



Design and Implementation of an Integrated Curriculum: A Case Study

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Abstract

The construction Management program at Purdue University has introduced a unique educational model for its undergraduate degree. This curriculum transformation has been the most complex initiative ever undertaken by the School of Construction Management Technology. It is believed that no other academic program has implemented the integration of this magnitude encompassing the entire four-year curriculum. This paper provides a “30,000-foot view” of the novel educational approach including brief discussions about: the motivation for starting the transformation; the concept of knowledge “decompartmentalization”; horizontal and vertical integration of the curriculum; foundational elements of the “new” learning environment; and some of the major challenges that have been encountered, ranging from organizational to pedagogical. The main goal is to facilitate the exchange of ideas aimed at advancing the quality of undergraduate education regardless of the field of study. It is recognized that the model in its current state may be too complicated for adoption as a “whole”, however, there are many aspects of the model that other institutions can study and potentially benefit from.

Keywords: education, construction, decompartmentalization, synchronization, undergraduate

1. Introduction

Purdue University is an internationally recognized leader in technology, engineering, and agricultural education. Among Purdue's alumni are Nobel Prize winners, 26 astronauts (including the first, last, and most men on the moon), literary figures, journalists, politicians and university and corporation presidents. Consistent with Purdue's culture of relentless pursuit of excellence, the School of Construction Management Technology (SCMT) has been successful in maintaining the reputation as a premier institution for the advancement and dissemination of knowledge in the field of construction management (CM). The School is housed in the Purdue Polytechnic Institute (PPI) which is one of the 12 academic colleges of the University. The School is offering a full spectrum of degrees including baccalaureate (BS), masters (MS) and doctorate (Ph.D.) degrees. The subject of this paper is the curriculum transformation of the undergraduate degree. An overview of a rather unique educational experiment is provided, with a summary of some of the main challenges encountered, results accomplished and lessons learned. The goal is to encourage the discussion and exchange of ideas aimed at advancing the quality of undergraduate education regardless of the field of study.

2. Motivation behind the curriculum transformation

A brief history and description of the state of the undergraduate program at the time when the decision to proceed with transformation was made (fall 2015) are provided below.

Purdue undergraduate (BS) degree in construction management (CM) was officially introduced in 1967. The program was one of the first two CM programs in the United States that were accredited in 1979. Throughout its history the program has demonstrated organized and sustained efforts of providing a quality education aimed at enabling students to become problem solvers and critical thinkers. One of the strengths of the program has been the “hands-on” learning through the application-based classroom and laboratory learning experiences. A part of that experience comes from the minimum 800 hours of actual construction work that each undergraduate student is required to complete prior to graduation.

Purdue CM graduates have been among the most sought-after entry-level construction management professionals as they have consistently demonstrated their readiness to work in any sector of the construction industry, for any type and size of company, nationally and internationally. Purdue career fairs have been traditionally the largest CM fairs in the country offering excellent prospects for employment, with the job placement of practically 100%. By all relevant indicators the program was thriving and running at “full speed” with no apparent reasons to suggest a need for a major curriculum overhaul. Given these circumstances and the fact that higher education institutions are notoriously hard to change, a more expected outcome would have been to continue with the same course in line with a popular management principle: *“If it ain't broke, don't fix it”*. Nonetheless, in fall 2015, the decision was made that the School starts working on curriculum transformation that would even further enhance the learning experience of its students.

The principal motivating factor for CM curriculum transformation was another transformation that was underway at the Purdue Polytechnic Institute (PPI), the home of the School of Construction Management Technology (SCMT). To address a changing economy and a changing student base, the PPI had been reforming its teaching philosophy around, so called, *10 Elements of Transformation*, which included: (1) Theory-Based Applied Learning; (2) Team

Project-Based Learning; (3) Modernized Teaching Methods; (4) Integrated Learning-In-Context Curriculum; (5) Integrated Humanities Studies; (6) Competency Credentialing; (7) Senior Capstone Projects; (8) Internships; (9) Global/Cultural Immersions; and (10) Faculty-to-Student Mentorship.

The curriculum transformation of the CM program was in direct response and alignment with the *10 Elements of Transformation*, however, the extent of the transformation has been significantly broader and more complex. The impetus for the transformation was the fall 2015 School's retreat meeting in which the question was asked "*If you could start over from scratch, what would you do?*" The faculty set a goal to transform curriculum into an innovative learning environment that would create a "*seamless transition from college to industry*". After two years of preparation the new curriculum was launched in the fall 2017 semester and the first cohort of students following the new curriculum graduated in December 2020, one semester ahead of schedule.

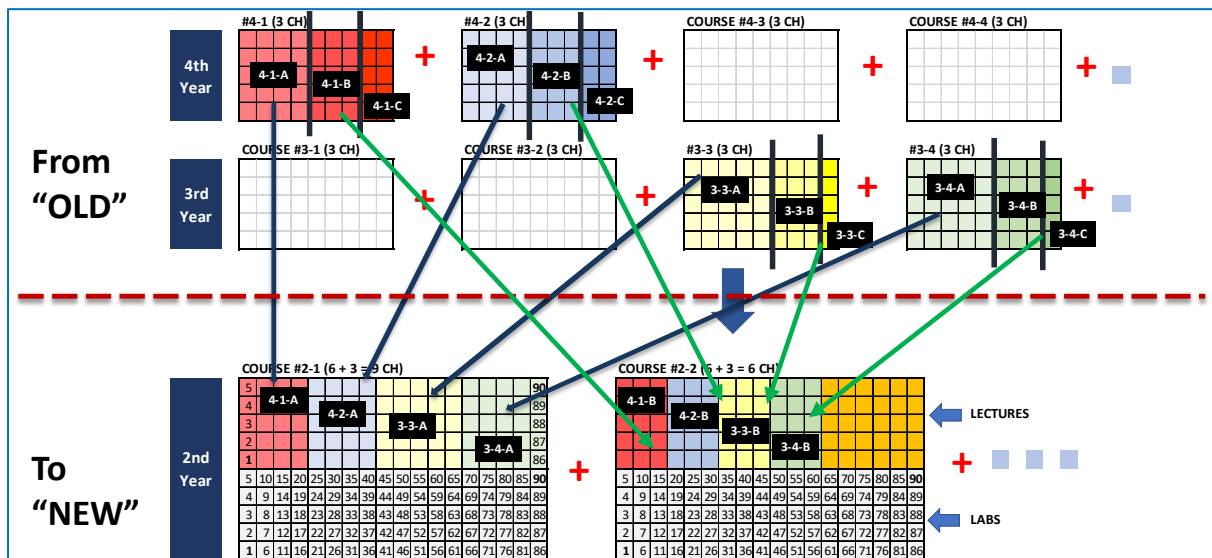
Several conference papers have provided a detailed discussion about the overall preparation and planning stages of transformation (Benhart et al., 2017, and Santon et al., 2018), the design and implementation of the first fully transformed 6-credit-hour course (Metzinger et al., 2019) and an example of how one specific subject, construction history, was integrated into an overall CM curriculum (Metzinger et al., 2018). The focus of this paper, however, is placed on the encountered challenges and lessons learned since the new curriculum has been implemented.

3. Two foundational elements of transformation: Knowledge de-compartmentalization and horizontal and vertical integration

The point of departure in the transformation process was the belief that the content of the CM program already represented adequately the contemporary Construction Management Body of Knowledge (CM BOK). Consequently, it was decided that the contents of the "old" and "new" transformed curriculum remain practically identical. What was substantially different between the two versions was the manner in which the individual content topics were introduced over the 4-year period of study.

The "old" curriculum was organized in a traditional way with the CM knowledge being "compartmentalized" in a number of (typically) 3-credit-hour courses, with each course covering a single discipline/ subject (such as, scheduling, estimating, statics, etc.), taught by an individual subject matter expert, in an "appropriate" year, and (typically) in isolation from other courses. The new curriculum, on the other hand, took a novel approach in which the CM knowledge was "de-compartmentalized" by combining material from several single-discipline courses into new "integrated" multi-discipline courses, resulting in a "horizontal" integration of curriculum. A portion of the material from any "old" single-discipline course is included in a number of new courses and every subject/ discipline is studied over multiple semesters, resulting in a "vertical" integration of curriculum. Figure 1 graphically depicts that process.

Figure 1. CM knowledge “de-compartmentalization”



It is important to note that this horizontal and vertical integration was implemented only on core construction management courses, which represent about 50% of all coursework. General education courses are still offered in a traditional way as single-discipline courses. Figure 2 compares the coverage of the Estimating subject in the old and new curriculum. As it can be seen, in the “old” curriculum estimating was covered in a single 3-credit-hour course (BCM 375) in the 3rd year, while in the new curriculum, it is covered in (at least) 5 courses throughout the entire four years of study; in CM 100 (1st year), in CM 200 (2nd year), in CM 300 (3rd year), and in CM 400 and CM 450 (4th year).

Figure 2. Comparison of coverage of Estimating subject area

	YEAR 1	YEAR 2	YEAR 3	YEAR 4
ESTIMATING "OLD"	-	-	BCM 375	-
ESTIMATING "NEW"	CM 100	CM 200	CM 300	CM 400 CM 450

One of the outcomes of these interventions was that the single-discipline 3-credit-hour courses are replaced by unusually large multi-disciplinary courses of six and nine credit hours, such as CM 200: Intermediate Pre-Construction Management. As it can be seen from Figure 3, this 9-credit-hour course is made up of (at least) 15 different subjects (sort of “mini-courses”), and is taught by a team of 10+ instructors. The complexities of such an arrangement are addressed later in the paper.

Figure 3. Subject areas/ disciplines covered in CM 200 course (9-CH)

CM 200	ESTIMATING	PLAN READING	ACCOUNTING	CAREER PREPARADNESS	COMMUNICATIONS
	SCHEDULING	SUSTAINABILITY	HISTORY	PROJECT MANAGEMENT	DESIGN MANAGEMENT
	STRENGTH OF MATERIAL/ SOILS/ STRUCTURES	SAFETY	MEP	COMPANY MANAGEMENT	OTHER

4. Challenges with designing and implementing a new learning environment and lessons learned

As mentioned, the contents of the old and new curriculum remained practically identical. What has changed is the “manner” in which the content is taught and learned. Heavy emphasis is placed on Active Learning (“*anything course-related that students in a class session are called on to do other than simply watching and listening to a lecture and taking notes*”) (Felder and Brent, 2016), and Project-Based Learning (PBL) (“*a teaching method in which students gain knowledge and skills by working for an extended period of time to investigate and respond to an authentic, engaging, and complex question, problem, or challenge*”) (Felder and Brent, 2016). There are typically four team “project” assignments in each 9-credit-hour course covering multiple subjects/ disciplines. Documents and project files from actual projects (“case studies”) are extensively used. The majority of assignments are team assignments, and all courses are taught by a team of instructors (co- and team-teaching will be addressed later in the paper). It is believed that this new learning environment provides students more opportunities to synthesize material earlier in their college career rather than waiting for a capstone course in their senior year. Also, it is believed that the students better retain their knowledge about specific subjects by scaffolding its content throughout the four-year program rather than condensing the subjects into “stand-alone” 3-credit-hour courses.

However, designing and implementation of this novel educational model has been anything but a “smooth sailing” and it was characterized by a number of expected and unexpected challenges. In fact, the transformation has turned out to be the most complex initiative ever undertaken by the School. Some of the most complex aspects of the transformation are discussed below. The challenges are categorized into three broad groups: (1) organizational: change management, need for more faculty lines, increased cost, and assessment of success of transformation; (2) course-related: management of individual courses, and the content and topic integration; and (3) pedagogical: utilization of co- and team-teaching.

4.1 Change management

Reference literature describing experiences of other academic programs that have attempted to implement similar transformations was not available. Given the fact that there was no roadmap to follow, the SCMT faculty has had to demonstrate a great deal of creativity and ingenuity in implementing this transformation. One of the chief challenges has been maintaining a high level of enthusiasm in this long, complex and wearing “exercise”. The lack of proper resources, high work load, and at times less than perfectly managed conversations about what should be done occasionally resulted in frictions among some faculty members. Several faculty members openly questioned the rationale for pursuing this transformation. The School experienced an unusually high faculty turnover in academic years 2017-2018, 2018-2019, and 2019-2020 of

15.5%, 12.6%, and 19.4% respectively (including retirements). The situation has changed in the last 3 academic years, and there have been no faculty turnover during that period. In order to objectively assess the overall perception among the faculty members about the transformation efforts, the School conducted an anonymous Qualtrics survey in 2019, 2020, and 2021. The survey revealed that there were faculty members who didn't have a favorable opinion about the School's ability *"to bring the transformation to a successful completion"*. Building and maintaining the sense of openness for changes remains to be one of the chief challenges. Need for a robust culture of continuous improvement is a critical prerequisite for the ultimate success of this transformation, as the "fine-tuning" of this unique model will require years of additional work. As an example, in one of the recent semesters there were 12 special meetings related to the transformation, with 695 person-hours invested in discussions with additional 300+ hours of preparation time, that produced a 300-page document of original scholarship material. The School's approach is best summarized by the words of the founding president of Ollin College that the success of any institution devoted to innovation will be determined by its ability to remain open to change, as the learning model that is best suited to today's world is unlikely to be optimal for the world of 10 or 20 years from now (Miller, 2010).

4.2 Need for more faculty lines

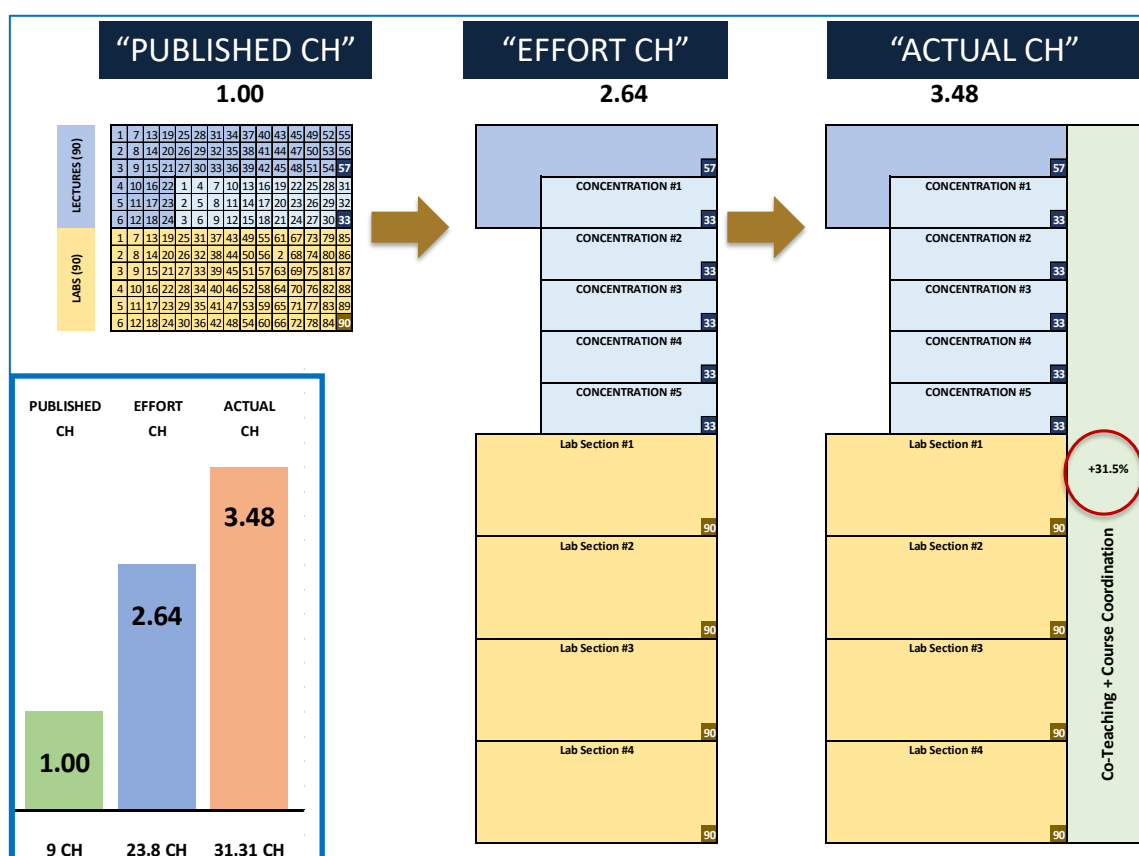
Working on the transformation has taken a toll on faculty and staff in terms of physical and mental fatigue. Particularly demanding were the first three years after the launch of the new curriculum (2017-2020) as the School was teaching-out the "old" curriculum, while developing and introducing new courses. In addition, introduction of co-teaching and team-teaching imposed additional challenges, one of which was the determination of "actual" faculty teaching efforts ("loads"). A new methodology for calculating actual efforts was developed in the fall 2019 as a result of a comprehensive analysis that was conducted over the period of 4 months. One of the surprising findings was that some faculty members had had consistently high teaching loads, much higher than what it was believed to be. Using the findings of that analysis, the School was able to make a strong case for additional faculty lines. In total, over the period of the last four years, 13 additional faculty and staff members were hired: 7 Tenure-Track positions, 1 Professor of Practice, 3 Lecturers, 1 Administrative Assistant, and 1 Lab technician. More faculty members and the utilization of the new methodology have significantly improved the balance and fairness of how the teaching responsibilities are shared among faculty members. With new hires, the School currently has 26 full-time faculty members making it one of the three largest construction management programs in the United States.

4.3 Increased cost

The new educational model is more expensive due to (1) a significant lab component in each course (which requires splitting classes in multiple lab sections), (2) utilization of multiple instructors for co-teaching and team-teaching, (3) complex course coordination that consumes faculty time which needs to be accounted in teaching load calculations, and (4) the need that each course must have one or two course managers (a single course manager is given credit of 3 credit hours when calculating his/her teaching load just for managing the course; if there are two co-course managers – each is given a credit of 1.5 credit hours). This cost increase is not "apparently obvious" and if not recognized may cause a great deal of frustration on the part of faculty members (who end up being "overloaded" with unaccounted teaching responsibilities) and the administration, once they are presented with the requirement for additional

unanticipated resources (need for more faculty and more lab facilities usage time). The School has developed a methodology for calculating the actual amount of needed resources, using credit hours (CS) as measurement units. A brief summary of the methodology follows. The analysis starts with the “Published” credit hours, the number of credit hours that the course carries, as it is “published” in the University catalog, and shown in a student’s transcript. Published credit hours are used to calculate the cost for a student or the tuition revenue that is generated by the University (Published CH x Cost (\$)/CH). If the course contains a lab component, and the class needs to be split into several lab sections (due to the space or equipment limitations, for example), each of the additional lab sections beyond the first will need extra faculty time, and extra facility/ equipment usage time. Extra faculty time is expressed in credit hours, representing additional teaching load. These credit hours are added to the “Published” credit hours, and the new construct is called “Effort” credit hours. Effort credit hours represent the minimal number of credit hours (i.e., the “floor” cost) needed to deliver a particular course. Time invested in course coordination meetings, use of multiple instructors for co- and team-teaching, and time of course managers all represent additional time commitments on the part of faculty. That time, expressed in credit hours, is added to the “Effort” credit hours, and the total is the “Actual” credit hours invested in delivery of a particular course. The ratio between the Actual and Published credit hours, which is always equal or greater than 1, indicates the “discrepancy” between the cost of delivering a course (Actual CH) and the revenue collected by the University (Published CH), and that discrepancy can be significant. Figure 4 shows an extreme case for the course CM 300, assuming four lab sections, and five “concentration” sub-groups within the class, with actual credit hours exceeding the published credit hours for more than 300%.

Figure 4. Actual credit hours (“cost”) of delivering CM 300 course



4.4 Assessment of success of transformation

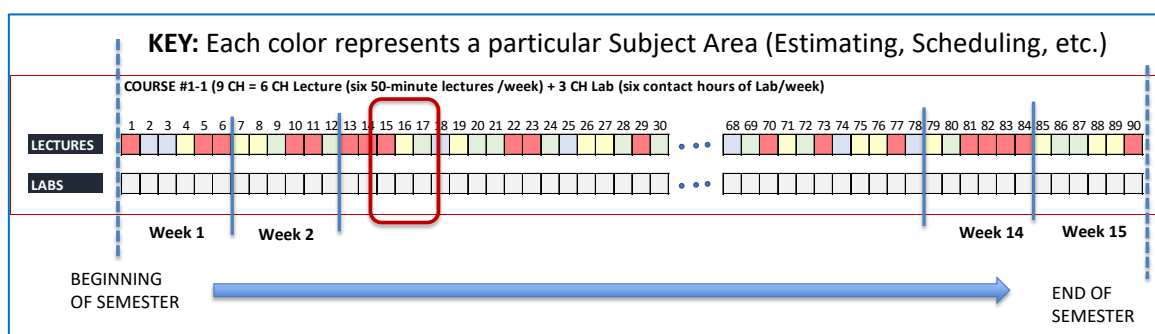
The program has so far graduated three cohorts of students under the new educational model. The overall sentiment among the faculty about the quality of graduates and the prospect that they will quickly develop in top-notch professionals is optimistic. There is, however, a limited amount of “hard” data to support that optimism, which is collected from the direct measurements of 20 ACCE (the accrediting organization for construction management programs) Student Learning Objectives (SLO) that are conducted every semester. This is not sufficient “proof” that the new model is indeed leading to improved learning, or that the “new” graduates are better prepared for the 21st century challenges than their predecessors following the “old” model. The program is yet to start conducting surveys of employers and alumni- these surveys are typically conducted 3-5 years after graduation. These longitudinal studies of alumni and employers (the industry) will provide more objective data for the overall assessment, but it will take perhaps 10 or more years before the School will be able to fully assess the success of its new educational model.

There is, however, anecdotal evidence that the transformation is on the good path and is heading in the right direction. For example, an industry executive who shared his impressions about the CM students in an (unsolicited) email that was addressed to the SCMT faculty stated: *“You ...should be extremely proud of the product of students you are putting out into the Construction Industry. The future of construction is in great hands with students from this department and it is easy to see why over 200 companies come to the career fair in search of Purdue CM students.”* Also, first two cohorts of students who followed the new curriculum produced the winners of the prestigious national essay competition sponsored by the Associated General Contractors (AGC) two years in a row (2021 and 2022), which was an unprecedented accomplishment. And, in the fall 2022 semester, the School’s career fair was attended by 219 companies which set a new all-time record.

4.5 Management of individual courses

New courses have become much bigger and more complex to manage. A composition of a typical 9-credit-hour course is shown in Figure 5.

Figure 5. Typical structure of a 9-credit hour course



There are ninety 50-minute “lecture” sessions, and ninety 50-minute corresponding “lab” sessions. Teams of instructors, in some cases more than 10 of them, are involved in teaching a course, making the course coordination exceptionally complex. As a result, there is a need for frequent coordination meetings between team members, and also, for each course, it was necessary to assign one or two “Course Managers” who are responsible for the overall course

coordination. This is a very complex and time-consuming task, and to recognize the efforts invested in that assignment, a single course manager is given a “credit” of 3 credit hours that is applied to his/her teaching load; in case of two co-course managers, each manager is given a credit of 1.5 credit hours. A quick look at a typical course grade book, which is managed in the Brightspace learning management system, reveals the degree of complexity commonly found in managing new courses. As an example, the spring 2023 version of CM 200 course had 98 students and there were about 165 assignments (reading quizzes, class activities, lab activities, tests, exams, team project assignments, etc.) that each student was graded on, creating over 16,000 instances of grading. Some of the items that remain to be the focus of attention in future are finding the optimal lecture-lab ratio, consolidation of the number of instructors involved in teaching a single course, and reducing 9-credit-hour courses to more manageable 6-credit-hour courses.

4.6 Content and topic integration

The content of each multi-disciplinary course was originally determined based on an analysis conducted by an assigned faculty team. It was anticipated that this would be just a starting point and that more iterations will be needed in order to find the optimal (1) “ingrediencies” (i.e., what part of which subject area to include in a particular course), and (2) the “recipe”, the best way, in terms of sequencing and timing, to integrate the various subject areas within a given course. Similarly, the integration of various subject areas across the entire curriculum will require a continuous refining. Using an imaginary course shown in Figure 5 as an example, it is expected that there is a rationale for why and how the specific topics for, for example, lectures #15, #16, and #17 (representing three different subject areas) were chosen? Also, it is expected that the three topics are synchronized, i.e., offered in the most meaningful sequence from the student’s learning point of view? Currently, for many individual sessions there is no strong rationale that would convincingly justify the selection of the session’s topic timing and the sequence in which the topics are presented. Fine-tuning of individual courses and the search for the “optimal” integration of topics within a single course and across the entire curriculum has proved to be a never-ending journey. Also, the focus will be in ensuring that technology integration in individual courses is up-to-date, responsive to market needs, relevant, and effective in preparing students for future careers.

4.7 Utilization of co-teaching and team-teaching

One of the distinguishing elements of the transformation is that each course is now being taught by a team of faculty members who are responsible for the instruction of materials in their areas of expertise. The main driver for utilizing team-teaching was the fact that the new courses are multi-disciplinary requiring a stronger collaboration among various subject matter experts. All three distinct models found in literature, namely, Interactive, Participant-observer, and Parallel (White et al., 1998) have been utilized in this transformation to various degrees.

The interactive approach, which requires two or more teachers to be present in class at the same time, who are all actively involved in delivering and debating the content of the session has been currently used very rarely, only in a few individual sessions. The participant–observer model, or “co-teaching”, as it is internally called, where two or more teachers are present at the same time, with each team member presenting their material independently with little or no intervention from other team members has been used in a limited number of individual lecture and lab sessions, perhaps less than 5% of time. In the parallel model, or “team-teaching”, as it

is internally called, each member teaches only those sessions assigned to them due to expertise or availability. That approach is utilized in every course, 100% of time. We differentiate “co-teaching” from “team-teaching”, in recognition that the “co-teaching” is a more complex teaching arrangement. Identifying which sessions/ topics should be co-taught, what is the best way to conduct the joint sessions, which instructors should team up for a particular joint session/topic – these are some of the challenges that will require significant additional efforts. Improving and increasing the use of co-teaching and team-teaching, maintaining stability in teams, and providing formal training in the pedagogy of team-teaching will remain to be the focus of attention in future.

5. Conclusion

The focus of this paper was a novel undergraduate educational model that is being implemented by Purdue University’s construction management program. Specifically, the emphasis was on the set of challenges, classified as, organizational, course-related, and pedagogical, that have been encountered in the implementation of the new model. The overall sentiment among the faculty is that the new model allows the students to develop strong leadership, teamwork, and presentation skills, as well to learn how to deal with and manage vaguely-structured problems. It has been recognized that, at the moment, there is insufficient data to provide a reliable answer to the questions like: Does the new model lead to improved learning? or, Are the “new” CM graduates more competent than their predecessors following the “old” model? It will take perhaps 10 more years before it will be possible to fully assess the success of this educational experiment.

Another important question is about the scalability of this learning model and how suitable it is for a full or partial adoption by other institutions? It is believed that, due to its complexity and the overall cost, the model may appear to be an unattractive candidate for adoption as a “whole” by other institutions. However, it is also believed that there are some elements that are worth studying and that other institutions can potentially benefit from.

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