Advancing Career-Ready Construction Graduates: A Bayesian Evaluation of NACE Competency Integration in a Capstone Course

Dr. Mohsen Goodarzi, Ball State University

Dr. Mohsen Goodarzi is an assistant professor of construction Management at Ball State University. He received his PhD. in Construction Management from Michigan State University in 2021. His research focuses on sustainability in the built environment, life cycle costing, and construction education.

Dr. Tamer Breakah, Ball State University

Dr, Tamer Breakah is an Associate Professor of Construction Management at Ball State University. His research focuses on Construction Materials, Project Management, and Construction Education

Dr. Mohamed Abdel Raouf Metwally, Ball State University

Dr. Mohamed Abdel Raouf has been working as an Assistant Professor at Construction Management and Interior Design Department at Ball State University since 2024. He was working previously as an adjunct assistant professor and research associate in the Construction Engineering department and center for sustainable development at American University in Cairo for 14 years. Also, he was working for 10 years as a full time engineer/project manager/research and development manager in different corporates in energy and gas, cement, and real estate industries.

Advancing Career-Ready Construction Graduates: A Bayesian Evaluation of NACE Competency Integration in a Capstone Course

Mohsen Goodarzi[1], Tamer Breakah[2], and Mohamed Abdel Raouf[3]
[1,2, &3]Ball State University

Abstract:
The construction industry increasingly demands graduates who possess not only technical expertise but also strong professional and career readiness competencies. This study examines the integration of the National Association of Colleges and Employers (NACE) Career Readiness Competencies within a senior-level Construction Management Capstone course. Data was collected using an online survey in which students assessed their self-perceived proficiency at both the beginning and end of the semester across five Course Learning Outcomes and eight NACE career readiness competencies. Responses from 41 students were analyzed. To support rigorous inference in an applied educational setting and accommodate outcome-level variability, a Bayesian hierarchical modeling approach was employed to estimate expected patterns of competency development. Posterior estimates indicate a high probability of positive perceived development across all assessed competencies, with stronger expected growth in critical thinking, leadership, and professionalism, and comparatively lower growth in global and intercultural fluency. These findings suggest that Capstone learning environments are well-positioned to support career readiness development while also highlighting areas for targeted curricular enhancement. Methodologically, this study demonstrates the value of Bayesian approaches for competency-based assessment in construction management education.

Key Words: NACE Competencies, Capstone, Construction Education, Career Readiness

Introduction

Preparing construction management graduates for the dynamic and competitive workforce requires not only technical expertise but also a suite of transferable professional competencies. In recent years, engineering and construction education communities have increasingly emphasized career readiness to support students' successful transition from academia to professional practice. Career readiness encompasses cognitive, interpersonal, and intrapersonal skills that employers consistently report as essential for entry-level success, such as critical thinking, communication, teamwork, and professionalism. To operationalize career readiness in higher education, the National Association of Colleges and Employers (NACE) Career Readiness Competencies have emerged as a widely accepted framework identifying eight core competencies considered critical for college graduates entering the workforce. NACE's framework consists of eight competency areas: Critical Thinking/Problem Solving, Oral and Written Communication, Teamwork and Collaboration, Technology Use, Leadership, Professionalism/Work Ethic, Career Management, and Global/Intercultural Fluency (NACE, 2024).

Despite the acknowledged importance of competencies like those suggested by NACE, evidence showing systematic integration of these competencies into construction management curricula and the resulting impacts on student outcomes remains limited. Integrating competency development within capstone and high-impact practices is particularly relevant for construction

programs, where students engage in real-world problems that mirror industry challenges. The present study investigates this pedagogical integration in the context of a senior-level Capstone course, using a Bayesian hierarchical model to estimate expected growth in self-perceived career readiness competencies. In order to highlight the importance and the need for this investigation, it is essential to situate the study within the current state of research on career readiness and competency integration in higher education, with a focus on construction education.

Literature Review

Several studies have examined the role of competency development in facilitating successful early careers in STEM and engineering education. For instance, Newell and Ulrich (2022) investigated STEM alumni perceptions of NACE competencies, concluding that integrating career-related competency development, especially through experiential learning like undergraduate research, supports graduates' professional readiness. Their findings reinforce the argument that competency development should be embedded within disciplinary contexts rather than treated as ancillary to technical instruction.

Other work in engineering education emphasizes the broader concept of career readiness and the importance of high-impact practices such as internships, co-ops, and project-based capstone experiences. Webber et al. (2023) analyzed career competencies and underscored the value of structured work experiences for reinforcing competencies such as communication and problem solving, while acknowledging that meaningful integration requires intentional design and alignment among students, faculty, and employers.

Despite the growing scholarship on career readiness in STEM fields, literature specific to construction management education remains sparse. Within construction education research, few studies have explicitly examined the integration of NACE competencies into curricula or assessed their impact on student outcomes. A notable example is the recent work by Goodarzi et al. (2025), which investigated NACE competency integration in a junior-level construction course, Construction Estimating, and reported significant self-perceived improvements across several competency areas. This study highlighted differential growth among competencies and pointed to curricular emphasis as a potential determinant of uneven development. Earlier work by Goodarzi (2023) explored implementing NACE competencies within sustainability-oriented project modules, finding positive effects on teamwork and communication competencies. However, this effort was primarily descriptive and did not employ inferential models capable of quantifying expected competency growth while accounting for outcome heterogeneity.

In construction education, capstone courses often involve multidisciplinary collaboration, stakeholder engagement, and applied decision-making, all of which align with professional competency development. Capstone courses have been extensively studied as culminating experiences that foster synthesis of knowledge and professional skill development. (Dutson et al., 1997) established early evidence that capstone design courses enhance students' problem-solving and teamwork abilities, particularly when projects reflect real-world constraints. Subsequent studies have reinforced the role of capstone experiences in supporting professional identity formation and readiness for practice.

Beyond disciplinary research, practitioner reports from NACE and academic partnerships further emphasize the importance of embedding career readiness into experiential and high-impact

practices. For instance, recent NACE reports outline strategic approaches for integrating career readiness competencies across curricula and student services, recommending multiple competency touchpoints, including capstone experiences, to reinforce outcomes (NACE Career Readiness Taskforce, 2023). Such frameworks suggest that higher education institutions must not only adopt competency definitions but also intentionally scaffold development through curriculum design, assessment, and reflective practice.

Taken together, this body of work indicates that while the need for career readiness integration is widely recognized, there is limited empirical evidence on systematic implementation and assessment strategies in construction management education, particularly at the Capstone level and using robust statistical models suited to ongoing studies.

Research Gap and Study Purpose

Despite growing scholarly attention to career readiness and competency integration in engineering education (Newell & Ulrich, 2022; Passow & Passow, 2017; Webber et al., 2023), empirical investigations within construction management programs remain comparatively limited. Most published studies in construction education have focused on instructional innovation or student perceptions rather than systematic evaluation of competency development across multiple domains (Dutson et al., 1997; Goodarzi, 2023). Moreover, while recent work has begun to examine NACE competency integration in construction curricula (Goodarzi et al., 2025), such studies have primarily relied on traditional frequentist pre–post analyses. These approaches, while informative, provide limited insight into outcome-level heterogeneity, uncertainty quantification, and cumulative evidence building, particularly in small-sample, applied educational settings. Collectively, this literature indicates a need for construction-specific, capstone-level investigations employing more robust analytical frameworks to evaluate competency development.

Recent methodological scholarship in education research advocates for Bayesian approaches as a means of addressing these limitations, particularly in small-sample and applied educational settings. Bayesian hierarchical models allow researchers to estimate expected effects while accounting for variability across learning outcomes and supporting cumulative evidence building over time.

Therefore, building on prior scholarship, this study addresses the need for rigorous, construction-specific evidence on career readiness development within capstone education. By integrating the NACE Career Readiness Competencies into a senior-level construction management Capstone course and employing a Bayesian hierarchical modeling framework, the study advances both pedagogical practice and methodological rigor. Specifically, this research seeks to examine expected changes in students' self-perceived career readiness competencies, explore variability across competency domains, and demonstrate the utility of Bayesian methods for ongoing competency-based curriculum assessment. The following section describes the research methodology used to achieve these objectives.

Methods

Study Design and Participants

This study employed a survey-based design to examine changes in students' self-perceived competencies over the duration of a senior-level Construction Management Capstone course. The survey was carried out at the end of the semester of 2025. After receiving the IRB approval, the survey was distributed among the 51 students who took Capstone this semester; 43 completed the online survey. However, after excluding the incomplete responses, the final analytic sample consisted of 41 students who responded to all questions regarding pre- and post-course self-perceived competencies/proficiencies across two domains:

1. **Course Learning Outcomes (CLOs)**: Five CLOs aligned with technical, analytical, and professional expectations of the Capstone course, as outlined in Table 1.

2. **NACE Career Readiness Competencies**: Eight competencies defined by the National Association of Colleges and Employers, including Critical Thinking, Communication, Leadership, Teamwork, Technology, Professionalism/Work Ethic, Career Development, and Global/Intercultural Fluency (see Table 2).

All items were measured on a five-point Likert scale (1 = strongly disagree to 5 = strongly agree). In addition, students ranked the eight NACE competencies based on perceived growth during the course (1 = highest growth, 8 = lowest growth).

Data Preparation

For each CLO and NACE competency, individual-level change scores were computed as the difference between post-course and pre-course responses. Positive values indicate perceived improvement over the course duration. No missing data was observed for the analyzed variables.

Statistical Analysis

To evaluate competency development while accounting for both individual variability and outcome-level differences, a Bayesian hierarchical modeling approach was employed. This method was selected to support probabilistic inference in an ongoing study and to provide stable estimates across multiple correlated learning outcomes.

For each outcome j, student-level change scores Δ_{ij}were modeled as:

$$\Delta_{ij} \sim \mathcal{N}(\mu_j, \sigma^2)$$

Outcome-level means $\mu_j$were assumed to arise from a higher-level distribution:

$$\mu_j \sim \mathcal{N}(\mu_0, \tau^2)$$

Separate models were estimated for CLOs and NACE competencies. Posterior distributions were obtained using Gibbs sampling with 5,000 iterations, discarding the first 1,000 as burn-in and retaining 4,000 posterior draws for inference.

Results

Changes in Course Learning Outcomes

Table 1 summarizes observed pre- and post-course scores for the five CLOs, along with Bayesian posterior estimates of mean change. Across all CLOs, posterior mean changes were positive, with posterior probabilities of improvement equal to 1.000 for each outcome. Observed mean change scores ranged from 0.585 to 0.854, with the largest estimated gains associated with CLOs related to collaborative practice and professional execution. The hierarchical model estimated an overall latent mean change of 0.727 across CLOs, with a 95% credible interval of (0.019, 1.452) and a posterior probability of improvement of 0.978, indicating strong evidence of positive perceived growth at the course level.

Table 1. Course Learning Outcomes (CLOs): Pre–Post Change and Bayesian Estimates (n = 41)

Outcome	Pre Mean (SD)	Post Mean (SD)	Δ Median (IQR)	Δ Mean (SD)	Est. Δ Mean	95% CrI (2.5%, 97.5%)	P(Δ>0)
CLO1: Knowledge of CM processes & applications	3.220 (0.759)	3.805 (0.601)	1.0 (1.0)	0.585 (0.774)	0.589	(0.324, 0.855)	1.000
CLO2: Adapt/implement CM methods across the process	3.244 (0.767)	3.976 (0.524)	1.0 (1.0)	0.732 (0.742)	0.731	(0.464, 0.998)	1.000
CLO3: Evaluate buildings with green rating systems	3.024 (0.790)	3.634 (0.859)	1.0 (1.0)	0.610 (0.972)	0.613	(0.347, 0.883)	1.000
CLO4: Build collaborative relationships in industry teams	3.195 (0.813)	4.049 (0.705)	1.0 (1.0)	0.854 (1.014)	0.848	(0.565, 1.110)	1.000
CLO5: Use CM as a language/process; execute responsibly	3.195 (0.715)	4.024 (0.689)	1.0 (1.0)	0.829 (0.834)	0.825	(0.553, 1.093)	1.000

Changes in NACE Career Readiness Competencies

Table 2 presents analogous results for the eight NACE competencies. Posterior mean changes were positive for all competencies, with posterior probabilities of improvement equal to 1.000 in every case. Estimated mean changes ranged from 0.466 (Leadership) to 0.679 (Career Development). The hierarchical model estimated an overall latent mean change of 0.565 across NACE competencies (95% credible interval: 0.094 to 1.042), with a posterior probability of improvement of 0.988. These results suggest broadly positive perceived development across career readiness domains, while allowing for variability among competencies.

Table 2. NACE Competencies: Pre–Post Change and Bayesian Estimates

Outcome	Pre Mean (SD)	Post Mean (SD)	Δ Median (IQR)	Δ Mean (SD)	Est. Δ Mean	95% CrI (2.5%, 97.5%)	P(Δ>0)
Critical Thinking/Problem Solving	3.366 (0.829)	3.976 (0.790)	1.0 (1.0)	0.610 (0.771)	0.610	(0.332, 0.875)	1.000
Communication (technical & non-technical)	3.439 (0.838)	4.000 (0.742)	1.0 (1.0)	0.561 (0.867)	0.560	(0.281, 0.842)	1.000
Leadership	3.439 (0.743)	3.902 (0.700)	0.0 (1.0)	0.463 (0.925)	0.466	(0.189, 0.741)	1.000
Technology	3.293 (0.814)	3.854 (0.654)	1.0 (1.0)	0.561 (1.097)	0.563	(0.296, 0.833)	1.000
Professionalism/Work Ethic (ethics)	3.439 (0.709)	4.049 (0.669)	1.0 (1.0)	0.610 (0.833)	0.605	(0.334, 0.884)	1.000
Career Development (plans/goals)	3.488 (0.840)	4.171 (0.704)	1.0 (1.0)	0.683 (1.035)	0.679	(0.407, 0.948)	1.000

Table 2. NACE Competencies: Pre–Post Change and Bayesian Estimates

Outcome	Pre Mean (SD)	Post Mean (SD)	Δ Median (IQR)	Δ Mean (SD)	Est. Δ Mean	95% CrI (2.5%, 97.5%)	P(Δ>0)
Teamwork/Collaboration	3.512 (0.810)	4.049 (0.631)	1.0 (1.0)	0.537 (0.951)	0.540	(0.267, 0.808)	1.000
Global/Intercultural Fluency	3.341 (0.693)	3.829 (0.667)	1.0 (1.0)	0.488 (0.746)	0.495	(0.231, 0.767)	1.000

Variability Across Outcomes

Posterior estimates of the between-outcome standard deviation (τ) indicate meaningful heterogeneity in perceived growth across both CLOs and NACE competencies. For CLOs, the posterior mean of τ was 0.798, while for NACE competencies it was 0.662, suggesting greater dispersion in outcome-level effects for course-specific learning outcomes than for career readiness competencies.

Table 3. Hierarchical Model Hyperparameters (Posterior Summaries)

Set	n students	Outcomes	Overall Est. Δ Mean	95% CrI	P(Δ>0)	Between-outcome SD (τ) mean	Within-outcome SD (σ) mean	Posterior draws
CLOs	41	5	0.7268	(0.0189, 1.4524)	0.9775	0.7975	0.8791	4000
NACE Competencies	41	8	0.5651	(0.0941, 1.0423)	0.9875	0.6618	0.9124	4000

Student Rankings of Perceived Competency Growth

Students' ordinal rankings of NACE competencies provide convergent evidence supporting the model-based findings (Table 4). Critical Thinking received the lowest mean rank (highest perceived growth), followed by Leadership and Professionalism/Work Ethic. Global/Intercultural Fluency received the highest mean rank (lowest perceived growth), indicating a relative gap in perceived development within the Capstone experience.

Table 4. NACE Growth Ranking (Lower = Higher Perceived Growth)

Competency	Mean Rank	Median Rank
Critical Thinking/Problem Solving	2.439	2.0
Leadership	2.732	2.0
Professionalism/Work Ethic (ethics)	3.195	3.0
Communication (technical & non-technical)	3.951	4.0
Career Development (plans/goals)	4.756	5.0
Technology	4.780	5.0
Teamwork/Collaboration	6.341	7.0
Global/Intercultural Fluency	7.805	8.0

Discussion and Conclusion

This study explores the integration of NACE Career Readiness Competencies within a senior-level Construction Management course, Capstone, using a Bayesian hierarchical modeling framework. In this study, the findings are interpreted as expected patterns of competency

development rather than definitive outcomes, as data collection will continue across subsequent offerings of the Capstone course to strengthen the robustness and generalizability of the results. The posterior estimates derived from the current cohort provide early evidence regarding how students may experience professional growth within a Capstone learning environment that emphasizes applied problem-solving, collaboration, and industry-aligned deliverables.

Across both Course Learning Outcomes and NACE competencies, posterior distributions consistently favored positive mean change, with high posterior probabilities of improvement. These probabilistic estimates suggest that Capstone-level pedagogical structures, such as team-based project delivery, iterative feedback, and industry-contextualized problem solving, are likely to support measurable gains in students' perceived readiness for professional practice. In particular, competencies associated with critical thinking, leadership, and professional responsibility are expected to exhibit stronger growth trajectories, aligning with the central goals of Capstone coursework in construction education.

At the same time, the hierarchical model revealed meaningful variability across competencies. Competencies such as Global/Intercultural Fluency and Teamwork, while still exhibiting positive expected change, demonstrated comparatively smaller posterior mean estimates and lower perceived growth rankings. This pattern suggests that while Capstone courses may effectively reinforce technical and cognitive competencies, certain globally oriented and cross-cultural skills may require more intentional instructional scaffolding. Integrating international case studies, cross-disciplinary collaboration, or structured reflection on cultural contexts may help strengthen these areas in future iterations of the course.

Beyond its instructional findings, this study makes several important contributions to construction management education research. Pedagogically, it demonstrates a structured approach for embedding nationally recognized career readiness competencies within a Capstone learning environment that closely mirrors professional construction practice. Methodologically, the study advances assessment practices by applying a Bayesian hierarchical modeling framework, offering a transparent and flexible alternative to traditional pre–post analyses that is particularly well suited for applied educational settings with modest sample sizes and ongoing data collection. Substantively, the study contributes discipline-specific evidence to the limited body of literature examining career readiness development in construction management programs, especially at the Capstone level, where professional competencies are most directly exercised. Collectively, these contributions provide a replicable framework for educators seeking to systematically assess and refine competency-based curricula, while supporting continuous improvement aligned with evolving industry expectations.

Limitations and Future Work

Several limitations should be acknowledged. First, the study relies on self-reported measures of competency development, which may be influenced by response bias or students' evolving understanding of professional competencies over time. While self-perception is a meaningful indicator of career readiness, future work should triangulate survey data with external assessments such as instructor evaluations, industry partner feedback, or performance-based rubrics. Second, the current analysis reflects data from a single Capstone course at one institution, which may limit generalizability. Construction management programs vary widely in

curricular structure, industry engagement, and student demographics. Expanding the study across multiple cohorts and institutions would strengthen the external validity of the findings. Third, the study is explicitly ongoing, and the present results should be interpreted as preliminary posterior estimates rather than conclusions. One strength of the Bayesian framework employed here is its capacity for iterative updating. As additional student cohorts complete the Capstone course, future analyses will incorporate new data to refine posterior distributions and improve estimation precision.

Future work will focus on three primary directions. First, longitudinal tracking of multiple cohorts will enable direct comparison of competency growth across academic years and curricular revisions. Second, model extensions, such as incorporating student background variables or project typologies as predictors, will allow deeper exploration of factors influencing competency development. Finally, future analyses may integrate multivariate Bayesian models to examine interdependencies among competencies, providing a more holistic understanding of how career readiness develops within Capstone learning environments.

References

Dutson, A. J., Todd, R. H., Magleby, S. P., & Sorensen, C. D. (1997). A Review of Literature on Teaching Engineering Design Through Project-Oriented Capstone Courses. *Journal of Engineering Education*, 17–28.

Goodarzi, M. (2023). Implementing NACE Competencies in LEED Lab to Prepare a Career-Ready Workforce. *ASEE Annual Conference and Exposition, Conference Proceedings*. https://doi.org/10.18260/1-2--43554

Goodarzi, M., Breakah, T., & Garshasby, M. (2025). *The Impact of NACE Competency Integration on Students' Perceived Career Readiness in Construction Management Education*. https://doi.org/10.18260/1-2--57233

NACE Career Readiness Taskforce. (2023). *Strategic Approaches to Integrating Career Readiness Competencies*.

National Association of Colleges and Employers (NACE). (2024). *What is Career Readiness?* https://www.naceweb.org/career-readiness/competencies/career-readiness-defined/

Newell, M. K. J., & Ulrich, P. N. (2022). Competent and employed: STEM alumni perspectives on undergraduate research and NACE career-readiness competencies. *Journal of Teaching and Learning for Graduate Employability*, *13*(1), 79–93. https://doi.org/10.21153/JTLGE2022VOL13NO1ART1534

Passow, H. J., & Passow, C. H. (2017). What Competencies Should Undergraduate Engineering Programs Emphasize? A Systematic Review. *Journal of Engineering Education*, *106*(3), 475–526. https://doi.org/10.1002/jee.20171

Webber, K. L., Stich, A., Grandstaff, M., & Case, C. (2023). Board 402: The Importance of Career Competencies for Engineering Students. *2023 ASEE Annual Conference & Exposition Proceedings*. https://doi.org/10.18260/1-2--43140