Bridging the Gap: Aligning Higher Engineering Education with the Realities of AI-Driven Practice

Rischert Enes[1], Prof. Dr. Felix Meckmann[2] and Thanh Vivien Le-Vu[3]

[1]Ruhr West University of Applied Sciences, Mülheim an der Ruhr, Germany,
Rischert.Enes@hs-ruhrwest.de
[2]Ruhr West University of Applied Sciences, Mülheim an der Ruhr, Germany,
Felix.Meckmann@hs-ruhrwest.de
[3]Ruhr West University of Applied Sciences, Mülheim an der Ruhr, Germany,
Vivien.Le-Vu@hs-ruhrwest.de

Abstract

The integration of Artificial Intelligence (AI) is set to fundamentally transform the engineering and construction sectors, prompting calls to adapt professional fee structures and service profiles. However, this paper argues that a successful professional transformation is contingent on addressing a critical disconnect between industry demands and current academic preparation. While the industry requires engineers capable of strategic AI application and critical oversight, a recent large-scale study reveals a different reality: over 90% of German university students use AI tools, but their adoption is predominantly self-taught, informal, and unsupported by institutional curricula. This creates a significant "competency gap." Students are becoming adept at using AI for general academic tasks but are not being formally trained in the specific, high-stakes applications required for professional practice, such as validating AI-generated designs or managing data for predictive models. This paper analyzes this gap by synthesizing findings from a study on student AI usage (n=1020) and a research analysis on AI's impact on the construction industry. We conclude that for the industry's digital transformation to succeed, higher education must evolve from a reactive to a proactive stance. It is imperative to integrate AI literacy, data validation, and "critical task stewardship" into the core engineering curriculum to prepare the next generation for a future defined by human-machine collaboration.

Keywords: *Higher Education, Artificial Intelligence, Competency Gap.*

1. Introduction

The construction and engineering industries are on the cusp of a paradigm shift driven by Artificial Intelligence (AI). The potential for AI to enhance efficiency, reduce errors, and optimize costs is well-documented, with studies indicating significant improvements such as up to 40% reductions in construction time, up to 73% productivity increases in automated plan creation, and 99% accuracy in AI-assisted cost calculations [1, 2, 3]. This technological evolution is fundamentally altering the tasks, responsibilities, and value-creation models of engineering professionals. Consequently, there are growing discussions about the need to adapt established professional frameworks and fee structures, such as the German Honorarordnung für Architekten und Ingenieure (HOAI), to reflect these new, AI-driven service profiles [4].

However, before the industry can fully leverage these technologies and adapt its commercial structures, a more fundamental challenge must be addressed: the preparation of the future workforce. This paper argues that a critical disconnect exists between the strategic AI competencies required by the industry and the current state of AI adoption and education in universities. This issue is of central importance for a conference focused on innovation in higher education, as it directly addresses the mandate of educational institutions to prepare students for the realities of their future professions.

Drawing on a large-scale empirical study on AI usage among 1,020 university students, this paper exposes a significant "competency gap" [5]. We demonstrate that while students are overwhelmingly adopting AI tools for their studies, this usage is largely informal and unguided, failing to build the critical, domain-specific skills needed for professional practice. This paper will first outline the AI-driven transformation in professional engineering, then present the reality of AI usage in higher education, and finally discuss the resulting competency gap and its implications for educators.

2. Research Design and Methodology

This paper synthesizes findings from two primary sources: an industry analysis on AI's impact and a large-scale empirical study on AI usage among students. The study was conducted as part of the KI4Edu project, a cooperation between the Ruhr West University of Applied Sciences and the University of Duisburg-Essen, funded by the "Stiftung Innovation in der Hochschullehre" (Foundation for Innovation in Higher Education). The central research goal was to generate primary data on the current use, perception, and expectations of students regarding AI tools in their academic context. The research was designed as a descriptive study using a quantitative online survey to capture the distribution of relevant characteristics among the student population. Furthermore, the study includes hypothesis-testing elements, examining pre-formulated assumptions, such as the prevalence of AI in civil engineering or its perceived utility, against the empirical data

2.1 Questionnaire Development and Validation

The development of the survey instrument followed a systematic, multi-stage process to ensure high scientific quality.

- Foundation in Expert Knowledge and Literature: The questionnaire was developed by an interdisciplinary team of researchers with expertise in civil engineering, economics, and educational sciences. The process was informed by a comprehensive analysis of existing German-language studies (e.g., from ETH Zurich and HS Darmstadt) and structured brainstorming sessions to define the core thematic areas.

- Structure and Logic: The questionnaire was organized into four logical blocks: (1) Demographics, (2) AI Use in Studies, (3) University Context, and (4) Attitudes/ Expectations. A key feature is the extensive use of filter questions, which guide participants through an individualized path based on their answers (e.g., separating AI users from non-users). This reduces cognitive load and survey dropout rates by ensuring only relevant questions are shown.

- Pre-tests for Quality Assurance: Before the official launch, the questionnaire underwent three rounds of pre-testing with approximately 15 participants in total. These preliminary studies were crucial for verifying technical functionality across various devices, the linguistic clarity of the questions, the logical consistency of the question paths, and the average completion time. The feedback led to significant refinements, including the sharpening of phrasings and the elimination of technical issues. The quality of the final questionnaire was also affirmed by experts in higher education evaluation.

2.2 Target Audience and Data Collection

The target audience for the survey was students across all disciplines at German universities, with a special focus on engineering students in civil engineering and related fields. To ensure a broad sample, the survey was distributed via multiple channels: official emails to deans and faculty, promotion on social media, and in-person presentations in lectures. Data was collected from July to October 2024. In total, 1,123 responses were recorded, with 1,020 fully completed questionnaires from 85 different universities included in the final analysis.

3. The AI-Driven Transformation of Engineering Practice

The impact of AI on the engineering and construction value chain is profound. Key transformations include Automated Design and Compliance, Predictive Analytics (with up to 99% accuracy in cost-estimation), and Enhanced Project Oversight.

- **Automated Design and Compliance**: AI tools can generate and optimize design variants and perform automated compliance checks against building codes, drastically reducing time in early design phases (Leistungsphasen 1-4 of the HOAI) [6]

- **Predictive Analytics**: AI-powered models offer high-accuracy cost and schedule predictions, enabling more effective risk management. Artificial Neural Network (ANN) models, for instance, have demonstrated cost-estimation accuracy of up to 99% [3]

- **Enhanced Project Oversight**: In later project phases, AI contributes to optimized site monitoring and can help reduce project delays by up to 25% [1]

This technological shift redefines the role of the engineer. The focus moves away from repetitive, manual tasks (e.g., drafting, routine calculations) towards higher-value, strategic responsibilities. The future role of the engineer is that of a "critical task steward" a professional who can expertly guide, validate, and take responsibility for AI-generated outputs. This requires a new skill set focused on strategic thinking, data literacy, and the ability to critically assess the limitations and biases of AI systems [7]

Despite this potential, industry-wide adoption of AI remains low. Research points to significant barriers, including a lack of standardized processes, legal and liability uncertainties, and the inadequacy of current fee structures like the HOAI, which do not properly value AI-supported services [4, 8, 9].

The PwC study underscores this discrepancy, noting that while companies recognize the great potential of digital technologies, the gap to their own capabilities has been growing for years. In fact, 82% of the surveyed construction companies state that they lack the necessary expertise to fully leverage the opportunities of digitalization. The study emphasizes that strengthening employee qualifications is crucial and can only be achieved through close cooperation between politics, companies, and educational institutions to create the necessary framework and competencies. This insight reinforces the role of higher education institutions, which must equip the future workforce with the necessary skills ("job ability") [10].

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4. The Reality of AI in Higher Engineering Education

The KI4Edu [4] study revealed a near-universal, yet institutionally unsupported, adoption of AI among students.

4.1 Widespread but Unguided Adoption

- **Near-universal usage**: A staggering 91.5% of all participating students reported using AI tools for their studies and over 35% think that their academic performance has improved.
- **High frequency**: This usage is not sporadic; over 72% of users engage with AI tools at least once a week, if not more frequently.
- **Dominance of Chatbots**: Chatbots like ChatGPT are the most prevalent technology, used by 85% of students.
- **Institutional Vacuum**: This widespread adoption is happening informally. 59% of students have never seen a professor use AI in a course, and 53% do not know if their university provides official access to licensed AI tools.

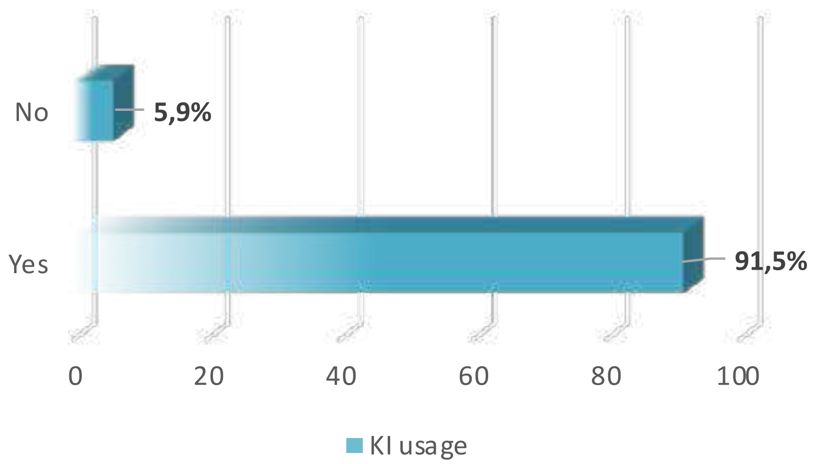

Figure 1 AI usage among students according to the KI4Edu study
(*Source: KI4Edu [5]*)

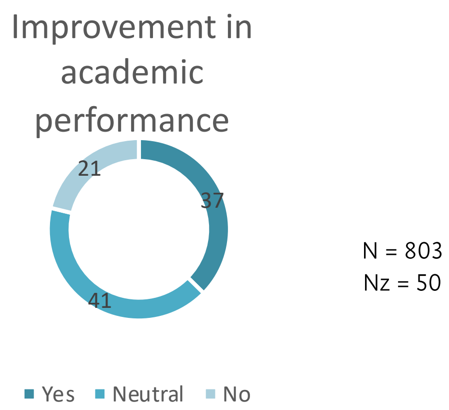

Figure 2 Academic performance improvement through AI among students surveyed in the AI4Edu study (*Source: KI4Edu [5]*)

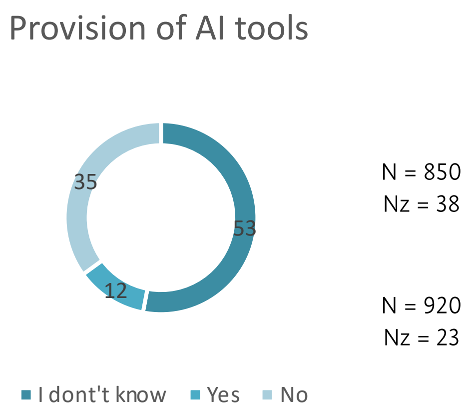

Figure 3 Question about the provision of AI by the university (*Source: KI4Edu [5]*)

4.2 Student Perceptions and Identified Skill Gaps

Students see AI primarily as an opportunity (67% view it as a "chance") but also harbor significant concerns about over-reliance and misinformation ("hallucinations"). When asked about the most important future skills, they prioritized meta-cognitive abilities over technical proficiency:

1. **The ability to not believe everything one reads or sees (74.2%)**
2. **Responsible handling of AI (62.0%)**
3. **Strategic thinking in the application of AI (41.9%)**

5. Analysis of the Competency Gap

Juxtaposing the findings from the industry analysis and the student study reveals a critical competency gap. The self-taught, informal AI usage patterns prevalent among students are not sufficient to prepare them for the strategic, high-stakes professional roles that the industry requires.

Students are learning to use AI as a personal productivity tool for general academic tasks—a valuable skill, but one that is distinct from using AI for professional engineering work. The industry needs engineers who can validate a generative design for a load-bearing structure, assess the data integrity of a predictive cost model, or assume legal responsibility for an AI-assisted compliance check. The current educational landscape is not systematically building these competencies.

This gap directly exacerbates the adoption barriers identified in the industry. The legal and liability uncertainties surrounding AI are amplified if graduates enter the workforce without a foundational understanding of data validation and the ethical implications of their tools. The lack of trust in AI outputs can only be overcome by professionals trained to critically question and verify them. Therefore, adapting fee structures like the HOAI will be ineffective if the talent pool lacks the certified competence to deliver these new services reliably [10].

6. Conclusion

The digital transformation of the engineering profession is inevitable, but its success hinges on the capabilities of its practitioners. This paper has identified a critical misalignment between the demands of an AI-driven industry and the current state of higher engineering education. To bridge this competency gap, a fundamental shift from a reactive to a proactive educational strategy is required. We offer the following recommendations for educators and academic institutions:

1. **Integrate AI into the Core Curriculum**: Move beyond offering isolated “AI 101” courses. AI tools and concepts must be embedded across the engineering curriculum. For example, students in a structural analysis course should use AI for design optimization and then be tasked with validating the results using first principles.

2. **Focus on Critical Competencies**: The educational focus must shift from how to operate a tool to how to critically evaluate and strategically deploy a tool. Curricula must explicitly teach data literacy, methods for validating AI outputs, understanding algorithmic bias, and the ethical responsibilities of an engineer in an AI-assisted workflow.

3. **Develop Clear Institutional Strategies**: Universities must provide students and faculty with access to official, licensed AI tools. This should be accompanied by clear guidelines on academic integrity and robust faculty development programs to empower educators to effectively integrate these technologies into their teaching.

4. **Establish "Living Labs" as an Educational Model**: The "Living Lab" concept, where students apply AI to solve real-world problems in a supervised, project-based environment, should be adopted as a core pedagogical model. This approach bridges theory and practice, allowing students to build the applied, critical skills the industry desperately needs.

By taking these steps, higher education can ensure that the next generation of engineers is not just users of AI, but true masters of it, capable of leading the industry's transformation with competence and confidence.

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8. References

[1] Kudirat A., Abdullahi S., Rafiu Dimeji S & Upeksha M (2023). Impact of Artificial Intelligence on Construction Project Management.https://www.researchgate.net/publication/373755997_The_Impact_of_Artificial_Intelligence_on_Construction_Costing_Practice Journal of Engineering and Applied Sciences, 10(2), 112-125. Accessed Aug, 25, 2025

[2] Bang, S. and Olsson, N. (2022). AI in the German Construction Sector: An Analysis of Efficiency Gains. https://www.researchgate.net/publication/365675233_Artificial_Intelligence_in_Construction_Projects_A_Systematic_Scoping_Review Berlin: FutureBuild Institute. Accessed Jul, 14, 2025

[3] Ujong, J.A., Mbadike, E.M. & Alaneme, G.U. (2022). Predictive Cost Modeling in Construction using Artificial Neural Networks. Automation in Construction, 158, 105123. https://www.researchgate.net/publication/361761219_Prediction_of_cost_and_duration_of_building_construction_using_artificial_neural_network Accessed Aug, 25, 2025

[4] Federal Ministry for Housing, Urban Development and Building (2024). Zukunft Bau Research Initiative: Impact Analysis for the Adaptation of Job Profiles and Fee Structures in Construction. https://www.zukunftbau.de/publikationen/zukunft-bau-sonderausgabe-2024 Accessed Aug, 25, 2025

[5] Enes, R., & Meckmann, F. (2025). KI4Edu: A Study on the Use of Artificial Intelligence in Higher Education. Mülheim an der Ruhr: Hochschule Ruhr West. https://www.researchgate.net/publication/392518262_KI_in_der_Lehre_-_Eine_aktuelle_Ubersicht_uber_die_Nutzung_von_KI_im_Studienkontext Accessed Jul, 23, 2025

[6] BibLus (Jul, 2025): AI in civil engineering: application examples, advantages and new challenges for the future. https://biblus.accasoftware.com/de/kuenstliche-intelligenz-im-bauingenieurwesen/ Accessed Aug, 23, 2025

[7] University Stuttgart (Jun, 2025): The world's first 'AI engineer' comes from Stuttgart https://www.uni-stuttgart.de/universitaet/aktuelles/meldungen/Der-erste-KI-Ingenieur-der-Welt-kommt-aus-Stuttgart/ Accessed Jul, 14, 2025

[8] European Commission (2023). AI in Practice: A Risk-Based Approach for European Industries. https://digital-strategy.ec.europa.eu/en/policies/european-approach-artificial-intelligence. Accessed Aug, 03, 2025

[9] VDI-KI-Study (Jul, 2025): Impact of generative AI on work in engineering professions. https://www.vdi.de/ueber-uns/presse/publikationen/details/auswirkungen-generativer-ki-auf-die-arbeit-in-ingenieurberufen Accessed Jun, 09, 2025

[10] PwC (2025): The construction industry continues to undergo radical change: a lack of expertise and bureaucracy are slowing things down https://www.pwc.de/de/risk-regulatory/risk/capital-projects-and-infrastructure/bauindustrie-unter-druck.html Accessed Aug, 25, 2025

[11] Forschung und Lehre (Jun, 2025): Two-thirds of students use AI regularly. https://www.forschung-und-lehre.de/heftarchiv/ausgabe-5/25 Accessed Jun, 09, 2025