Mapping Software-Engineering Industry AI Use to Software-Engineering Curriculum: Developing the AI-USE Framework

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Abstract: Estimates predict a global deficit of 4 million software engineers by 2025, further complicated by the software engineering (SE) industry's escalating use of artificial intelligence (AI). To tackle this issue, our research suggests that computer science (CS) curricula in middle and high schools need to be updated to incorporate SE industry segments that significantly employ AI. This strategic curriculum alignment is significant for preparing a workforce equipped to meet future industry demands. Our initial analysis involved reviewing nine international AI education guidelines to evaluate current methods for integrating AI into SE education. The findings indicated a pronounced lack of specific guidance connecting AI applications in the SE industry with educational content. To address this, we performed a systematic literature review of 12 research papers focusing on AI's role across the SE industry, followed by multiple rounds of inductive content analysis. An industry segment was deemed "essential" if it was referenced in 75% or more of the papers' findings. Through this method, we identified 10 essential SE industry segments for inclusion in CS education: software development, software maintenance, process improvement, software economics, knowledge management, project management, software testing, software security, quality assurance, and deployment and operations (DevOps). These findings led to the creation of the AI-USE (Artificial Intelligence Usage in Software Engineering) framework, which maps these 10 key segments to the predominant uses of SE in the industry as identified in the literature. Further inductive content analysis helped us develop subsegments for these essential areas. Ongoing framework development involves refining these subsegments and gathering feedback from industry and academic professionals. We anticipate that the fully developed AI-USE framework will significantly enhance SE education, equipping the next generation of software engineers with the AI proficiency required to address the industry's evolving demands.

Keywords: Artificial intelligence in education, Generative AI, Computer science education, Software engineering, SE education

1. Introduction

The demand for software engineers represents an immediate concern especially since the software engineering (SE) industry is expected to grow 25% in the next four years (Stavaridis, 2023). This growth exacerbates the challenges in "...developing complex software systems that meet quality standards and deadlines, as traditional methods involve time-consuming and repetitive tasks often resulting in delays and cost overruns" (Stavaridis, 2023). The complexity of modern software systems necessitates more efficient and effective development methods.

Artificial intelligence (AI) tools like GitHub Copilot and ChatGPT are transforming the SE industry. The increasing reliance of the SE industry on AI is transforming development practices across all stages of the software development life cycle (SDLC). AI tools support human developers by automating routine tasks, enabling them to focus on more creative and complex aspects of software engineering. Additionally, AI tools can provide the ability to "...automatically document software codes and provide debugging routines that offer automated suggestions for improvement or deliver code examples for particular problem sets" (Barenkamp, 2021). Additionally, AI tools can increase efficiency and productivity by using neural networks that can "...assist software coding, allowing for natural language to be processed into software code" will increase efficiency and productivity (Stavaridis, 2023).

Although AI technologies can provide benefits to software engineers, the SE industry still faces challenges in ensuring that the workforce has the necessary skills to leverage these AI technologies effectively. Focusing on the education of future software engineers can help mitigate these challenges. As AI-driven tools like GitHub Copilot and automated testing frameworks become more prevalent, they introduce new security vulnerabilities and testing challenges that must be addressed to ensure the safety and reliability of software systems. These challenges are especially key in the context of the software supply chain, where the rapid spread of AI-generated or AI-tested code can exacerbate security risks on a global scale. Addressing these issues within SE education is essential to prepare the next generation of engineers for the complexities of AI-integrated development environments. Aligning middle and high school computer science (CS) curricula with industry needs in software engineering and computer science, particularly in the area of AI, is essential for several reasons. First, it ensures that students acquire relevant skills that are in high demand in the job

market, improving their employability. The rapid advancement and integration of AI in various industries necessitate a workforce proficient in AI technologies and methodologies. By incorporating AI experience into early CS education, students can develop a strong foundation that prepares them for future careers in these emerging fields. Second, early exposure to AI concepts and tools can stimulate students' interest and engagement in computer science. This engagement can foster a deeper understanding and appreciation of the subject, potentially leading to increased enrolment in CS courses and a more diverse and robust pipeline of future software engineers.

Incorporating SE industry-relevant skills and knowledge into middle and high school curriculum can help bridge the gap between education and practical application. Garousi et al, 2019 stated that "...it is important to synthesize and aggregate the results of all of these studies to provide a single "consolidated" view on how to align SE education with industry needs, and to find out the most important skills in the industry and the knowledge gaps, i.e., the SE topics that should get more education and training." This alignment ensures that the education system produces graduates who are ready to meet the current and future needs of the industry, contributing to the overall growth and innovation within the field. Garousi et al. (2019) conducted a review that showed "...the importance of SE professional practice and soft skills in general, the importance of certain areas in SE education (especially requirements, design and testing), knowledge gaps in specific areas of SE (especially configuration management, SE models and methods as well as SE process), and the importance of real- world examples in SE courses." However, their research did not focus on the integration of AI in SE industry practice.

As mentioned previously, AI tools like GitHub Copilot are transforming the software development process by automating routine tasks and providing contextually relevant code suggestions, which can significantly improve efficiency and productivity. However, the successful integration of these technologies in professional environments requires a workforce that is adept at using and managing AI tools, highlighting the importance of integrating these experiences into educational curricula while maintaining a focus on strong oversight and best practices in security. The overarching objective of our research consists of developing the AI-USE (Artificial Intelligence Usage in Software Engineering) framework to give guidance to SE educators in effectively conveying methods of AI usage in the SE industry, better preparing SE students for the workforce.

2. Methodology

The development of the AI-USE framework consisted of multiple steps including: reviewing current AI education guidelines, conducting a systematic review of research papers, identifying industry segments, and identifying industry subsegments. The authors of the paper both have over 10 years of CS teaching experience as well as several years of software development experience. Both authors have presented on the use of AI in the high school and middle school levels at cybersecurity conferences and AI symposiums. Additionally, one author has conducted qualitative and quantitative research for over 10 years and holds a U.S. patent for a SE project that was completed for the U.S. Department of Defense (DoD).

2.1 AI Guidelines Review

For our framework development process we began by examining nine international AI education guidelines published within the last three years. We conducted searches to identify AI education guidelines and focused on ones that addressed AI in education from 2021 to present. Table 1 shows the nine education guidelines selected and reviewed for the current study. The main focus points of the educational guidelines included AI literacy and comprehensive education, ethical AI utilization, professional development and competency, AI in curriculum design and other areas.

Table 1: Nine International AI Education Guidelines

Title (Organization)	Year
Computing Curricula 2020 CC2020 Paradigms for Global Computing Education (Association for Computing Machinery (ACM) and Institute of Electrical and Electronics Engineers (IEEE))	2021
Artificial Intelligence and Education: A critical view through the lens of human rights, democracy, and the rule of law (Council of Europe)	2022
Teachers' AI digital competencies and twenty-first century skills in the post-pandemic world (Springer)	2023

Title (Organization)	Year
Artificial Intelligence and the Future of Teaching and Learning: Insights and Recommendations (U.S. Department of Education)	2023
AI literacy in K-12: a systematic literature review (International Journal of STEM Education)	2023
Artificial intelligence (AI) learning tools in K-12 education: A scoping review (Journal of Computers in Education)	2024
Guidance, Considerations, & Intentions for the Use of Artificial Intelligence in West Virginia Schools (West Virginia Board of Education)	2024
Generative AI Implementation Recommendations and Considerations for PK-13 Public Schools (North Carolina Department of Public Instruction)	2024
Human-Centered AI Guidance for K-12 Public Schools (Office of Superintendent of Public Instruction)	2024

Although the nine AI education guidelines provided general guidance in education regarding AI integration, our analysis identified a gap in the linking of SE industry AI usage to education. The gap between AI use in SE education and current industry practices with regards to AI provided the basis for the next steps in our research. The SE industry is using AI in ways that are not addressed in current curricula guidance.

2.2 Identification of Essential AI-Related SE Industry Segments

After identifying the lack of connection between SE industry AI usage and education, we conducted a systematic literature review research papers on AI use in the SE industry. The selection of these papers followed a pre-set criterion to ensure a comprehensive and unbiased review. We did a systematic online search using strings including "Research on Software Industry AI Use", "AI usage in the SE industry research", "AI usage in SE industry education" among others. From the initial search results, we screened papers based on the relevance to the SE industry, the presence of empirical data, and the discussion of AI applications (Table 2). Papers that did not meet these criteria were excluded.

Table 2: Criterion for selection process

Criterion	Description
Relevance to SE Industry	The paper must discuss AI applications within the context of the software engineering industry.
Empirical Data	The paper should include empirical data or case studies demonstrating the use of AI in SE.
Discussion of AI Applications	The paper should provide detailed information on AI technologies used in software development.
Evaluation of AI Tools	The paper must include methods and metrics for evaluating AI tools, such as code quality and productivity impacts.
Human-AI Interaction	The paper should examine interactions of human developers and AI tools.
Ethical and Privacy Considerations	The paper should discuss ethical implications and privacy concerns related to AI use in SE.
Impact on Skill Development	The paper should address how AI tools and concepts impact skill development and training in SE.

We determined that using guidance from the industry and its current AI usage based on research we could identify key segments impacted by AI on the SE industry.

Table 3: Research papers used in analysis

Title (Organization)	Year
Artificial Intelligence, Automation and Work (National Bureau of Economic Research)	2018
Systematic review of research on artificial intelligence applications in higher education – where are the educators? (International Journal of Educational Technology in Higher Education)	2019
Applications of AI in classical software engineering (AI Perspectives)	2020
Investigating Explainability of Generative AI for Code through Scenario-based Design (ACM)	2022
Productivity Assessment of Neural Code Completion (ACM)	2022
The Robots Are Coming: Exploring the Implications of OpenAI Codex on Introductory Programming (ACM)	2022
Developers talking about code quality (Empirical Software Engineering)	2023
Does Artificial Intelligence Promote or Inhibit On-the-Job Learning? Human Reactions to AI at Work (Systems)	2023
The Influence of Artificial Intelligence on Productivity in Software Development (Politecnico di Torino)	2023
From Copilot to Pilot: Towards AI Supported Software Development (University of Toronto & University of Victoria)	2023
Autonomous Intelligent Software Development (The Johns Hopkins Applied Physics Laboratory)	2023
The Rise of Intelligent System Development: A Qualitative Study of Developers' Views on AI in Software Development Processes (Umeå University)	2023

In the first round of analysis, we found 20 industry segments mentioned in some of the research papers we reviewed. Within each paper we used the frequency of each segment for determining essential segments (75% discussion threshold). To be deemed essential, segments must have been discussed in at least 75% of the research papers in our analysis. For example, Software Development was discussed in 12 of the 12 papers we reviewed while Development and Operations (DevOps) was discussed in 9 of the 12 papers (75% of all papers). We chose to use a 75% credibility threshold similar to the work done by Panagioti et al. (2019), where 75% indicate high heterogeneity, respectively. We were able to find if an industry segment was discussed in each paper by doing a search within each digital paper for each segment. Based on this criteria, these are the 10 essential SE industry segments defined:

Table 4: Top 10 Segments Deemed Essential

SE Industry Segment	Total Count	AI Integration/Use Description
Software Development	12	Automating code generation (& code completion), suggesting code improvements, or facilitating debugging processes.
Software Maintenance	12	Predicting software vulnerabilities, automating patches, or assisting in legacy code interpretation.
Process Improvement	12	Analyzing development processes, identifying bottlenecks, or suggesting optimizations.
Software Economics	12	Predicting costs, analyzing return on investment, or optimizing pricing strategies.
Knowledge Management	11	Organizing documentation, facilitating knowledge sharing, or automating information retrieval.
Project Management	10	Optimizing resource allocation, tracking project progress, or predicting project timelines.
Software Testing	10	Enhancing automated testing, generating test cases, or identifying potential points of failure.
Software Security	10	Detecting anomalies, predicting breaches, or automating security audits.

SE Industry Segment	Total Count	AI Integration/Use Description
Quality Assurance	10	Monitoring software quality, identifying regressions, or automating compliance checks.
Deployment and Operations (DevOps)	9	Optimizing deployment processes, managing infrastructure, or ensuring continuous integration/continuous deployment (CI/CD).

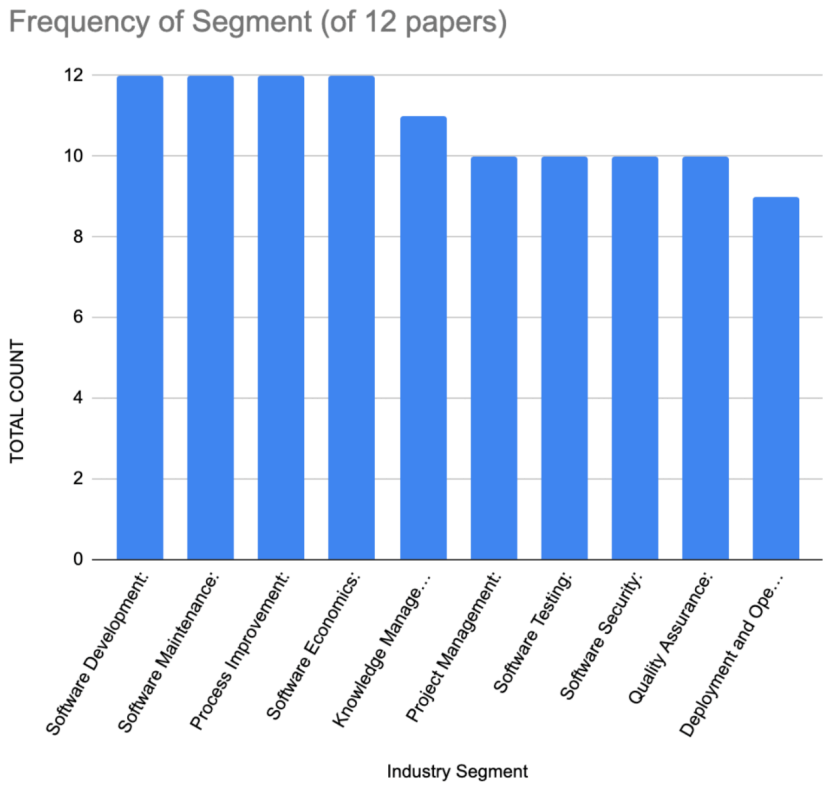

Figure 1: Frequency of top 10 segments in the 12 literature papers

By classifying each segment to each paper and storing the data in a spreadsheet, we were able to calculate the frequency of each segment overall. If there was no mention of a segment in a given paper, it is noted for reference. We were then able to calculate the frequency of each segment in the pool of our 12 papers in the literature review, listed in the graph above (Figure 1).

2.3 Identification of Essential AI-Related SE Industry SubSegments

In order to determine the subsegments, we conducted a similar process of identifying frequency of topics discussed in each of the segments by paper.

In our second round of analysis we based our framework on further insights from the research of the peer-reviewed papers in our analysis on AI-Usage in the SE Industry. We determined three sub-segments per segment to focus on in our framework based on frequency and expected impact on the industry through inductive content analysis. The total count refers to the number of times the topic appears in 1 of the 12 papers. For example, Code Generation, a sub-segment of Software Development, is mentioned in 10 of the 12 papers.

Table 5: AI-USE subsegments (AI use examples)

Top 10 Segments	AI-Use Sub-Segment 1	Total Count	AI-Use Sub-Segment 2	Total Count	AI-Use Sub-Segment 3	Total Count
Software Development	Code Generation	10	Code Completion	9	Software Prototyping	8
Software Maintenance	Automated Error Fixes	8	Code Refactoring	8	Bug Prediction	4
Process Improvement	Workflow Automation	12	Performance Optimization	12	Quality Control	9
Software Economics	Economic Impact Analysis	11	Resource Allocation	7	Cost Prediction	2
Knowledge Management	Semantic Reasoning	12	Automated Documentation	7	Knowledge Graphs	3
Project Management	Project Scheduling	10	Risk Assessment	8	Effort Estimation	5
Software Testing	Test Optimization	9	Fault Detection	5	Automated Test Generation	1
Software Security	Automated Patching	7	Security Risk Analysis	3	Vulnerability Detection	1
Quality Assurance	Code Quality Evaluation	10	User Feedback Analysis	10	Performance Benchmarking	6
Deployment & Operations (DevOps)	System Optimization	11	Monitoring & Alerts	5	Continuous Integration/Deployment	1

3. Expected Impact and Implications

We expect an enhancement of SE education through our AI-USE framework (Addison Lilholt, 2024). The AI-USE framework significantly enhances SE education by integrating AI concepts and applications into the curriculum. This framework is designed to cover critical areas of SE, including software development, maintenance, process improvement, economics, knowledge management, project management, testing, security, quality assurance, and DevOps. Each area is broken down into specific segments, providing detailed guidance on the use of AI tools and techniques.

For example, in software development, students learn about AI-driven code generation tools like GitHub Copilot and OpenAI Codex, which automate the creation of code snippets and templates, thus increasing efficiency and reducing manual coding efforts. Similarly, AI tools for code completion, such as IntelliCode and Kite, provide contextual suggestions that enhance coding speed and accuracy. In the segment of software maintenance, AI tools are employed for bug prediction, code refactoring, and automated error fixes. Predictive models trained on historical data can identify potential issues early, while refactoring tools and automated debugging systems ensure cleaner and more maintainable code. The framework also emphasizes AI's role in process improvement through workflow automation and quality control. By incorporating AI tools for cost estimation and resource allocation, the framework helps students understand how to predict and manage development costs and optimize resource use. Students learn that knowledge management is enhanced through the creation and use of knowledge graphs and automated documentation generation, improving knowledge sharing and decision-making. Project management is streamlined with AI-driven task management and risk assessment tools, which enhance task distribution and project security. In software testing, AI tools automate test case generation and execution, leading to faster and more comprehensive testing cycles. Security is bolstered by AI techniques for threat detection and vulnerability management, providing early detection of security threats and continuous system protection. Quality assurance benefits from AI-driven analysis of quality metrics and user feedback, ensuring higher software quality and user satisfaction. Finally, students are introduced to the segment of deployment and operations (DevOps) where AI tools enable faster release cycles and efficient resource utilization.

Overall, the AI-USE framework provides a comprehensive approach to enhancing SE education by equipping students with the knowledge and skills to leverage AI tools effectively, preparing them for the evolving demands of the software engineering industry.

The AI-USE framework addresses the evolving demands of the software engineering (SE) industry by integrating AI-driven tools and techniques into the educational curriculum, ensuring that students are well-prepared for the current and future outlook of the industry. It hopes to increase skill relevance and employability by familiarizing students with AI technologies, increasing their efficiency and productivity among other aspects of improvement.

The AI-USE framework hopes to prepare students for the evolving demands of the SE industry by equipping them with the latest AI tools and techniques, ensuring they can enhance productivity, improve quality, manage resources efficiently, while focusing on secure programming, software testing within CI/CD environments, and supply chain security, ensuring that students are equipped to address the critical security challenges posed by AI in software engineering. This comprehensive approach ensures that graduates are ready to meet the current and future challenges of the software engineering industry.

4. Goals for the Future

We hope to continue to develop our framework through various methods to ensure we provide high quality and applicable information moving forward. We hope to conduct Feedback Collection where we conduct interviews with SE Professionals from various segments of the SE industry to gather insights on the relevance and applicability of the AI-USE framework. The feedback will help us understand if our framework aligns with industry needs and where adjustments are necessary. This could be done through surveys and questionnaires to obtain quantitative data on the framework's effectiveness and areas for improvement.

We would also like to implement a standardized process for defining scope and impact where we would rank segments and subsegments as High, Medium, or Low impact based on feedback from industry professionals. This will help prioritize areas that need more focus and ensure the framework addresses critical aspects of the SE industry. We would also conduct an impact assessment to regularly assess the impact of each segment on the SE industry by analyzing feedback and industry trends. We could then adjust the framework to emphasize high-impact areas and address any gaps identified.

Finally, we would like to define the relationship to the Software Development Life Cycle (SDLC) to ensure that each segment and subsegment of the framework is mapped to specific phases of the SDLC. This will help educators and students understand the practical application of AI tools and techniques throughout the software development process.

5. Additional Methods for Continued Development

To further the development of the AI-USE Framework we would hope to conduct pilot programs and case studies where we implement pilot programs in collaboration with industry partners to test the AI-USE framework in real-world settings. According to research, pilot studies help identify potential issues, refine methodologies, and ensure that the framework can be effectively implemented on a larger scale. This process aids in the successful adaptation and scaling of educational initiatives (Institute of Education Sciences, 2023). We would document the outcomes and lessons learned to refine the framework. During this we would develop case studies based on successful implementations of AI tools in SE education. We would use these case studies as teaching materials to demonstrate the practical benefits of the framework.

It would be important to build academic-industry partnerships between academic institutions and industry to ensure continuous exchange of knowledge and best practices. These partnerships could provide students with internships and project opportunities that align with the AI-USE framework. Additionally the establishment of advisory boards composed of industry experts and academic leaders to provide ongoing guidance and support for the framework's development would be beneficial.

Regular updates and reviews should be made to the AI-USE framework to incorporate new AI technologies and methodologies. This will ensure that the framework remains current and addresses the latest developments in the SE industry. We would like to publish annual reports on the progress and impact of the framework, highlighting key achievements and areas for further improvement.

In addition we would like to assess feedback loops while conducting iterative improvement that allow for continuous input from users of the framework, including students, educators, and industry professionals using this feedback to make iterative improvements to the framework.

We have begun the development of an online platform where users can share their experiences and suggestions for enhancing the framework. This platform for ongoing development and collaboration. Such a platform can act as a community hub, allowing for collaboration and dissemination of best practices (Institute of Education Sciences, 2023).

By implementing these goals and methods, we anticipate the AI-USE framework remains a dynamic and valuable tool for SE education, effectively preparing students for the evolving demands of the software engineering industry.

6. Conclusion

The AI-USE framework addresses the global shortfall of software engineers by integrating AI concepts and applications into educational curriculum for middle and high schools. This strategic alignment aims to equip the future workforce with the necessary skills to meet the escalating demands of the SE industry, which is increasingly reliant on AI technologies. Our research involved a comprehensive review of nine international AI education guidelines and a systematic literature review of 12 research papers focusing on AI's role across the SE industry. Through this process, we identified 10 essential SE industry segments for inclusion in CS education: software development, software maintenance, process improvement, software economics, knowledge management, project management, software testing, software security, quality assurance, and deployment and operations (DevOps).

The AI-USE framework maps these essential segments to their predominant uses in the industry, providing detailed guidance on the application of AI tools and techniques and must also incorporate the necessary aspects of secure programming and software testing. This framework is designed to enhance SE education by covering critical areas, such as AI-driven code generation, bug prediction, workflow automation, cost estimation, and security threat detection. To ensure the framework remains relevant and effective, we propose an ongoing development process involving feedback from industry and academic professionals, regular updates, pilot programs, and academic-industry partnerships. By implementing these measures, the AI-USE framework will continuously evolve, preparing students to leverage AI effectively and meet the future challenges of the software engineering industry. This continued effort aims to create a future workforce that is more effective and capable of utilizing AI, potentially giving anyone using the framework a competitive edge globally.

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