-masters, and the discipline's current movement toward inquiry-based learning can be seen as a reconnection of subject content and instructional practices through master/apprentice problem solving. Master/apprentice instruction is a holistically realized constructivist learning environment. The best way to probe the issue of master/apprentice instruction—its constructivist characteristics, and its potentials for construction education—is to examine the existing pedagogy of the professional disciplines related to building construction: architecture and its allied fields.

Studio-based learning

Both construction and architecture were historically taught through the master/apprentice system before they became diploma-based disciplines. But while construction education entered the university by remaking itself under the lecture course paradigm, architectural education entered with its major instructional environment intact: the studio. Like the fine arts to which it is also related, the architectural studio survived the transition to undergraduate education because it was central to teaching students the essential nature of professional problem solving. This process of problem engagement is called design, and its pedagogy is called studio-based learning. Architectural education has used studio-based learning since the mid-nineteenth century, as have the allied fields of landscape architecture and urban design.

In studio-based learning, the design process engages ill-structured problems that are ambiguous in beginnings, means, and ends (Jonassen, 1997, 2000; Kitchner, 1983; Rowe, 1987). Students propose solutions through the design of artifacts—which may be physical, textual, conceptual, or a combination—engage in critique of those artifacts, and then iterate the propositions. Students use all of the socialized, discursive feedback aspects of the studio-based learning pedagogy: teacher-student discourse, student-student discourse, and design object-student discourse, which is the feedback provided through the manipulation of and reflection on the artifacts being made (Lawson, 1990; Rowe, 1987; Schön, 1985). Because studio-based learning problems are ambiguous, they must be worked at iteratively (Mesoarovic, 1964; Rowe, 1987; Watts, 1966), and any one design problem may contain hundreds of iterative artifacts. Through iteration, students engage failure and correction to build their skills of self-reflection, higher-order thinking, and learning transfer. Formative forms of assessment are embedded in the fabric of activity in the studio, and the teacher's role in these discursive moments of project reflection and judgment is where teacher subject content knowledge is fully integrated with the pedagogy (Schön, 1985).

Given all of its characteristics, studio-based learning is perhaps the most holistically realized constructivist pedagogy in education. Instruction in the studio is student-centered because its foundation is the problem-solving work of students. Knowledge is built by the reflection necessary for problem solution, and its cycles of iteration form a very effective method of cognitive development. The studio environment is completely socialized and collaborative, and this immersive culture builds standards of professional practice. Teachers are masters in studio-based learning, and they holistically incorporate subject content knowledge and pedagogical knowledge within their classroom practices.

Constructivist questions: How is inquiry-based learning *best* applied?

To assert the constructivist strengths of studio-based learning does not in itself condemn all other forms of inquiry-based instruction. However, studio-based learning does offer an important critique of other applications of inquiry-based learning since its characteristics are so holistically integrated. A number of these potential problems in inquiry-based construction education have been introduced here. There is the question of facilitation which separates subject content from instructional practices. There is the tendency of the three-credit course and its similarly regimented curricula to make any inquiry-based instruction episodic and much less effective. Finally, there is the issue of what instructional processes should be used to solve problems, and whether there is any method as good as design thinking at developing the practical skills of professionals in construction.

Difference between studio-based learning and other inquiry pedagogies

The inquiry-based learning applications in construction education that most closely resemble studio-based learning are design projects, integrated curricula projects, and capstone projects. In these types of inquiry assignments, students are given ambiguous problems for which there are only ambiguous solutions; they are "design" problems. The problems necessarily require previously-learned knowledge and skills that are iteratively applied through trial and error. The classroom atmosphere of problem-solving invites collaborative discussion, evaluation, and sharing of resources. The work required to produce a solution is a significant student effort, often many weeks or longer. Other applications of inquiry-based learning—project- and problem-based learning, inter-disciplinary group work—may be similar in some ways to design, integrated curricula, or capstone projects, but generally involve fewer of the characteristics of these methods. This implies that these applications become less similar to studio-based learning and ultimately less constructivist as well.

Whether or not a particular inquiry pedagogy is realizing the full potential of constructivism is not dependent upon what it is called; it is dependent upon the characteristics of instruction and learning in the classroom. For example, a construction program with capstone projects does not suggest that the entire curriculum is constructivist, nor does it even guarantee that the particular capstone project is constructivist. To date, there has been a tendency in construction education to apply inquiry-based pedagogies without ensuring that they are implemented with the necessary qualities to make them effective. When compared with the holistic nature of studio-based learning, the gulf between these pedagogies as they have been applied and real constructivist learning becomes more evident.

Shallow versus deep constructivism

As applications of inquiry-based learning become less constructivist, there invariably is a shift in control from the student to the teacher—and what the teacher perceives to be the needs of the assignment and the classroom. Because instructor control is the most persistent legacy of the traditional lecture classroom, this is often the single most important question of whether or not an inquiry application will be effective. Unless faculty have a good background in professional construction practice, most undergraduate instructors have little experience in leading problem-solving activities since they never saw this type of instruction in their own educations. The frequent result is that the instructor becomes dependent upon methods of facilitation rather than practices of mastery. Said another way, the instructor tends to act like a "teacher" with the student rather than a "master" skilled at problem solution.

Where teacher practices focus on the subskills and facilitation processes necessary to organize classroom actions, the result is "learning and activities that are expected to lead eventually to knowledge building rather than engagement directly in it." This is what education theorists Marlene Scardamalia and Carl Bereiter call "shallow constructivism" (2003). Alternately, they say that "deep constructivism" is the purposeful advancement of the frontiers of knowledge in the community; it is "knowledge building." By definition, to work within the knowledge and skills of the discipline to solve problems is participating in knowledge building. In studio-based learning, the classroom environment of solving problems through design thinking is necessarily deep constructivism.

To the extent that inquiry-based pedagogies are applied without the benefit of master teaching, the tendency is for such applications to be shallow constructivism. This is more likely true if the instructor has few skills of practical problem-solving in the discipline and is more likely to use facilitation methods with students rather than design thinking. Another significant problem in construction education is that such classroom environments were rarely experienced by faculty in their own educations, so the model of high-quality inquiry-based teaching is an unfamiliar one. This is not the case in architecture, for example, where all faculty and practicing architects can participate in knowledge building in the studio because they experienced the process during the entire length of their educations. In fact, when student work is debated in the most sophisticated form of public engagement in the studio system—the "jury"—architectural practitioners are frequently invited as critics of the work, and they have little difficulty in becoming central participants in the discussions. They are familiar with the discursive methods used in the jury because it is both the way work is assessed in the studio classroom and the way it is assessed in practice. In other words, the forms of debate embedded in architectural education are brought from professional practice into the studio environment. Thus, everything a student does in studio-based learning has the potential to participate in the knowledge building of the discipline as a whole.

Immersive constructivism

The student experience of design thinking and knowledge building that occurs in high-quality constructivist learning is directly opposed to the passive and rote experience of the traditional lecture classroom. Given over twelve years of becoming adept at operating within that paradigm in the K-12 environment, students enter undergraduate construction programs expecting to be taught and largely unwilling to accept responsibility for their own learning. While it is not easy for students to shift to a master/apprentice environment, studio-based learning has shown that—given full immersion in the pedagogy—students accept, thrive, and come to celebrate the change. This is primarily because students realize the value and motivation that ownership over their own learning provides them. It is also significant that the studio environment visibly demonstrates to students that they have entered the profession by directly engaging in its problem solving.

Unfortunately, the tendency in the university is to resist this immersive environment. The instructional paradigm of the three credit course and the parallel separation between subject content and practical application pervades the system. Attempting to reconnect this separation, inquiry-based instruction in construction education has been almost uniformly implemented within this existing paradigm. This creates a significant problem; students are constantly flipping between diametrically opposed forms of instructional delivery (de Graff & Kolmos, 2007). In the inquiry environment, they are expected to lead and control their own work, and then in the next lecture class they are expected to follow and passively listen as the instructor feeds them knowledge. Given the confusing choice between the familiarity of the passive role and the challenges posed by actively controlling their own learning, students often assume passivity in both classroom environments.

Inquiry-based learning becomes less constructivist as its applications are made more episodic. This is because students are not immersed in the inquiry pedagogy. When problem-solving work is instituted as discrete assignments in the traditional three-credit lecture course, students try to remain in their familiar passive condition and instructors invariably respond by fulfilling that expected role. This is perhaps the most common problem in implementing inquiry-based learning applications. Because students are unskilled in design thinking and knowledge building strategies, instructors overcompensate by telling students what to do, or they seize control of the problem-solving process in an attempt to guide the work toward more acceptable outcomes. The gravitational pull of the traditional instructional paradigm is at the center of this struggle.

Design thinking as constructivist instruction

The separation of subject content from pedagogical practice removed professional mastery from the instructional methods available to undergraduate education. When the benefits of inquiry-based pedagogies became desirable again, education research created the "teacher-facilitator" to accommodate them. From the perspective of deep constructivism, this invention of facilitation was rarely going to be successful. Problem solving in the classroom is best realized holistically by applying subject content through disciplinary practice. This constructivist instruction requires an understanding of the teacher-master as a problem solver, a design thinker, and a knowledge builder.

There is little difference between the kind of reflective thinking inherent to professional problem solving and the kind of representation and organization of that thinking inherent to teaching problem solving to others. In the master/apprentice pedagogy, the questions posed by the student in the process of engaging a problem are reframed by the master through anticipation of the potential routes of iteration. The master uses his skill of design thinking to create the particular and appropriate instruction. These discourses with the student—which takes place repeatedly over the course of years and through the entire range of subject content—illuminate the practice of the discipline. Students see how decisions are made within the multivariate aspects of a problem, and they develop the reflective skills of practice: prioritizing, analyzing, and synthesizing problem aspects so that solutions may be proposed.

Where teachers are not masters of subject content knowledge through practice, this kind of instruction is virtually impossible. However, that is not to suggest that a master of a particular kind of subject content is necessary to teach problem solving in that content. The gift of design thinking that comes with disciplinary mastery is that it becomes a method of problem solving that can supersede the particularities of content. For example, a master of construction management is not limited to working with a particular type of client or project, but he uses the skills of design thinking to gather new resources and synthesize new solutions for clients and projects he has never seen before. That he constructs such solutions through methods which have become internalized and consistent to his own practice is something recognized as a characteristic of professional mastery (Rowe, 1987; Schön, 1983). It is also a function of the studio-based learning environment that instructors of widely different backgrounds participate equally in problem solving throughout the curriculum. In architectural education, for example, students with questions about a particular structural issue in their design might independently consult with their instructor from civil engineering, or this kind of faculty resource can be brought in by the studio instructor for the benefit of the entire class. Ultimately, organizing the content and scope of the classroom problem to be solved is yet another demonstration of the skills of design thinking by the master teacher.

Conclusions in the form of further questions

If the current study suggests further empirical examination of inquiry-based learning in construction education, its tentative conclusions reside in the hope of encouraging more exploration of high-quality constructivist pedagogies, and specifically that of studio curricula. It is a fortunate coincidence that construction education shares a disciplinary boundary with a field like architectural education that has managed to establish itself outside of the normative instructional model of the university. This fact provides unique possibilities. It not difficult to imagine that construction education should be able to leverage its close disciplinary relationship with architecture to build better inquiry-based learning methods than any of the other STEM disciplines. In fact, academic consortiums like the Architecture and Construction Alliance—a group of twelve U.S. universities with both construction and architecture programs—already are engaging in collaborations that may produce these kinds of new reforms. As education research begins to look closer at the "studio" model and "design" as a pedagogic process, construction education would do well to change its understanding of those terms from the traditional realm of architecture to the more general, cross-disciplinary meaning that now defines them.

Among the most pressing problems for the further advancement of high-quality inquiry-based pedagogies—and particularly that of the studio model—is the question of how to produce undergraduate faculty with the essential design thinking skills for master/apprentice instruction. The demand by universities for more faculty research runs in direct opposition to a constructivist curriculum that would require faculty more experienced in professional practice. Construction education may have to consider teaching credentials that invest more value in breadth of subject content expertise and comprehensive design thinking abilities. This may be especially crucial as project delivery systems increasingly move toward integrated design-build practices and construction programs advance changes to meet this challenge. There will also need to be work done at administrative levels to lower student/teacher ratios for good studio instruction. This will require strong evidence of student learning outcomes through empirical studies.

Ultimately, further experiments in inquiry-based learning will provide the opportunity to rethink and re-imagine construction curricula by professionalizing instruction through comprehensive learning environments. Given the arguments examined here, these classrooms will likely look much more like studio learning than anything currently being implemented in construction education. Through the example of studio-based learning, we know that quality constructivist learning is possible in the university. The question for construction education is how we get there.

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