

## Construction Engineering Students Cognitive Apprenticeship Approach

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# **Cognitive Apprenticeship Approach as the Foundational Learning Method for Construction Engineering Students**

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## **ABSTRACT**

Industry has voiced the need for gap reduction in the experiential and theoretical learning that exists in today's CEM curriculum. Student success is a direct reflection of the priority in the external stakeholders that will be discussed in this paper. Creation of a course that could reduce the gap is the first step in this process to align courses, instructor strengths, and industry needs, while meeting and/or exceeding the expectations of the student. The course curriculum herein provides an opportunity to lead by example as well as provide a model for training instructors in content delivery – promote enduring outcome by using application based delivery. The course proposed by this paper is being developed for the Division of Construction Engineering and Management at Purdue University. Motivation is found in many different forms but unified by the desire of the instructor to create student success in the construction industry. The course seeks to implement a cognitive apprenticeship approach as the foundational learning method along with additional methods which are implemented on case by case bases. Utilization of the principles found in Making Learning Whole should result in a learning environment that encourages the student to immerse themselves in the apprenticeship model. All of this effort equates to the primary enduring understanding that each student completing the course should subscribe to because the course has been constructed to prepare the undergraduate student in developing work plans to complete day to day operations. Such operations will be integrated into a comprehensive plan to complete a project in a safe and economic method. Moreover, a variety of knowledge is worth being familiar with relative to construction engineering that can be cataloged in the course; and, this portion of the course/project evolves based on industry trends and development of future courses in the Division of CEM.

## **INTRODUCTION**

Construction Engineering constitutes a wide range of disciplinary strategies. The Division of Construction Engineering and Management (CEM) at Purdue University has been “preparing undergraduate engineers to serve the construction industry as professional engineers and managers” since the late 1970's with theoretical and experiential learning objectives. In recent years, it has come to the attention of CEM that a gap exists between these objectives. It is not clear if it is a

societal gap or industry demand that has created it but industry representatives and students alike have voiced their concern. The long-term initiative by CEM is to align these objectives within the Construction Engineering curriculum and continue to be a leader in the development of the future of the construction industry. The short-term initiative is to develop a Means and Methods course. The Means and Methods instituted by the construction professional involve safety and economic considerations associated with a project that have binding legal ramifications. The Construction Professional enters a legal agreement to provide the Owner a project per plan and specification within budget.

Additionally, the Construction Professional must provide a safe working environment for the employees while being profitable. The proposed course, Fundamentals in Construction Engineering – Means and Methods I, has been designed to prepare the undergraduate student in developing work plans to complete day to day operations that will be integrated into a comprehensive plan to complete a project in a safe and economic method.

As mentioned above, recent dialog with industry representatives and students unveil, during Industry Advisory Board meetings for CEM, a perception that the students have a knowledge gap between the objectives which amounts to a lack of understanding of how to build. It is necessary to take the experiential learning promoted by the Division's internship program and merge it with the construction engineering curriculum. Therefore, the enduring outcome defined for this curriculum project is focused on developing the abilities, knowledge areas and qualities of the construction engineer by merging the two experiences so a better understanding of how to build is developed. It should be noted that CEM has a challenge in delivering this experience due to the lack of physical lab space. This research will offer solutions to the issue by exploring a variety of delivery methods used in other academic settings and/or within the industry. Although this is a challenge, it will prove to be an opportunity to explore options that have been used in different environments.

It is important to integrate the characteristics of the instructor creating the Means and Methods course but with emphasis on student success. The instructor is driven, energetic and committed to the success of the student; the two principles are dependent. Student success is a direct reflection of the priority in the external stakeholders discussed in the previous section. Self-reflection for the Division of Construction Engineering and Management leads us to believe an overhaul of the current Construction Engineering curriculum is required. The creation of the Means and Methods I course is the first step in this process to align courses, instructor strengths and industry needs while meeting and/or exceeding the expectations of the student. The curriculum project herein will provide an opportunity to lead by example as well as provide a model for training instructors in content delivery – promote enduring outcome by using application based delivery.

The enduring understanding is: Development of work plans to complete day to day operations for a project that will be integrated into a comprehensive plan to complete a project in a safe and economic method. In developing the master builder, the ability to cultivate the knowledge base is found to be the work plan that is tangible and deliverable. The industry doesn't have a "standard" for the creation of

the work plan nor do companies call the deliverable by the same name. Although there is no standardization, it can be agreed that certain components should be contained in each deliverable. There are components that are similar regardless of the type of construction: schedule, material, labor and equipment but depending upon the type of construction the analysis and selections will differ. The enduring understanding of this project is intended to be the catalyst for the development of the new-aged master builder but as a by-product it may develop a standard for the industry.

To propose a Means and Method course as the foundation of construction engineering courses, this paper performed the followings:

- Extensive literature reviews on pedagogy of learner's behaviors and cognitive apprenticeship
- Investigate and categorize relative learners of construction engineering
- Develop structures and details of the course
- Describe implementation plans
- Assess and discuss the proposed course

## **LEARNERS IN CONSTRUCTION ENGINEERING**

The intended learners needed to be separated into short-term and long-term categories. The short-term category reflects a sub-set of learners who will be impacted by this curriculum in the 0-5 year period. The long-term category reflects a sub-set of learners who will be a part of the CEM 5-10 year plan.

The short-term category will focus on undergraduate learners who will either be a junior or senior in CEM, Civil Engineering (CE) or Building Construction Management (BCM). The course will initially be populated by a majority of CEM students as a technical elective course aimed at augmenting the experiential and academic experiences outlined in the construction engineering curriculum. The special needs (or characteristics) of the CEM students are generalized as follows:

Students in construction engineering will work in a competitive global arena as work will (and is) abundant outside of the U.S. Globalization will become a challenge for the student in their professional careers and the instruction they received should help prepare them by exposure to relevant topics and exercises (Darwish et al. 2012). Engineering students work in small groups to solve problems which mimic industry in a proportionate perspective. The community of practice theory aligns well with this notion about the learners need for training associated with working in groups (Wang 2003). Students who study the construction and engineering curriculums "learn how to develop schedules" better in the non-traditional sense by using 4D (four dimension) rather than the previous method of 2D (two dimension) visualization (Wang 2003).

Based on the interview and application process implemented by CEM, the students who enter the program fit two general categories:

Novice – Students that have had some exposure to the construction industry and came to Purdue to study construction engineering.

Beginners – Students who know nothing about construction and came to Purdue to study engineering because they are good at math and science.

CEM students will have completed the second of their required three internships so a significant foundation will have been established in the field as well as in the classroom.

The following table (Table 1) illustrates the thought process in developing the curriculum relative to the learners based personal experience, freshmen program entry interviews and characteristics outlined in Enabling Engineering Student Success (Atman et al. 2010). It was necessary to build the table because the intent is to expand the offering to other learners following the curriculum developed in this project.

**Table 1. Taxonomy of Current and Future Learners**

SUBJECT	LEARNER		
	Undergraduate	Graduate	Practitioner
<b>Prior Knowledge</b>	Minimal based on two internship experiences	Will vary dependent upon undergraduate studies and previous work experiences – outstanding opportunity for international students and domestic students to share experiences for which each can learn from one another	Significant amount of work experience therefore the body of knowledge will most likely exceed that of the instructor
<b>Beliefs</b>	Information provided will be “the exact answer” therefore we must train them that it is an experience to draw from, information provided will assist them in decision-making on the job, augmenting their internship experience	The course will provide them a foundation to draw upon when making critical decision	Opportunity to share best-practices with a goal of improving the overall industry
<b>Attitudes (Atman et al. p. 87)</b>	Can do something to change the world we live in as they have psychological and social responsibilities	Mature approach to the course and eager to learn	Two schools of thought will exude: those that are here to learn and open minded, those that are here to impart their wisdom as ego/self-centered characters
<b>Motivations (Atman et al. p. 87)</b>	Preparation for internships and/or full-time employment	Either enriching prep for full-time employment and/or an opportunity to be promoted within their current work situation	Following the description in Attitudes: those here to improve their production at work, those here to “share” their wisdom
<b>Potential Conflicts</b>	None anticipated	Their perception of what best practices may or may not be based on theoretical studies they have been exposed to as an undergraduate student	Goes back to the attitude and motivation for why they are in the class although in the end, if it turns out to be more a of think-tank then conflict is dismissed because the goal

			would be to develop a repository of best-practices
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## MODULES

The modules will be structured to incorporate several sessions to reinforce what is important to know and do by building a series of games suitable for junior level students (Perkins 2009) throughout a semester. The sessions will be structured to develop individual components that are important to know and do, which allow the student to work on the hard parts (Perkins 2009). The components that are important to know and do are

**Contract and Scope:** Students should be able to read a contract and determine the scope of work to be provided and under what terms. Please note there are a number of contracts, delivery methods, so the course will only be able to focus on one or two of these. Students should be able to meet with a client prior to the development of a contract to determine scope and provide guidance in the design and construction phases. A graduate level Means and Methods would explore the financial aspect of the project development from the owner's perspective as well as the maintenance.

**Plans and Specifications:** Students should be able to read and interpret different types of plans. The variation in plans can range from design stage (schematic design to construction documents) to type of construction (transportation construction to industrial construction). Student should be able to read and interpret specifications because they complete the criteria for design intent.

**Schedule:** Student should be able to construct a schedule for the specific work defined as part of the whole project, assigning hours, resources and equipment within budget. Student should be able to create appropriate types of schedules based on work composition using various scheduling programs.

**Selections:** Student should be able to select the appropriate equipment to perform the work scheduled. Student should be able to assign the appropriate crew (labor resources) to perform the work scheduled. Student should be able to select the appropriate material to perform the work scheduled in conjunction with plans and specifications as well as adhering to the internal needs of necessary temporary constructed elements.

**Finances:** Student should be able to develop an estimate based on limited information from the client. Student should be able to develop a budget based on plans and specifications in order to develop contracts and execute buy-outs. Student should be able to incorporate the budget within their work plan and track actual costs associated with the field installation – variance analysis.

**Contractual Obligations:** Student should be able to develop purchase orders or payment requests in accordance with general conditions of the project. Student should be able develop change orders related to but limited to: scope creep and unforeseen conditions.

A variety of knowledge is worth being familiar with relative to construction engineering that can be cataloged in the Means and Methods I course. This portion of the course/project will evolve based on industry trends and development of future

courses in the Division of Construction Engineering and Management at Purdue. Knowledge worth being familiar with will be used to analyze work and develop work plans. In most cases, the knowledge will consist of material that the student will be responsible for learning outside the classroom in preparation for application in the classroom. The knowledge will encompass the following categories: Techniques: Students should be familiar with the basic operations of earthwork. Students should be familiar with the basic operations of concrete placement. Students should be familiar with the basic operations of pipe installation. Visual Identification and Terminology: Students should be able to identify techniques. Students should be able to articulate the processes involved. Knowledge based resources: Students will be exposed to alternate methods of learning. Students will be introduced case studies repositories.

## **IMPLIMENTATION**

The students enrolled in the Means and Methods course will be exposed to a hybrid of theories and learning concepts based on the research that the instructor has completed but the overarching process learners will be subjected is the cognitive apprenticeship model (Svinicki 2004) using the theories of community of practice and constructivism to support using various concepts of each. This learning theory aligns well with the historical interpretation of the construction industry. The management and field operation professionals in construction two to three generations ago learned by observation and ‘trial & error’. Historically these positions were filled by individuals who worked their way through the trades using an apprenticeship model. These professionals came from agrarian backgrounds, a stark contrast of Millennia’s who cut their teeth on technology as toddlers and generally anticipate instant success as well as career advancement.

The undergraduate construction engineering student is the focus of the Means and Methods course. Today this student will enter the work force and hold positions previously mentioned throughout their professional career without the luxury of the experiences of their predecessors. This begs the question how to simulate the learning and that’s why cognitive apprenticeship has been selected: alignment with historical learning process and the learner characteristics associated with successful professionals.

It is important to understand that currently construction engineering students at Purdue within CEM utilize a combination of experiential and theoretical learning to expand their knowledge of the construction industry. The experiential learning is to provide structure (McMillan 2008) but is ultimately driven by the needs of the industry partners who sponsor the internship. Theoretical learning, the curriculum, is relatively unchanged in the past 20 years since the author was a student in CEM and that is where the thesis mentioned previously will begin to answer the challenges and opportunities of developing the elite builders.

The proposal found in this project is an opportunity to develop a deliberate process using sessions of learning over a period of time that are combined to form modules of application ultimately improving the theoretical learning environment within the cognitive apprenticeship model to close the gap previously mentioned between the current curriculum practice of experiential learning and theoretical



learning. The use of authentic activities, direct experience, service learning and coaching with feedback, to name a few, will be used to encode the enduring the understanding.

## **ASSESSMENT AND DISCUSSION**

The objectives if the proposed course are the student components that are important to know and worth knowing for the development of the enduring outcome. The three most important objectives have been noted by an asterisk (\*) in the following discussion:

- i) Students should be able to read a contract and determine the scope of work to be provided and under what terms. Please note there are a number of contracts, delivery methods, so the course will only be able to focus on one or two of these.
- ii) Students should be able to meet with a client prior to the development of a contract to determine scope and provide guidance in the design and construction phases. A graduate level Means and Methods would explore the financial aspect of the project development from the owner's perspective as well as the maintenance.
- iii) Students should be able to read and interpret different types of plans. The variation in plans can range from design stage (schematic design to construction documents) to type of construction (transportation construction to industrial construction).
- iv) Student should be able to read and interpret specifications because they complete the criteria for design intent.
- v) Student should able to construct a schedule for the specific work define as part of the whole project assigning hours, resources and equipment within budget.\*
- vi) Student should be able to create appropriate types of schedules based on work composition using various scheduling programs.
- vii) Student should able to select the appropriate equipment to perform the work scheduled.
- viii) Student should be able to assign the appropriate crew (labor resources) to perform the work scheduled.
- ix) Student should be able to select the appropriate material to perform the work scheduled in conjunction with plans and specifications as well as adhering to the internal needs of necessary temporary constructed elements.\*
- x) Student should be able to develop an estimate based on limited information from the client.
- xi) Student should be able to develop a budget based on plans and specifications in order to develop contracts and execute buy-outs.\*
- xii) Student should be able to incorporate the budget within their work plan and track actual costs associated with the field installation – variance analysis.

- xiii) Student should be able to develop purchase orders or payment requests in accordance with general conditions of the project.
- xiv) Student should be able to develop change orders related to but limited to: scope creep and unforeseen conditions.

The Fundamentals in Construction Engineering course will use the principles defined in Making Learning Whole with emphasis on cognitive apprenticeship model for learning although Project-Based Learning (PBL) and Game-Based Learning (GBL) will be integrated too. These learning structures will be used to illustrate the mode in which the 7 principles suggest by Perkins will create an effectively blended learning environment. The Means and Methods – I course instructional outcome is that the student (learner) will become proficient in developing work plans that will detail the safety and economic strategies for a successful project for integration into a comprehensive plan. This enduring understanding that the student should take away from the course should be a catalyst for the development of the new-aged master builder but as a by-product it may develop a standard for the industry.

Students are expected to participate and attend class for exposure to a variety of educational opportunities. Each opportunity will be categorized as one of the following: Attendance, Class Participation, Quizzes, Session Assignments, Modules Assignments and Peer Evaluation. Students will have multiple opportunities to exercise the knowledge they have gained in a deliberate and distributed approach with activities that can be graded using the following generalized rubric.

A rubric will be developed for assignments prior to the actual delivery of the course integrating guest lecturers and final content sequence. It should be noted that each activity will be worth different points and the percentages provided indicate the maximum amount of points that will be awarded for the assignments. The students will experience in this class a set of game-based learning and project-based learning opportunities which will engage the student and make this course a “must take”. The course will be collaborative and apprentice based as constraints permit. The students should expect that the instructor will maintain a high level of energy and bring his A-game to each session/module.

The instructor has shed the historical approach to teaching and learning so the student should change his/her perception of an instructor. The instructor for this course should be a mentor and coach to the students which they can depend upon year round. The students should expect timely review and processing of deliverable items and if grading is not delivered in a timely fashion, the students should petition the instructor for the material. The student should note that the instructor’s style is to be inquisitive so you will find him answering your question with an additional question to invoke critical thinking and ownership of the work being completed. Moreover, students should understand that this course intended to develop your critical thinking skills and apply your engineering education. Student should thoroughly review and prepare for each session by obtaining material posted on Blackboard 24-48 hours prior to course meeting. Students should remain patient and begin to learn how to be a “problem finder”. Furthermore, students are to prepare for each session by reading material posted on Blackboard for the course in anticipation of starting each session with a quiz. The quizzes are intended to reinforce key elements to be covered in each session.

## CONCLUSION

This paper discussed importance and needs of Means and Methods courses in construction engineering educations. As the short-term initiative instituted by the construction professional, this paper proposed the Means and Methods course which is Fundamentals in Construction Engineering for the undergraduate students. Motivation of proposing the course is found in many different forms but unified by the desire of the instructor to create student success in the construction industry. Industry has voiced the need for gap reduction in the experiential and theoretical learning that exists in today's CEM curriculum. The proposed course will implement a cognitive apprenticeship approach as the foundational learning method although additional methods will be implemented on case by case bases. Utilization of the principles found in Making Learning Whole should result in a learning environment that encourages the student to immerse themselves in the apprenticeship model. All of this effort equates to the primary enduring understanding that each student completing the course should subscribe to because the course has been constructed to prepare the undergraduate student in developing work plans to complete day to day operations. Those operations will be integrated into a comprehensive plan to complete a project in a safe and economic method. The expected instructional outcome of the proposed Means and Methods course is that the student (learner) will become proficient in developing work plans that will detail the safety and economic strategies for a successful project for integration into a comprehensive plan. These learning outcomes should be a catalyst for the development of the new-aged master builder but as a by-product it may develop a standard for the industry.

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