

Navigating the Dual Edges of AI in Engineering Education: Opportunities, Challenges, and Societal Readiness

Asad Azemi
Computer Science and Engineering Technology
University of Maryland Eastern Shore
Princess Anne, MD USA
aazemi@umes.edu

Abstract— This research full paper describes how integrating Artificial Intelligence (AI) in engineering education represents a transformative shift with profound implications. In this work, we outline the multifaceted impact of AI, emphasizing its benefits and potential misuse within the classroom, and extend to consider its broader societal implications. AI's introduction in engineering education signals a new era of personalized learning environments. Its capacity for analyzing vast data sets enables tailored educational experiences, addressing individual student needs with unprecedented precision. AI-driven tools can identify learning gaps and provide customized resources, optimizing the learning process. These advancements are not without pitfalls. A notable concern is the misuse of AI by students, such as leveraging AI to complete assignments unethically, which undermines learning objectives and academic integrity. Beyond the classroom, AI's influence on society, particularly in the labor market, is a double-edged sword. AI poses a threat to traditional job markets. Automation risks displacing a significant portion of the workforce, particularly in sectors reliant on routine tasks. We have emphasized the importance of a balanced approach, advocating for the responsible integration of AI in educational settings with human oversight to prevent unethical use, potential job displacement, and other societal impacts. We have also advocated for studying and designing new pedagogical approaches and courses that would integrate AI-based applications such as ChatGPT to enhance problem-solving and critical thinking among students.

Keywords—*Artificial Intelligence, Large Language Model, ChatGPT, Learning Methodologies.*

I. INTRODUCTION

Innovation is an integral part of human existence and history. Innovation has been recognized as an essential component of advancements and modernization. In the rapidly evolving landscape of engineering education, traditional educational models are increasingly perceived as inadequate in preparing students for the complexities of modern engineering challenges and the integration of new technologies and methodologies such as Learning Management Systems (LMS), automated grading systems to sophisticated simulations and adaptive learning platforms have been transformative. Among all, AI-based applications stand out and offer a multitude of tools that promise to revolutionize the educational paradigm. The newest tool being discussed among educators is Large Modeling Language (LLM) derived platforms. A large language model is an artificial

intelligence algorithm that applies neural network techniques with many parameters to process and understand human languages or text using self-supervised learning techniques. Tasks like text generation, machine translation, summary writing, image generation from texts, machine coding, chat-bots, or Conversational AI are applications of the Large Language Model. Examples of such LLM models are ChatGPT by open AI [2], Copilot by Microsoft [2], and BERT (Bidirectional Encoder Representations from Transformers) by Google [3], etc. [4]. In this work, we focus on using one of these platforms, ChatGPT.

The impact of LLM products such as ChatGPT is not fully recognized. Researchers and public figures talk about its possible impact. Influential people such as Warren Buffet, renowned investor and chairman of Berkshire Hathaway, compared it to nuclear power, "We let a genie out of the bottle when we developed nuclear weapons," "AI is somewhat similar — it's part way out of the bottle." His image and voice were recently replicated by an AI-backed tool, and as he said it, they were so convincing that they could have fooled his own family. Researchers across academia have also sounded the alarm regarding the dangers that AI-based tools can impose and, at the same time, pointing to their benefits. A simple search using the keywords "engineering education" and "ChatGPT" will bring up around 8500 published papers in Elsevier's Compendex database as of May 12, 2024 [5]. Almost all papers we have accessed try to provide a balanced perspective and cover benefits and shortcomings. For example, [6] evaluates ChatGPT's problem-solving ability and success rates. The findings suggest that while LLMs like GPT-4 can solve well-specified problems, human intervention is crucial for effectively handling authentic, real-world challenges. The study identifies three main failure modes in ChatGPT's problem-solving: inaccuracies in modeling the physical world, difficulties making reasonable assumptions about missing data, and calculation errors. In [7], the authors evaluate the performance of ChatGPT in supporting design and manufacturing tasks. The provided results show that ChatGPT achieved high performance in answering extension of knowledge questions but struggled with critical analysis questions. [8] discusses the impact of ChatGPT on education, highlighting its potential to enhance teaching practices and student learning experiences. It addresses the challenges and risks associated with integrating AI technology in education while proposing a practical model for ChatGPT-enabled smart education. The paper proposes leveraging

ChatGPT to optimize teaching quality, enrich digital resources, enhance teaching strategies, and promote interactive feedback for educators. It also suggests using ChatGPT to develop personalized learning programs, generate intelligent learning content, and provide intelligent Q&A and tutoring for students. Additionally, it advocates for addressing ethical risks, improving information transmission, and managing knowledge levels in the education ecosystem. In [9], the authors study the ChatGPT's impact on post-secondary education. Their focus group study revealed a consensus among participants that ChatGPT will inevitably be integrated into courses and assignments. However, its incorporation requires clear guidelines, redesigned assessment methods, and transparent AI policies to ensure responsible usage and mitigate drawbacks. Recommendations included balanced in-class and take-home assignments, improved assessment strategies, and proactive measures to address challenges like academic integrity, ethical issues, privacy, and bias. [10] analyzes the role of ChatGPT and other AI tools in transforming higher education. It views ChatGPT as a student-driven technology that significantly influences teaching, learning, and assessment practices. While technology empowers students by providing personalized learning and enhancing educational resources, it also introduces challenges, such as the need for new strategies in student training, curriculum development, and technology governance. The paper suggests that embracing ChatGPT could lead to innovative educational practices but requires careful integration into the existing educational frameworks. [11] examines the integration of the ChatGPT into higher education environments, particularly focusing on its use in software engineering and scientific writing. It highlights ChatGPT's benefits, like aiding in assessment preparation and facilitating scientific writing tasks. The paper also discusses significant challenges, including the risk of academic dishonesty and the need for educational institutions to adapt their teaching and assessment methodologies to effectively incorporate AI tools without compromising academic integrity. [12] examines the evolving role of generative AI like ChatGPT in software engineering education. The authors discuss both the potential enhancements and challenges ChatGPT poses in educational settings. They emphasize that while AI can significantly aid in personalizing and enhancing the learning experience through immediate feedback and support, it also introduces complexities in maintaining academic integrity and the need for students to understand the content genuinely. The paper advocates adapting software engineering curricula to integrate AI better, ensuring it supports rather than replaces traditional learning methods. This involves shifting from traditional coding assignments to more innovative assessments to gauge better a student's understanding and application of software engineering principles. The findings suggest that educators need to supervise using AI tools to prevent misuse and harness their potential to improve educational outcomes effectively.

As these references and similar ones indicate, the effects of AI-based tools are not the same for all majors. While subjects that include problems that are not well-defined have less to worry about unethical usage of these applications, subjects that deal with well-defined problems, such as computer programming, need to find a solution quickly.

II. AIM OF THE PAPER

This paper aims to explore the dual-edged role of AI in engineering education. While the benefits of AI offer substantial improvements in educational outcomes and operational efficiencies, significant challenges and ethical concerns need to be addressed. Furthermore, we believe that AI-based applications such as ChatGPT are just the beginning of a much bigger revolution that requires a fundamental examination of how we teach and what we teach. In this paper, we call for finding ways to incorporate various AI applications to achieve higher learning outcomes while addressing the risk of academic dishonesty, the potential for increased educational disparity, and the broader societal implications of automation and job displacement. Additionally, the environmental impact of deploying AI at scale in educational settings raises further concerns that must be considered.

Through this exploration, the paper will provide a balanced perspective, assessing both the opportunities provided by AI-based applications in enhancing the learning experience and the challenges it presents in ethical and societal contexts, ensuring that its benefits can be fully exploited while mitigating potential drawbacks. We will next focus on advantages associated with generative AI, such as ChatGPT, which we have chosen as our focused example. We will then cover the disadvantages or dangers associated with these tools. After that, we will cover the societal impacts, and finally, we will present our suggestions on how we can use these tools in education, emphasizing that we are at the early stages of exploring the impact of AI, and this is just a preliminary perspective.

III. BENEFITS OF AI IN EDUCATION

As mentioned, researchers have identified several advantages of incorporating generative AI in engineering education. For example, [13] highlights the opportunities for personalized learning experiences, feedback, and virtual simulations that AI technology can offer students. It also addresses concerns such as biases, misinformation, ethical considerations, and the potential impact on traditional teaching methods. The paper raises several concerning questions about ChatGPT to demonstrate the capabilities and limitations of the AI-based application.

The following represents some of the authors' ideas based on previous work they published in areas directly connected to improved learning environments and individualized learning approaches [14]-[15].

Personalized Learning: Generative AI has the potential to revolutionize educational content by tailoring it to the learning pace and style of individual students. This could significantly enhance understanding and retention of complex subjects. The approach might involve suggesting supplementary resources, adjusting problem difficulty, or identifying areas requiring more in-depth analysis. This brings us closer to the realization of a truly individualized learning environment. We view this as the most significant advantage of designing or incorporating AI-based applications into our delivery methods, and we delve deeper into this concept by exploring other benefits that fall under this category.

Efficiency in Content Generation: ChatGPT or similar products can quickly generate a wide range of materials, such as programming examples, problem sets, and even textbooks, reducing the time educators spend on these tasks. We can also use other AI-based programs to modify the content to match one's learning preference. This can be considered a subset of the Personalized Learning that was mentioned before.

Real-time Feedback on Assignments: Use AI to provide immediate feedback on students' analyses in assignments. AI can assess the logic and methods used in student calculations or designs and offer suggestions for improvement, accelerating the learning process. Although real-time feedback on assignments exists with some software packages, their capabilities are limited to a few preprogrammed messages. A ChatGPT-like application can provide a much-focused response. This part can also be considered a subset of Personalized Learning that was mentioned before.

Challenge Students with AI-generated Problems: Use AI to generate complex, real-world problems that require innovative analytical approaches. This can challenge students to apply their theoretical knowledge practically and creatively. A personalized learning environment will also incorporate ways to generate problems and facilitate the mastery learning approach.

Enhanced Simulation and Modeling: In fields like computer science and engineering, generative AI can create detailed simulations and models that allow students to model problems and visualize the effects of different variables in real time. This not only makes learning more interactive but also helps in understanding complex systems and interactions more deeply. It should be noted that we currently have simulation software packages that can help with this task, but using a generative AI application will make the process much easier and more flexible due to the more straightforward interaction process.

Facilitate Group Projects: AI can manage and facilitate collaborative projects by helping track contributions, suggesting areas for improvement, and even mediating the division of tasks based on individual strengths and weaknesses. This will help with the ABET assessment that covers teamwork. ABET's Outcome 5 requires the "ability to function effectively on a team whose members provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives." Student Outcome 5 focuses on the performance of the team as a whole as well as individual performance.

Accessibility: Generative AI can help make education more accessible by providing learning aids in multiple languages or formats tailored to diverse learning needs, including those of students with disabilities.

Innovative Research: AI can assist in the research process by generating new ideas, algorithms, or data analysis methods, pushing the boundaries of what is possible in engineering disciplines.

IV. DANGERS

As mentioned earlier, recent papers regarding the use of AI-based tools, or ChatGPT in particular, have covered both benefits and dangers. For example, [16] presents the application

and impact of ChatGPT in engineering higher education. It explores the effectiveness of detection systems for AI-generated content and students' perceptions of LLMs' usefulness and acceptability. The study highlights that while LLMs can enhance educational tasks and student engagement, challenges regarding academic integrity and the reliability of detection systems remain significant. [17] discusses the need for educational institutions to invest in monitoring and remediation to combat cheating and prepare students better for higher education and the workforce.

Below are key points that should be considered under this section.

Dependency: There's a risk that students may become overly reliant on AI tools, potentially stunting their problem-solving skills and understanding of fundamental concepts.

Academic Dishonesty: The ease with which generative AI can produce complex outputs can tempt students to misuse these tools for assignments, leading to issues with plagiarism and integrity.

Quality and Accuracy: AI-generated content might not always meet academic standards or could be factually incorrect, misleading students, or causing confusion if not adequately monitored.

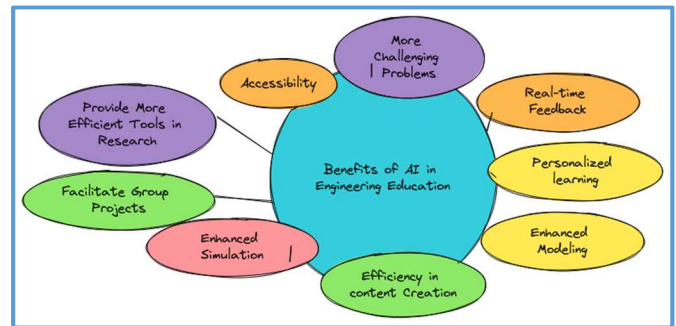


Fig. 1. A Sample List of Benefits of AI in Engineering Education

V. IS SOCIETY READY FOR THE CHALLENGES AND OPPORTUNITIES ASSOCIATED WITH AI-BASED APPLICATIONS?

In the upcoming sections, we will broaden our examination to include the general issue of societal readiness for AI technologies. This expanded perspective is essential for devising what we call a systems solution—an integrative approach to addressing the complexities introduced by AI. This will enable us to formulate a more holistic solution to the challenges at hand, which resembles the conceptual design step when we apply the engineering design methodology to solve a problem.

Society's readiness for AI-based applications like ChatGPT is a complex issue that balances a tightrope of technological enthusiasm and regulatory, ethical, and social preparedness. For example, [18] explores the significant changes AI brings to various industries, mainly focusing on its impact on workplace dynamics and job roles. It emphasizes how AI technologies, such as machine learning and robotics, are being used to automate repetitive tasks, enhance efficiency, and augment

human capabilities, leading to opportunities and challenges. Key points discussed include the potential for AI to create new job opportunities while posing risks of job displacement. [19] focuses on the significant influence of ChatGPT, emphasizing its dual roles both as an enhancer of interactive applications and as a potential source of ethical and social challenges. The paper acknowledges ChatGPT's benefits in streamlining tasks across various domains but also cautions about its capacity to perpetuate biases, spread misinformation, and disrupt employment. It advocates for a balanced approach to harnessing ChatGPT's capabilities while mitigating its risks through careful regulation, education, and ethical considerations.

It is clear that artificial intelligence stands as a dual-edged sword in its impact on society, offering substantial benefits while simultaneously introducing significant risks. In the following three sections, we will expand our spectrum beyond the LLMs and include general AI-based applications to understand the impacts better. It should be noted that there is a large number of published works in the areas we will not cover under this section as that would be outside the scope of this paper. Consequently, we will only provide a small sample of references for this section.

In order to answer the question that was posed in this section, we will first examine the benefits and dangers of AI and then come back to explore the question from a system viewpoint. From a systems design perspective, we acknowledge that one would start from the conceptual view and then move to detailed design. However, given the very complex nature of the issue, we decided to do the opposite in this paper as we believe we are still in the conceptual design/viewpoint regarding the AI applications, and the current benefits and dangers may not provide a good picture of what may come in the future. The benefits of this approach will become more obvious as we examine the recommendations given in the last part of the paper.

VI. BENEFITS OF AI FOR SOCIETY

To consider AI's impact on society, we will start by examining the identified benefits.

Enhanced Healthcare: AI can significantly improve healthcare outcomes by enabling personalized medicine, predictive diagnostics, and advanced surgical techniques. This allows for more accurate treatments and better patient care. Again, we see a large number of publications in this area covering various areas of healthcare, including diagnostics, prescription decision-making, drug discovery, and healthcare management.

Unleashing efficiency: AI technologies are not limited to a single sector, but rather, they boost efficiency across numerous industries. From transportation to manufacturing and services, AI optimizes processes, reduces downtime, and manages complex data systems, promising a more efficient future.

Environmental Monitoring and Protection: AI helps combat environmental issues by monitoring pollution levels, predicting weather patterns, and optimizing the use of natural resources, thereby contributing to sustainability efforts.

Improved Public Safety: AI enhances public safety through smarter surveillance systems, predictive policing, and emergency management, helping to prevent accidents and respond to emergencies more effectively.

Access to Information: AI powers search engines and personal assistants that provide users with quick access to vast amounts of information, improving education and decision-making processes.

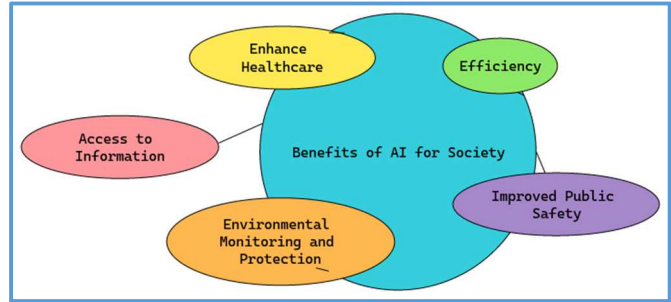


Fig. 2. A Sample List of Benefits of AI for Society

VII. DANGERS OF AI FOR SOCIETY

To better understand AI's impact on society, we now consider some of the more important dangers that have been identified.

Job Displacement: AI can lead to the automation of various jobs, from routine manufacturing tasks to complex analytical roles, potentially leading to unemployment and economic disparity.

Privacy Concerns: The use of AI in surveillance and data analysis poses significant privacy risks, as it can lead to the collection, storage, and potentially inappropriate use of personal data.

Bias and Discrimination: AI systems trained on biased data sets can perpetuate and amplify existing biases, leading to unfair decision-making processes in areas like recruitment, law enforcement, and loan approvals.

Security Risks: AI systems are vulnerable to hacking and other cyber threats, which can lead to significant security breaches, particularly in critical areas such as national security and personal data.

Loss of Human Interaction: As AI systems take over more services, there is a potential loss of personal touch in industries like healthcare, education, and customer service, affecting the quality of service delivery and human relationships.

As we conclude the sections on the various issues raised by AI's integration into society, it is evident that while AI holds transformative potential, it also poses significant challenges that demand proactive and thoughtful solutions. Addressing these concerns will require collaborative efforts from policymakers, academia, the tech industry, and the global community to develop ethical guidelines and robust frameworks that ensure AI advances do not come at the cost of societal well-being.

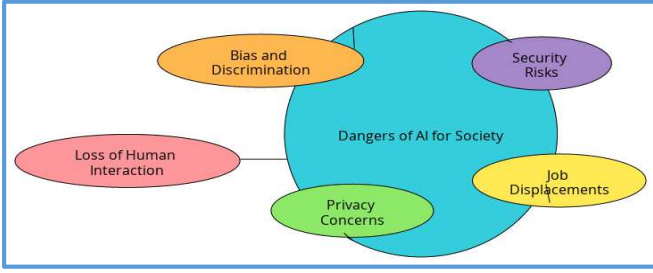


Fig. 3. A Sample List of Dangers of AI for Society

VIII. SYSTEMS VIEW AT SOCIETY'S READINESS FOR AI-BASED APPLICATIONS

In this section, we move from the current and more immediate impacts and try to understand better the overall picture and the way to come. We acknowledge that a thorough examination of the systems' viewpoint involves assessing the integrated and holistic impact across multiple domains—technological, ethical, socio-economic, and infrastructural—which also requires collaboration across various sectors as was pointed out in the conclusion of the previous section. Currently, we do not have an established infrastructure to promote such a collaboration. Therefore, we call for cooperation on the following points as the primary focus points or mandates.

Technological Literacy, Public Awareness, Ethical and Regulatory Framework: One of the primary concerns is whether the general public and policymakers possess sufficient understanding of AI technologies and their implications. While there is growing awareness of AI's potential to transform industries, the depth of knowledge among the broader population remains shallow and mostly comes from social media. From an ethical standpoint, a systemic approach calls for comprehensive guidelines that govern AI use. This means consistently developing universal ethical standards and regulatory frameworks across different sectors and regions. These frameworks should address issues such as data privacy, algorithmic transparency, and AI accountability, ensuring that AI applications operate within bounds that society deems acceptable. We believe this is one of the biggest challenges we face as regulators are involved in a catch-up game with the implications of the technology. An example that we are now very much familiar with is the deep-fake video and audio productions. We emphasize that without robust regulations and ethical guidelines, deploying AI applications risks society's ability to manage them responsibly.

Socio-Economic Structures: AI's impact on the labor market is a double-edged sword, offering opportunities for creating new job categories and risks of significant job displacements. We believe the full realization of the positive impact requires a significant change in the educational systems and workforce development, emphasizing skills that AI is unlikely to replicate soon, such as emotional intelligence, creative problem-solving, and interpersonal communication. Given that the job market plays a significant role in the economic stability of every society, this is a high priority. From what we have seen so far, AI

applications will significantly impact many industries, such as the movie and TV industries, and many jobs will be lost.

Technological Integration, Equity, and Accessibility: A systems perspective emphasizes the need for robust technological infrastructure that can support AI functionalities universally. This includes reliable Internet access, widespread digital literacy, and strong data security measures. Integrating AI requires not just individual gadgets but a network of systems that can efficiently manage large data flows and ensure seamless interactions between AI applications and users. Lack of equitable access to these requirements will create an equity and accessibility problem.

As a summary for the sections covering the impact of AI on society, we can say that while society recognizes the potential that AI brings about significant improvements in various sectors, there is a pressing need for enhanced educational efforts, stronger regulatory frameworks, and thoughtful consideration of ethical and social implications. To truly be ready for the era of AI, we must all play a part. Adjusting to this new landscape requires not just proactive strategies, but collaborative efforts across governments, industries, and communities. This collective action will be our gateway to our next section where we briefly examine a possible structure for the educational changes.

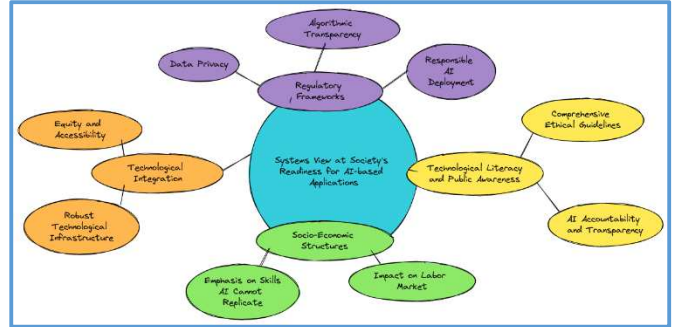


Fig. 4. Systems View of Society's Readiness for AI-Based Applications

IX. AI-BASED EDUCATION

As discussed earlier, AI technologies, especially those like ChatGPT, present a profound potential for disruption in education, significantly beyond acting as simple tools, and can be considered a paradoxical challenge. These tools distinctly differ from past technological integrations such as calculators or the Internet, which primarily augmented information access and computational efficiency. AI tools offer a deeper level of interaction and functionality; they can generate and synthesize content, solve complex problems, and simulate human-like interactions. This advanced capability fundamentally challenges traditional teaching methods and assessment modalities, potentially altering how learning objectives are defined and achieved. Therefore, we believe these technologies should not be seen merely as supplements to existing frameworks but as catalysts for a complete overhaul of how education is delivered and assessed. This shift involves developing new teaching methodologies that leverage AI's capabilities to enhance and transform learning experiences across various educational strategies, including problem-based learning (PBL), flipped

classrooms, and adaptive learning. Moreover, AI applications can enhance critical thinking by creating scenarios requiring detailed analysis, encouraging thoughtful debate among students by presenting multiple perspectives on issues and facilitating reflective thinking by questioning students about their reasoning and conclusions.

Expanding the integration of AI applications into teaching and learning requires a structured approach. As a second step, we advocate for creating cross-disciplinary applied courses that emphasize the practical use of AI tools. Such courses would be project-based, involving hands-on experience with AI technologies tailored to specific applications. For instance, a course could focus on utilizing various image-processing packages that employ AI for detection and prediction tasks in health-related applications. Students could work on real-world problems, applying AI to analyze medical images for early disease detection or monitoring patient's health.

Building on this foundation, a subsequent step would involve developing specialized LLMs to address specific fields, such as medicine. These LLMs would be trained to comprehend and generate responses to medical queries, enhancing their accuracy and relevance in healthcare settings. Focusing on a specific domain makes these systems more economically viable due to their targeted scope and potentially reduced training requirements.

Lastly, these specialized systems could be integrated into a distributed system configuration. This would allow various AI models, each with unique specialties, to communicate and collaborate, thereby leveraging their strengths in a cohesive and scalable manner. Such an interconnected system would enhance the capability of each AI model and expand its applicability across different sectors and disciplines.

This phased integration strategy ensures that AI applications in education are practical and adaptable. It provides students with valuable skills relevant to emerging technologies while also preparing them for future advancements in AI applications.

Finally, to effectively integrate AI into educational systems, it is also essential to develop new assessment methods that evaluate the acquisition of knowledge and the application of such knowledge in solving problems and thinking critically. These methods should leverage AI's strengths to assess students' abilities to synthesize information, solve complex problems, and generate innovative solutions.

This comprehensive approach ensures that AI constructively supports educational goals, promotes critical thinking and problem-solving skills, and maintains academic integrity. Such a paradigm shift is crucial to harness AI's potential responsibly and effectively, ensuring it augments the educational process rather than undermining it. This transition requires careful planning, continuous feedback, and iterative refinement, engaging educators, students, and technological experts in a collaborative effort to redefine the educational landscape.

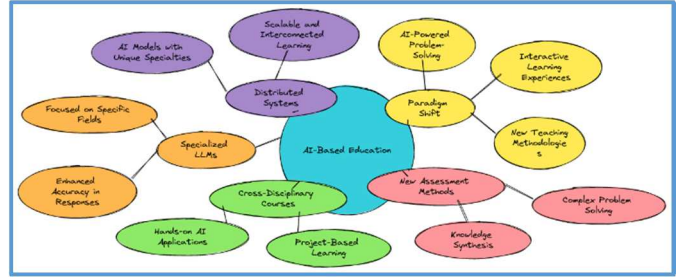


Fig. 5. An Example of an AI-Base Education Structure

X. REMARKS AND CONCLUSION

In this paper, we have tackled the complex landscape of integrating artificial intelligence (AI) into engineering education. We highlighted the benefits of AI in enhancing learning outcomes and operational efficiencies while addressing significant challenges and ethical concerns. We have emphasized the importance of a balanced approach, advocating for the responsible integration of AI in educational settings with human oversight to prevent unethical use, potential job displacement, and other societal impacts. As mentioned earlier, these points were shared by the most recent published works in this area. We also expressed concern about the lack of regulation using AI-based applications and the impact on the job market. As a final remark, we advocated studying and designing new pedagogical approaches that would integrate AI-based applications such as ChatGPT to enhance problem-solving and critical thinking among students. We believe such an addition will further enhance engineering design methodology and increase science and technology advancement. We also emphasize that AI-incorporated methodologies can further advance engineering design.

TABLE I. SUMMARY OF FINDINGS

Category	Findings
Personalized Learning	AI can significantly enhance personalized learning through adaptive content that addresses individual needs.
Educational Integrity	AI tools risk being misused for cheating, potentially undermining academic integrity.
Professional Development	Educators need ongoing training to effectively integrate AI tools in teaching.
Labor Market Impact	AI-driven automation may displace traditional jobs, affecting the labor market.
Societal Readiness	There is a general lack of preparedness for the broad impacts of AI, from privacy concerns to ethical issues.

TABLE II. SUMMARY OF RECOMMENDATIONS

Category	Recommendations
Personalized Learning	Develop AI-driven curricula that focus on individual learning styles and pace to improve engagement and knowledge retention.
Educational Integrity	Implement strict guidelines and use AI detection software to maintain academic integrity and prevent misuse.

Professional Development	Offer continuous professional development programs for educators to keep pace with AI advancements and pedagogical strategies.
Labor Market Impact	Prepare the workforce through education and training programs that emphasize AI literacy and skills for new job creation.
Societal Readiness	Enhance public understanding of AI through educational programs and robust policy frameworks to guide ethical AI use.

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