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(Case Study) Generative AI and the Future Engineering Workforce: Bridging Educational Gaps through Employer Insight and Data-Driven Analysis

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Abstract: With generative AI rapidly reshaping engineering practice, higher education faces growing pressure to prepare students and professionals for evolving workforce expectations. This paper presents preliminary findings from semi-structured interviews with civil, construction, and environmental engineering (CCEE) employers and alumni affiliated with a large, public R1 university. Interviews aimed to understand: (1) AI training and workforce development needs, (2) how training pathways shape professionals' perceptions of AI's opportunities, risks, and ethics, and (3) the role of universities in preparing graduates for AI-enabled engineering practice. Preliminary results indicate that perceptions of AI are shaped less by employers' beliefs about its disruptive impact than by exposure and training, with training possibly mediating the outlook, ethical concerns, and expectations for workforce readiness and university involvement. This work-in-progress is a preliminary analysis for a multi-college interdisciplinary project whose findings will inform future survey development, workforce analytics integration, and the design of AI-infused CCEE curricula, certificates, and industry-engaged learning pathways.

Keywords: civil engineering education, AI in the workplace, labor analytics, Workforce Preparedness, industry engagement, Curriculum Innovation, survey, Interview, qualitative research

Introduction

With Artificial Intelligence (AI) poised to rapidly transform technical work, the STEM workforce faces both disruption and opportunities. These shifts raise critical questions about how higher education can adapt to prepare students and working professionals for changing employer expectations [1]. In civil, construction, and environmental engineering (CCEE), this challenge is particularly urgent: the industry is grappling with waves of retirement, long-standing hiring and diversity gaps, and pandemic-era shifts in work and training [2] [3]. Like computer technology drastically changed engineering practice, generative AI has the potential to either exacerbate or bridge these challenges, depending on how educational institutions respond [4] [5] [6].

AI adoption is accelerating in practice, but training pathways and expectations for engineers are unclear and uneven, particularly the role of universities when students and employers are navigating the technology training simultaneously [1] [2] [3]. This paper presents preliminary findings from a qualitative study based on semi-structured interviews with civil engineering employers and alumni affiliated with the CCEE department of NC State University, a large, public land-grant research one (R1) university (NCSU). The study is designed to inform departmental decision-making around AI curriculum development and workforce engagement. Specifically, this paper focuses on three research questions: (1) what AI training and workforce development needs exist among civil engineering students and professionals; (2) where current AI users in civil engineering receive training, and how this shapes their perceptions of AI's opportunities, risks, and ethics; and (3) what role CCEE departments should play in preparing students and supporting alumni in an AI-enabled profession.

Background and Institutional Context: CCEE and AI Workforce Preparation

Early policies prohibiting the use of AI tools in university coursework have become more tolerant and nuanced [7]. Engineering programs are now transitioning toward instructional

approaches that emphasize responsible, transparent, and discipline-specific AI use [8]. Within NCSU, and the College of Engineering in particular, there is a growing recognition that AI literacy and fluency are becoming core professional competencies. As many practicing engineers and faculty are learning generative AI tools at the same time as students, employers frequently expect new graduates and early-career engineers to lead AI adoption and initiatives. The NCSU CCEE Department recognizes the need for employer-informed curriculum development, rather than technology-driven curriculum changes. This study serves as a foundational needs assessment to inform the CCEE department's potential directions for AI-related curricular and workforce initiatives: integration of AI topics into existing coursework, pilot AI-infused courses, data science and AI minors and certificates, and student–industry co-learning opportunities.

Methodology: Civil Engineering Interviews and Preliminary Analysis

We conducted a qualitative study based on semi-structured interviews with alumni and employers affiliated with the CCEE Department. The interview protocol asked questions on current and emerging uses of AI in engineering practice (broadly, including generative AI), workforce readiness, AI training, ethical considerations, and expectations for new graduates and the role of universities. Thus far, nineteen interviews have been conducted remotely via Zoom, audio-recorded, transcribed, and anonymized prior to analysis. Interviewees represented construction, contracting, transportation, and civil/environmental engineering organizations ranging from 2 to over 9,000 employees, with ages from 30s to 70s and roles including CEOs/Principals (29%), Vice Presidents (38%), and Regional Leads/Directors (19%).

Qualitative analysis followed a template analysis approach, in which two researchers conducted first-cycle open coding on a subset of transcripts to develop an initial codebook that was iteratively refined and applied across the full dataset. We utilized large language models to support second-cycle codebook refinement (OpenAI's ChatGPT 5.2) and, after verifying using human coding, for coding full interviews (*OpenAI* package in python using *gpt-5*). Based on code counts for relevant subsets of codes, interviewees were comparatively positioned along key analytic dimensions (e.g., optimism versus pessimism, incremental versus disruptive impact, training sufficiency, university influence). To verify code-based categorization, interviewees were also numerically scored from -1 to 1 on each dimension using *gpt-5*, verified with human coder scoring. Code co-occurrence and correlational analysis of these dimensions were used to identify patterns across interviews that support early identification of themes and interviewee clusters that will inform survey development for subsequent quantitative analysis.

Table 1: Preliminary analysis approaches for each research question in this paper

Research Question	Preliminary Analysis Approach
1. Training needs	Qualitative summary of responses related to AI and engineering skills training gaps for professional engineers and new graduates
2. Training versus AI perceptions	Qualitative summary of perception of training sufficiency dimensions and their comparative correlations with other analytic dimension scores
3. University role	Qualitative summary and correlations of university role with other dimension scores

Results

Interviewee Clusters

Interviewees can be broadly categorized into four clusters based on relative beliefs along certain dimensions. Figure 1 is a conceptual representation showing clusters in relation to two of these dimensions: AI outlook on the x-axis (pessimistic versus optimistic), versus AI impact on the y-axis (incremental versus disruptive). The shaded gradient illustrates that perceived training sufficiency (formal and informal) varies with AI outlook, but not necessarily impact. "Guarded" interviewees saw the potential impact of AI on engineering practice as lower and more incremental, with a relatively less optimistic outlook. Those who acknowledged AI's growing role but emphasized incremental integration, with moderate outlook, were labeled "Cautious." Those who viewed AI as highly impactful with higher trust in engineers' ability to adapt were "Optimistic," whereas the "Risk-Focused" expressed high potential impact, but with greater concern about potential risks.

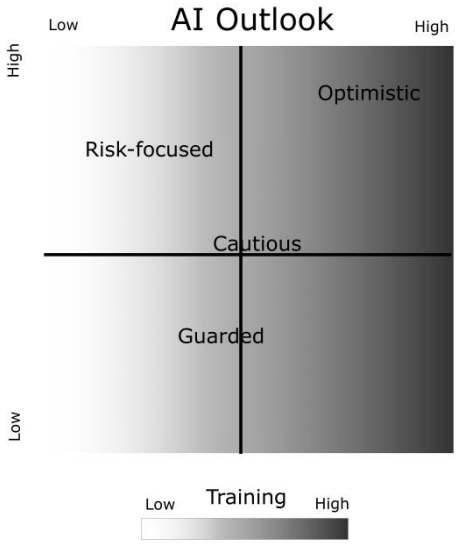

Figure 1: Interviewee clusters plotted along two code theme dimensions: AI Outlook (pessimism (low) → optimism (high)), AI Impact (incremental (low) → disruptive (high))

Code Co-occurrence Patterns

Figure 2 shows a heatmap of the Pearson correlation coefficients of each analytical dimension score against each other for each interview (n=19). For example, in the first column, positive AI outlook (optimism) shows weak-moderate and moderate-high positive correlation with greater sufficiency of self-training and influence of universities (0.30, and 0.74, respectively), but weaker/no correlations with AI impact and sufficiency of workplace training (0.05 and -0.24). Perceived AI impact did not have any strong correlations, showing interviewees who viewed AI as highly disruptive held a range of positive or negative perspectives on the other dimensions. Perceived sufficiency of training also correlated more with AI outlook (optimism), but not with perceived impact (disruptive potential), as also represented by the training gradient in Figure 1 (representing overall training—workplace and self-training). Perception of a strongly positive university role influencing AI in engineering correlated most with optimistic outlook (0.74), and moderately with greater perceived efficiency of self-training (0.44).

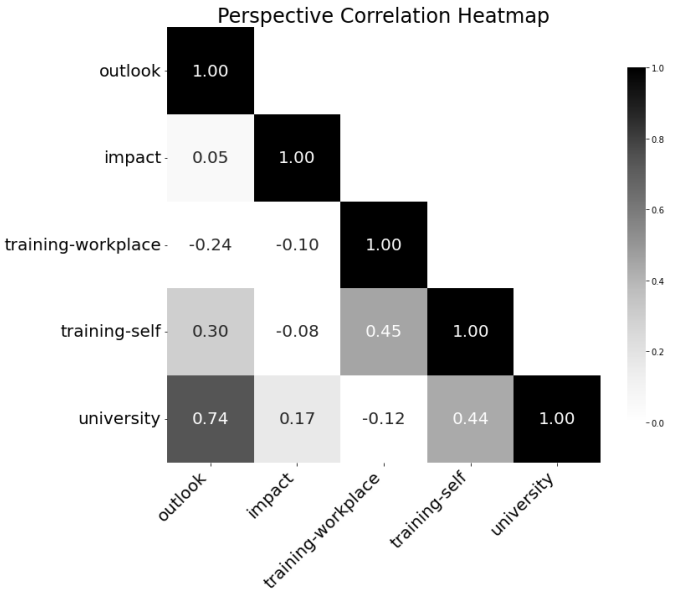

Figure 2: Correlation heatmap of code theme co-occurrence (outlook: pessimism → optimism; impact: incremental → disruptive; workforce- and self-training sufficiency, university impact

AI Training and Workforce Development Needs
Interviewees described widespread adoption of AI for writing and workflow acceleration, alongside the need for output verification and retention of core engineering skills and judgment. Many interviewees described workplace AI training and policies as non-existent, in-progress, or in their first iteration. Many expressed a basic desire to learn the extent of potential uses for AI tools and several mentioned reliance on new graduates for those answers, with some describing interdependency between newer and experienced engineers for cross-training AI tools and engineering competency. Reported training gaps were most acute at the workplace level, where expectations for rapid productivity gains often outpaced formal support, particularly for new graduates sometimes seen as over-reliant on AI for basic knowledge or lacking necessary training to verify outputs.

Training Shapes Trust, Ethics, and Perceived Risk
Self-training was the dominant mode of AI exposure amongst interviewees, with workplace training often perceived as unavailable or unused. Perceived sufficiency of self-training and workplace training were correlated with each other, but workplace training, being less available/adopted, had weaker correlations with other dimensions. Those with more sufficient self-training, on the other hand, tended to express more optimism about the role of AI in engineering practice and perceived university role, and less pessimism about ethical and legal AI risks. Training was more correlated with outlook than with impact. These patterns suggest that attitudes toward AI are closely tied to learning environments; tendency towards self-training either co-occurs with optimism or potentially greater exposure shapes outlook, ethical and professional perceptions of AI use.

Expectations for New Graduates and the Role of CCEE
Some respondents articulated a clear expectation that universities should introduce foundational AI literacy and emphasize verification and professional judgment. Additionally, belief in a strong university role correlated strongly with confidence in self-training, but not with perceived disruption potential. This suggests that expectations for academic intervention are driven not by the degree of perceived impact but are instead tied to AI exposure and degree of perceived optimism and risk.

Future Work
This paper presents early qualitative findings based on preliminary analysis of nineteen civil engineering employer interviews; future work will deepen the analysis through a more formalized qualitative research process. This preliminary analysis reports qualitative analysis by one coder after second-cycle refinement. Subsequent analysis will involve at least two analysts conducting systematic, iterative coding of interview transcripts with the aid of AI-assisted qualitative analysis tools, assessing intercoder agreement to converge to a finalized codebook.

Findings from the finalized qualitative analysis will directly inform the development of a survey instrument for deployment to a larger and more interdisciplinary population of the University alumni and employers inside and outside engineering disciplines. Survey items will further explore AI training pathways, trust and verification practices, perceptions of AI-driven change, and expectations for universities and employers, and illicit responses to support quantitative verification of the prevalence and strength of themes identified qualitatively. This mixed-methods approach will examine how AI penetration, perceptions, ethics, and workforce development needs differ across fields and industries (Co-investigators at the University include: CCEE, Computer Science, Poole College of Management, Operations Research, College of Natural Resources, and the Institute of Advanced Analytics).

Future work will integrate survey results with workforce and labor analytics relevant to the civil engineering sector in North Carolina and the broader NCSU alumni and employer network. These data will support evidence-based decision-making related to workforce demand, skill gaps, and regional trends in AI adoption. Together, qualitative and quantitative findings will inform the design and evaluation of AI-focused educational interventions within the NCSU CCEE department, including pilot AI-infused courses, certificates and micro credentials, and project-based learning opportunities for both students and practicing professionals.

AI statement
In this work, the authors used ChatGPT 5.2 to assist with codebook refinement, thematic pre-analysis of sanitized transcripts, and editing of manuscript language. Coding of sanitized transcripts was conducted with *gpt-5* in python *OpenAI* package and validated with human coding. The authors reviewed, edited, and validated all outputs, taking full responsibility for the accuracy, interpretation, and originality of the final content.

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