A Course in the Human Factors Approach to Construction Engineering and Management

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While modern construction relies heavily on technology, materials, and methods, the execution of design and the profession of Construction Engineering and Management is largely human-centric.

Construction Engineering and Construction Management graduates need to be equipped with the knowledge, analytical methods, technical skills, and human perspectives that will allow them to lead and manage themselves so that they can successfully lead and manage others as well as the various resources necessary to complete complex construction projects and schedules that meet or exceed contract, budget, and safety objectives on a consistent basis [1] [2] [3]. The key to construction productivity is human factors [4] . In a 2016 survey of 36 contractors, "communication" and "leadership style" were two (2) of the top six (6) factors influencing site productivity [5]. Additionally human factors has been identified as key component of effective safety management [6] [7] [8] on construction sites which has been attributed to increased labor productivity [9] [10].

Course Design

In an effort to equip senior-level undergraduates with the skills necessary to manage the multitude of issues related to human factors affecting safety and productivity on construction sites, faculty collaborated with industry to identify fourteen (14) major topics related to human factors, safety management, and productivity. The curriculum is regularly shared with local industry to determine relevance and discuss the inclusion of new topics necessary for students to know upon graduation. Throughout the years, the curriculum has been modified to fit these needs. Experiential and contextual learning dimensions covered in the course include stress management; burn-out avoidance; sleep and shiftwork effects on productivity, safety, and well-being; scheduled overtime impacts; workplace violence prevention; lean construction; Total Quality Management (TQM); scientific work measurement techniques; human productivity analysis; conflict mode/conflict management; aging and diverse workforce issues; construction ergonomics; motivation and reward systems; management and learning styles; integrated communications approaches; personality profile; ethics and courage; individual and group authenticity; and the various types of leadership and decision-making situations that occur in a fast-moving stream of risk management in construction projects.

Delivery of the course includes a compilation of carefully chosen reading assignments, comprehension quizzes, guided lecture notes, in-class activities, experiential learning, and industry guest presenters. Each week students are randomly assigned into groups of three-to-four students. This forces to students to collaborate with everyone in the course, builds community, and teaches team dynamics. The culminating project for the course are student-created video vignettes that each capture one of the course topics. These vignettes are short, fictional stories that leave an impression on the audiences' mind [11]. The purpose of the assignments is to allow students the opportunity to creatively reinforce the main thrust of each of the topics. Admittedly, there is generally resistance to the assignment when it is first assigned, but the instructors are always impressed by the quality of the work submitted and students seem to genuinely enjoy

sharing their work and seeing what their classmates have produced. Students have also commented that the vignettes "bring the topics" to life.

Course Format and Topic Schedule

The course is a three (3) semester credit hour course presented in two (2) seventy-five (75) minute sessions per week over sixteen (16) weeks. Students receive the reading materials for the course topic one (1) week prior to the topic being covered in class. Students are required to read all reading assignments and complete a reading comprehension quiz before coming to class. Each week, student teams are randomly assigned and projected on screen as students enter the room. Numbered table tents are provided, and students are required to sit with their team. Team composition changes at least once per week. Class begins with a short, five-to-fifteen-minute lecture with guided notes presented using a Surface Book in tablet mode, open dialog is encouraged during this time. After the guided lecture notes are complete, an activity or guest presenter is introduced to the class. Typically, all students have completed at least one (1) internship and are asked to share experiences related to the course topics with the class. The experience of relating classroom theories with their own real-life experiences is appreciated by the students. The last ten (10) minutes are reserved for the student teams to complete an in-class assignment related to the activity or guest presenter and is due at the end of class. Depending on the topic, individual assignments are assigned to be completed outside of class. The course also requires a closed-book, closed notes mid-term and comprehensive final exam. Compared to previous semesters using traditional PowerPoint® based lectures, exam averages for the active learning-style course were in the A- range as opposed to previous years when the class average exam scores were in the C+ range. Course design is currently being revised to include more rigor based on these results.

Week 1 - Course Overview and Construction Productivity Defined

The course begins with defining Scott Sink's Seven Elements of Productivity [12] and understanding the difference between efficiency and productivity in construction. To demonstrate the difference between efficiency and productivity using Scott Sink's Elements of Productivity, student teams organize themselves into a bookmaking company and must produce as many books and possibly using pre-defined parameters. After each of three (3) rounds, each team must calculate costs and productivity, then answer a series of questions related to the Seven Elements of Productivity. This activity was adopted from the Duffka School of Economics [13]. Students enjoy the competitive aspect of trying to produce more books than their classmates, but also have a memorable activity to drawn on when calculating production costs and other productivity measurements.

Week 2 - Motivation Theory and Application to Construction

Organizational behavior motivational theories including Herzberg's Motivator-Hygiene Theory, Maslow's Hierarchy of Needs, Alderfer's ERG Theory, McClelland's Theory of Socially Acquired Needs, Expectancy Theory, Path-Goal Theory, Goal Setting Theory, and Management by Objective Theory [14] are reviewed during this week. The entire class is given two case studies, one involving a small construction company and the other involving a large construction company. Each group is assigned a theory that was included in the reading assignments and discussed in class. The groups must use the motivational theory that was

assigned to their group to think of ways to effectively solve the problem using their assigned motivational theory. The groups present their thoughts to the class and class discussion is encouraged and facilitated by the instructor.

Week 3 – Job and Life Stressors and Coping with Stress

Job and life stressors are common in all types of organizations and prevalent in construction. Students learn about different physiological and mental responses to stress, how to identify sources of stress, and how to cope with stress. Students complete The Holmes-Rahe Life Stressors Index [15] to determine their own stress score and the likelihood that they will experience a stress-related illness in the next year. Students are sometimes surprised by how stressed they are and are generally anxious to learn ways to cope with stress. They also learn to recognize the toll stressful events may be taking on the lives of those they are managing, how productivity is affected by stress as well as employee health and wellbeing. In this module, students also learn about Maslach's Theory of Burnout and Burnout Inventory [16].

For this module's in-class activity, the lights are dimmed, students are given the opportunity to recline in their chair or lie on the floor and listen to a guided mediation designed to relieve stress. Students write about their experience during the last ten (10) minutes of class. Students wrote they felt "refreshed" after the meditation experience and were going to try to add reflective time to focus on stress management into their schedules. Many students were very concerned about their Life Stressors Index and wrote about coping mechanisms they plan to employ in order to improve their own lives. They also wrote about how they will look for signs of distress in their construction crews and work to improve work-life balance for themselves and their subordinates.

Week 4 – Leadership, Personality, and Learning Styles

The module begins by juxtaposing the definitions of leadership and management. For this first class in the module, student teams are given two sheets of paper: one that says "manager" and the other says "leader". The instructor reads a trait that can be attributed to a leader or a manager. Each team must raise the paper with the word they believe corresponds to that trait. The instructor encourages lively debate. To further engage students in different leadership and management styles, students determine their own leadership tendencies (Transactional or Transformational), management style preferences (Theory X or Theory Y), their Myers-Briggs Personality Types, and their Emotional Intelligence Inventory.

For the second course in the module, students are divided into five (5) or six (6) person teams. All students head to the hallway and bring their chairs with them. Team 1 stands around the corner while their classmates build an obstacle course of chairs, the instructor verifies there is a safe route through the course. During this time, Team 1 is choosing a leader and the "followers" are blindfolded. The leader must then navigate their entire team through the obstacle course without touching any chairs. Every chair that is touched results in a ten (10) second penalty. The team that makes it through the course in the least amount of time wins a prize. While this is going on, the instructor leads the class in discussions about why types of leadership and management styles are being used and how personality types might influence how the team works together. At the end of the

activity, the teams write a guided reflection on their experience and how they might draw on their experience in the future.

Week 5 – OSHA Construction Safety Standards and Safety Management

Because this course is human-centric, safety management is an essential topic. All students earn their Occupational Safety and Health Act (OSHA) 30-Hour Construction Safety Card in another course and this module is an extension of that education. The purpose of this module is to review OSHA history and recordkeeping requirements, OSHA Focus Four Construction Safety Hazard Categories, direct and indirect costs of accidents and injuries, safety risk mitigation strategies and programs, worker's compensation, and experience modification rate (EMR). The in-class activity for this module involves groups being randomly assigned one (1) of the OSHA Focus Four Categories. Students must logon to the National Institute of Occupational Safety and Health (NIOSH) Fatality Assessment and Control Evaluation (FACE) website [17] and report on a fatality related to their category. At the end of class, students must present their findings to the class. This experience is typically very sobering for students.

Week 6 – Sleep, Fatigue, Shift Work, and Work Performance

A guest presenter from a local sleep clinic is asked to present about human circadian rhythms; sleep-wake cycles; and body core temperature tracking and relationship to alertness and human performance. Students receive case studies in fatigue and impacts to safety, productivity, and performance. During this first day of the module students take the Epworth Sleepiness Scale [18] to determine their own sleepiness and then learn principles of sleep hygiene so they can become better sleepers and improve their own productivity. In the second day of the module, shift work and schedule rotation are defined, and best practices discussed. Student volunteers agree to wear wrist actigraphs every night for two weeks to measure their sleep. The student volunteers also agree to have their results shared with the class as means to reinforce the topic. All students are asked to evaluate their own sleep hygiene, spend two weeks improving their sleep hygiene, and then write a report on their findings. Students are typically amazed at how much better they feel after working to improve their sleep patterns. Recent graduates who are hired onto projects where they are working the night shift have expressed their gratitude for this topic being part of the curriculum. Some have even come back as guest presenters to discuss why learning about sleep is so important.

Week 7 – Professional Behavior in Social Situations

Better known to students who take this course as "knife and fork" school. Industry sponsors a "mocktail" hour and four (4) course dinner. During mocktail-hour students learn the correct way to make introductions and juggle a plate of food, a drink, a napkin, and still be able to shake hands. During dinner, students learn about meal progression, correct ways to manage a napkin and utensils, there is also frank discussions about what to do when the situation goes awry.

Week 8 – Scheduled Overtime and Productivity Impacts Mitigation

The module explains the difference between overtime, extended overtime, scheduled overtime, and the cumulative effects of scheduled overtime to productivity. Students

learn to calculate premium pay-efficiency and discuss 4/10 scheduling versus other types of schedules and fatigue recovery. The class activity involves calculating productivity efficiency for different case studies.

Week 9 – Work Observation and Construction Productivity Measurement Methods

This module includes cost reporting and progress monitoring productivity measurement, internal and external factors that influence construction productivity, and scientific productivity measurement tools including Field Count, Activity Sampling, and a brief introduction in Time Study. Students perform work sampling studies in the classroom of basic bolt-nut operations and practice using work measurement techniques discussed in the readings. Students are assigned an experiential learning project that requires them to visit a construction site and perform a work measurement study, calculate labor utilization rates, and write an executive summary detailing their findings.

Week 10 – Ethics in Construction Management

While ethics is discussed in several other courses and is not included in assessment for accreditation in this course, the instructors and industry felt this is an important module to include in a human-centric course. Theories discussed include Heinrich's Domino Theory [19], Blanchard-Peale Theory of Ethics [20], and ethical climate and safety performance in construction. The in-class activity uses The Fish Game [21]. Students cast their nets to catch as many fish as they can, but they must also leave the most fish at the end of the game to encourage sustainable behavior. Students are asked a series of questions related to the activity and the course materials to be turned in at the end of the class period.

Week 11 – Spring Break

Week 12 – Ergonomics in Construction

Construction work requires high force, high repetition, and awkward postures which can lead to work-related musculoskeletal disorders (WRMSDs). WRMSDs common in construction are introduced including: stenosing tenosynovitis, medial epicondylitis, lateral epicondylitis, carpal tunnel syndrome, DeQuervain's disease, Reynaud's syndrome, and tendonitis. Back anatomy and common back injuries; construction tool and equipment ergonomics; reduction of manual material handling (MMH) activities; and mitigation of WRMSD risk are also discussed in this module.

The first class period of the module is spent working with anatomical models to understanding exactly where in the body is affected by common construction-related WRMSDs. The second class period is all experiential with students having the opportunity to learn how to use hand dynamometers, pinch gauges, light meters, sound meters, psychomotor vigilance testing, and coefficient of friction testing using a Regan Scientific BOT 3000E digital tribometer.

Week 13 – Construction Workforce Demographics and Aging Workforce

The construction workforce is aging [22] and as such more susceptible to injury [23] [22] [24]. Techniques on how to successfully manage an aging workforce are discussed. An electrical contractor who is still working in 90s is the guest speaker for this module.

Week 14 – Total Quality Management (TQM) and Lean Construction

This module focuses on continuous improvement cycles and introduces Total quality Management (TQM), Deming's 14 Points, the Plan-Do-Check-Act Continuous Improvement Cycle, applying Lean thinking in construction, fishbone work process diagrams, Make Ready, and Pull Planning. In the first module, students participate in a pull planning and Last Planner® System activity. The classroom is transformed into a mock Big Room. The students are each given their roles in the project and the rough schedule. The entire class period is spent working together to achieve their final schedule and writing about their experience. Students learn about communication and get a better understanding of the construction process, as a whole, through this activity.

The second class period is a lesson in continuous improvement. Students are given an egg, a budget, and a worksheet with the continuous improvement cycle. They must design a device that will protect the egg when dropped from a height at least one (1) story high. Materials are each assigned a price that may be purchased form the class "store". Each team is given three (3) attempts to come up with the least expensive design that will protect the egg. Prizes are given for the best design at the least cost. Students must report on their continuous improvement cycle and lessons learned. This activity is not only entertaining, it enforces teamwork strategies, and is a memorable way to teach continuous improvement.

Week 15 – Conflict Resolution, Workplace Violence, and Jobsite Security

Conflict is not uncommon in the construction industry. When conflict devolves into violence, productivity plummets. The first class period of this module introduces the Thomas-Kilmann Conflict Mode Instrument and Induvial Conflict Mode Diagram [25]. Students first take the instrument themselves to learn about their own approach to conflict and then learn about the other conflict modes and how to best utilize their own strengths and negotiate with others. The topic is expanded to discuss conflict typically found on construction sites and how to cope with these conflicts [26]. During the second course of this module, a guest presenter discusses workplace violence and how to diffuse these types of situations, how to react to an active shooter, and jobsite security protocols. The guest presenter assigns each student team a real-life conflict scenario that have been experienced on one of their job sites. Each student team must work together to formulate a solution based on what they have learned about conflict management and present this solution the class. The guest presenter then shares with the class what actually happened, the outcome, lessons learned, and recommendations for how to handle similar situations in the future.

Week 16 – Student Vignette Presentations

Student teams are given the opportunity to present their final video vignettes during the last week of classes. Presentations are assessed by instructor rubric and peer review. Students comment that the vignettes "bring the topics to life" and genuinely enjoy watching the vignettes. It gives students to opportunity to communicate in manner that is much different than what they are used to, but still highly effective.

ABET Assessment and Continuous Improvement

ABET Student Outcome (SO) (3) is assessed in this course. This SO is defined as "an ability to develop and conduct experiments or test hypotheses, analyze and interpret data and use scientific judgment to draw conclusions". In the Work Measurement Module, students are individually assigned to go to a construction site of their choice (assistance is provided to students who do not have direct access to a site). Students must perform Activity Sampling and Field Count Sampling in addition to calculating Labor Utilization Factors. Students are required to present their findings in the form of an executive summary complete with tables, graphs, interpretation of results, and recommendations for improvement. The student submissions are evaluated using the rubric in Table 1. For the 2018-2019 Academic Year, students at this institution scored an average of 9.6/12. Areas of weakness were predominately in Area C because students had difficulty describing their procedure and solution in their executive summaries. More time will be spent in future semesters guiding students how to write executive summaries and communicate procedures, analysis, and recommendations.

Table 1. ABET Student Outcome (SO) (3) Assessment Rubric

Performance Indicators	**4 - Exemplary**	**3 - Proficient**	**2 - Apprentice**	**1 - Novice**
(A) Identifies key information and assumptions needed	All critical information and assumptions are identified, justified, and applied correctly	Most critical information and assumptions are identified and applied correctly; some justification given for assumptions	Substantial omissions of critical information and assumptions; misapplication of information and/or no justification of assumptions	Failure to identify and justify critical information and assumptions; major errors in applying them
(B) Selects appropriate principles, equations, and/or approaches to formulate the solution	Principles, equations, and approaches are correct and appropriate for the solution and its context	Minor errors in selected principles, equations, and/or approaches; other principles, equations, and/or approaches are more appropriate	Major errors in selected principles, equations, and/or approaches; other principles, equations, and/or approaches are much more appropriate	Principles, equations, and/or approaches are inappropriate for the context and/or are incorrect
(C) Solves and executes (or describes) solution procedure	Solution procedure is clear and correctly derived (or described)	Solution procedure is mostly clear and is derived (or described) with few errors	Solution procedure is unclear and is derived (or described) with some errors	Solution procedure is unknown and/or is incorrect (or not described)

While this course only assesses one (1) ABET SO, it contributes to the achievement of three (3) ABET SOs:

4. An ability to communicate effectively with a range of audiences.
5. An ability to understand ethical and professional responsibilities and the impact of technical and/or scientific solutions in global, economic, environmental, and societal contexts.
6. An ability to function effectively on teams that establish goals, plan tasks, meet deadlines, and analyze risk and uncertainty.

For ABET SO (4), students learn how to best communicate within their peer groups, subordinates, and their superiors based on their personality profiles, leadership style, and conflict management preferences. They are also taught basic professional behavior in social situations to better prepare them to operate in professional environments. For ABET SO (5), students have a module on professional ethics related to project management and safety management. Finally, ABET SO (6) is not assessed in this course but students are randomly assigned to a new group every week and for the final vignette project, which emphasizes the important of teamwork and working with a wide variety of individuals.

To continuously work to improve the course and meet the needs of industry, guest speakers and other industry representatives are frequently asked to review the course topics and make suggestions for revisions. For instance, conflict management and communication skills were added to the course based on feedback from industry. Recent graduates frequently comment that the stress management, sleep, shift work, and scheduled overtime sections are extremely beneficial their first years on the job and adjusting to the demands of the construction industry. The course evolves every semester based on the input from recent grades and industry.

Conclusion

The culminating course objective is for each individual student to know themselves and others within the framework of each human factors dimension so that they can know, manage, and motivate others more effectively. The outcome is a more fully integrated young construction professional who is better prepared to plan, communicate, lead, motivate, develop, and leverage human relationships for stronger commitment, higher performance, and teamwork.

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