Journal of Effective Teaching and Learning Practices. 2025;2(3):155-167
eISSN: 3048-9601

ORIGINAL ARTICLE

The Obligation of Artificial Intelligence (AI) Tools in Engineering Education 4.0

Dr. Riaz Kurbanali Israni[1], Yuvraj Kaushik Jani[2]
Associate Professor, Department of Electrical Engineering,
School of Engineering, R K University, Rajkot, Gujarat, INDIA
Assistant Professor, Department of Electrical Engineering
Unitedworld Institute of Technology, Karnavati University, Gandhinagar, Gujarat, INDIA

E-mail: riaz.israni@rku.ac.in

DOI: https://doi.org/10.70372/jeltp.v2.i3.23

Abstract

Engineering Education 4.0 (EE-4) represents the latest paradigm in engineering pedagogy, uniting time-honored instructional methods with cutting-edge technologies most notably artificial intelligence (AI). As AI underpins the Fourth Industrial Revolution, it is imperative that engineering curricula inculcate both theoretical understanding and practical proficiency in AI concepts and applications. This responsibility falls squarely on educational institutions, which must ensure that graduates emerge not only conversant with AI but capable of leveraging its capabilities to address complex, real-world challenges. In this study, we first establish a robust framework for evaluating engineering knowledge within AI-enhanced instruction by adapting the Technological, Pedagogical, and Content Knowledge (TPACK) model. This framework guides the design and deployment of AI-based instructional tools and provides a metric for assessing their pedagogical effectiveness. We then implement an AI-driven platform utilizing the conversational agent ChatGPT as a testbed for facilitating student engagement with authentic engineering problems. A cohort of undergraduate students at RK University, Rajkot, was invited to interact with the platform over the course of a semester, applying AI-guided insights to laboratory exercises, design projects, and collaborative assignments. Quantitative and qualitative analyses were performed to compare the framework's predicted levels of tool efficacy against observed student outcomes. Results indicate that, while theoretical evaluations of the AI tool forecast high pedagogical value, empirical evidence demonstrates that student performance improved commensurately, fulfilling the core objectives of Engineering Education 4.0. These findings underscore the obligation of engineering programs to integrate AI tools systematically, thereby preparing graduates to navigate and shape the rapidly evolving technological landscape.

***Keywords* — TPKS, Artificial Intelligence, ChatGPT, Engineering Education System, Industrial revolution 4.0**

1. INTRODUCTION

The exponential growth of scientific knowledge and its rapid transformation into technological innovations have become hallmarks of the modern era. These advancements offer immense potential to improve quality of life, drive economic growth, and address critical global challenges [1]. However, their responsible implementation especially in domains like education poses significant challenges that demand deliberate planning, ethical foresight, and inclusive practices.

Artificial Intelligence (AI) stands at the forefront of this transformation, with its integration into education systems having the power to reshape how students learn, engage, and solve problems. Yet, the extent to which AI will positively impact education depends largely on how thoughtfully it is designed, implemented, and governed. Without a clear framework, AI risks reinforcing existing educational disparities or compromising human-centric teaching values [2].

In the context of engineering education, where problem-solving, innovation, and adaptability are core competencies, integrating AI is not just beneficial it is essential. However, this integration must be guided by a balanced approach that maximizes AI's potential while upholding principles of quality, equity, and ethics.

This work is necessary to explore and validate practical, ethical, and pedagogical frameworks for AI integration in engineering curricula [3]. By fostering collaboration among educators, technologists, and policymakers, and grounding decisions in empirical evidence, this research aims to ensure that AI becomes a transformative tool that enriches learning outcomes, prepares students for future industry demands, and contributes positively to the evolving landscape of education [4].

1.1 Artificial Intelligence (AI):

AI was indeed introduced as a formal discipline in 1956 at the Dartmouth Conference by John McCarthy and his colleagues [4]. The aimed was to explore the idea of creating machines that could simulate human intelligence. AI is indeed an interdisciplinary field. It draws upon knowledge and techniques from various domains like, computer science, information theory, control theory, philosophy, psychology, neurophysiology and linguistics [5]. Researchers and policymakers are working together to ensure responsible AI which helps to enlarge the educational and industrial advancement [6].

1.2 ChatGPT:

ChatGPT is a language model developed by Open AI, based on the GPT (Generative Pre-trained Transformer) architecture. It is designed to generate human-like text and engage in natural language conversations with users. ChatGPT is a sibling model to InstructGPT and shares similar capabilities, but it is specifically fine-tuned for generating text-based responses in a conversational context [7].

ChatGPT has been trained on a diverse range of internet text, which allows it to provide information, answer questions, engage in discussions, and perform various language-related tasks [7] [8]. It is designed to be versatile and can be used for a wide array of applications, including chatbots, virtual assistants, customer support, and more.

GPT-1 (June 2018): OpenAI introduced the GPT-1 model, which was the first iteration of the Generative Pre-trained Transformer [9].

GPT-2 (February 2019): It was a significant advancement in language modeling. Initially, OpenAI expressed concerns about the potential misuse of the model due to its ability to generate coherent and contextually relevant text [10].

GPT-3 (June 2020): The third iteration of the GPT series marked a significant leap in terms of model size and capabilities. With 175 billion parameters, GPT-3 was one of the largest language models at the time [10].

Deployment in Applications: GPT-3, including its chatbot capabilities, was integrated into various applications and services across industries, from customer support to content the generation [11].

1.3 TPKS:

It is combination of technological knowledge, pedagogical knowledge and substance of knowledge. TPKS is the sympathetic of using a suitable technological tool to teach a content by implementing effective pedagogical strategies [12]. Let's recognize sub-parameters of TPKS as per below figure.

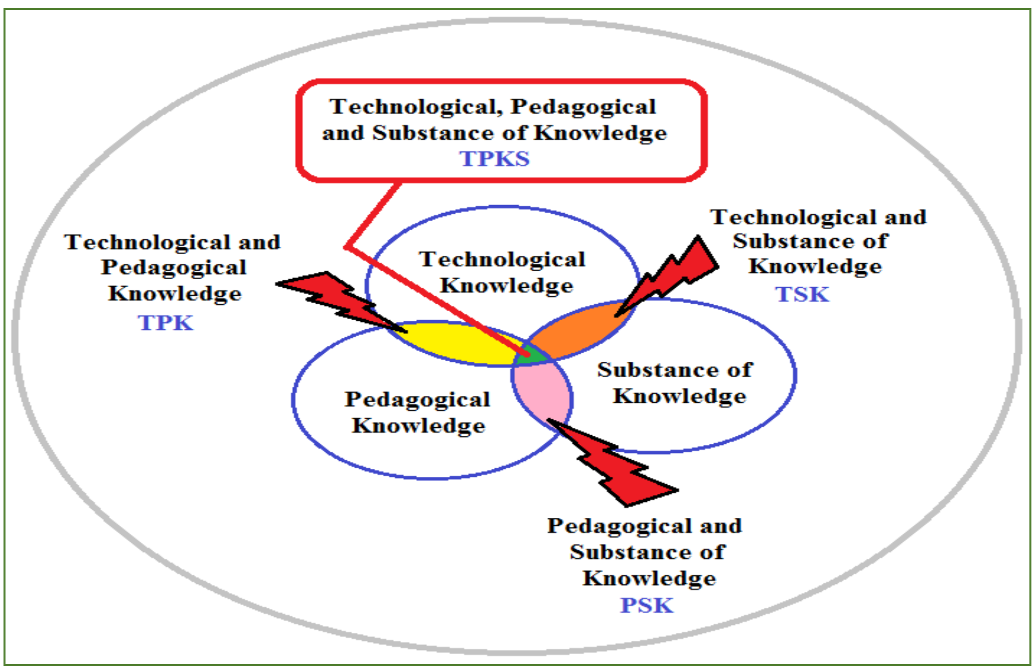

Fig. 1 TPKS Framework

TSK includes the knowledge about the meticulous technologies utilized within the substance field.

PSK is consisting of the suitable methodologies and strategies to educate a substance [13]. TPK is the knowledge about the nature of teaching and learning by deploying technology. TPK also covers the knowledge regarding the rewards and downsides of abundant technologies for explicit pedagogical approach. TPKS consists of a combined form of knowledge and skills of the other fundamental components [14]. TPKS is the understanding of using an appropriate technological tool to teach a content by implementing effectual pedagogical approaches.

1.4 Engineering Education 4.0:

This is based on four pillars: technologies, procedure, didactical methods, and skills. Engineering Education 4.0 is crucial for the emerging demands of Industry 4.0 and may fill the gap between Academia and Industry 4.0, by providing unique features and future skills [15].
Engineering Education 4.0 may embrace passive or active adaptively for self-regulated learning, AI-assisted task-time planning system, learning analytics, personalization of learning materials including, biofeedback from wearable, gamification, E-assessments and E-portfolio etc [16].

2. RESEARCH METHODOLOGIES

This lesson was designed to compare the concert of Open AI based ChatGPT with that of engineering students of RK University in answering Engineering Education 4.0 track questions [17]. In this expressive study, 46 numbers of engineering students have participated with pen-paper test. This test includes descriptive and multiple-choice questions with consist of 100 marks (two hours' time span).

Fig. 2 Snapshot of pen-paper test at RK University

The similar test was also given to ChatGPT, and the answers generated were compared with those

46 numbers of the engineering students [17]. The metadata were analyzed by using TPKS framework. These scrutinizes also include numbers and percentages values.

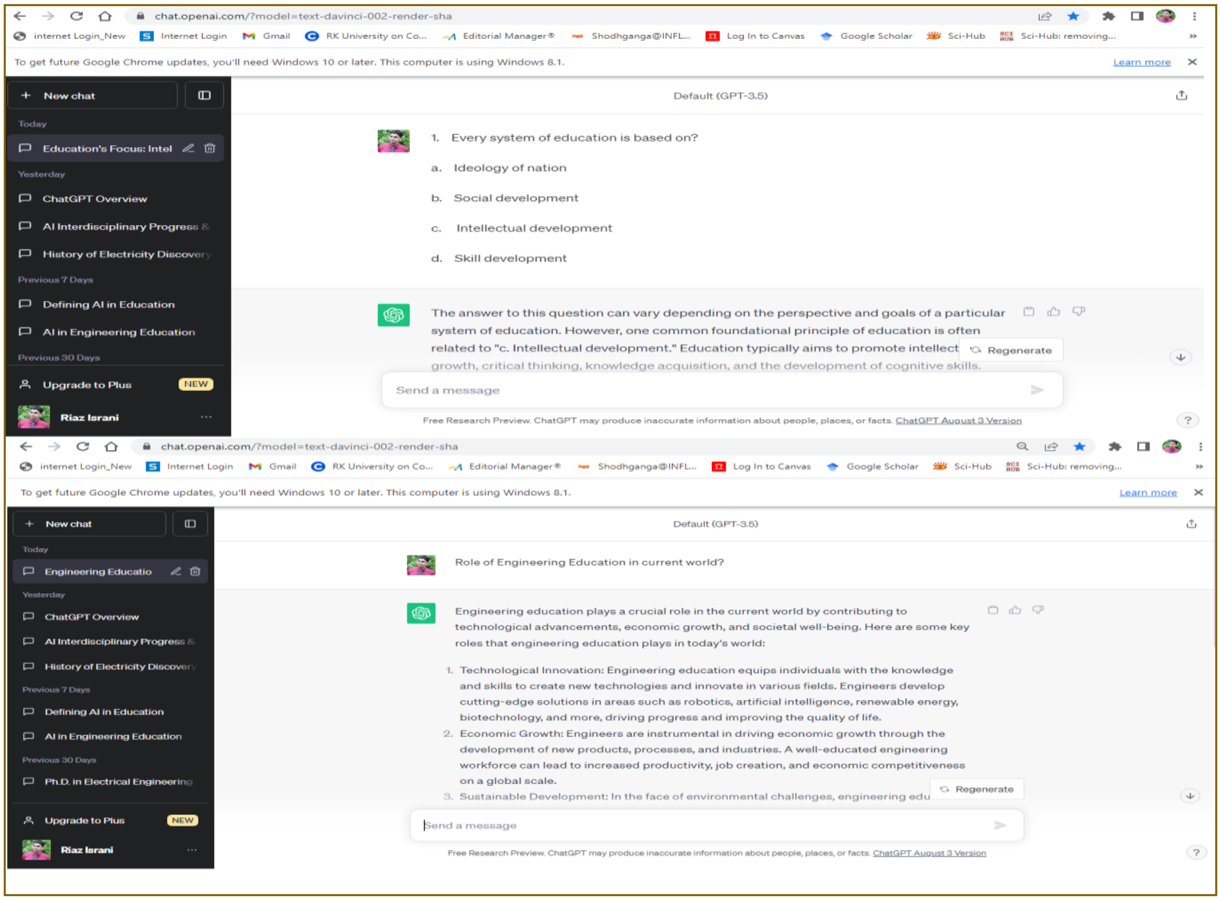

Fig. 3 Snapshot of the test gives by ChatGPT

Essentially, the test questions are designed with TPKS skeleton and assessment of the test also done by using TPKS framework. Furthermore, percentage and graphical analysis were also merged in the result part which represented in the next segment. Before going to the result section let us view the snapshot of the test gives by ChatGPT [18]. Now, look at the detailed formation of the question paper (Engineering Education 4.0) used in both the cases.

Table 1 Percentage Weightage for each scale of TPKS Framework

Sr. No.	Factors for Descriptive Question	Percentage Weightage	Factors for MCQs	Percentage Weightage
1.	TK	5 %	TPKS	10 %
2.	SoK	5 %	PSK	5 %
3.	PK	5 %	TSK	5 %
4.	TPK	10 %	TPK	5 %
5.	TSK	10 %	PK	5 %

6.	PSK	10 %	SoK	5 %
7.	TPKS	15 %	TK	5 %

3. RESULT INVESTIGATION

After vigilant exploration, we observed that all seven-factor of TPKS framework are valuable and significant in both the case. Now observe the detailed investigation of both the cases.

3.1 Case I: Pen-paper test given by engineering students:

In this case, 46 numbers of engineering students have attended the test (100 marks, 2 hours' time). This test was conducted at RK University and all engineering students are from the same university. The result was analyzed through TPKS skeleton as represented in the graphical evaluation mode as shown here [19].

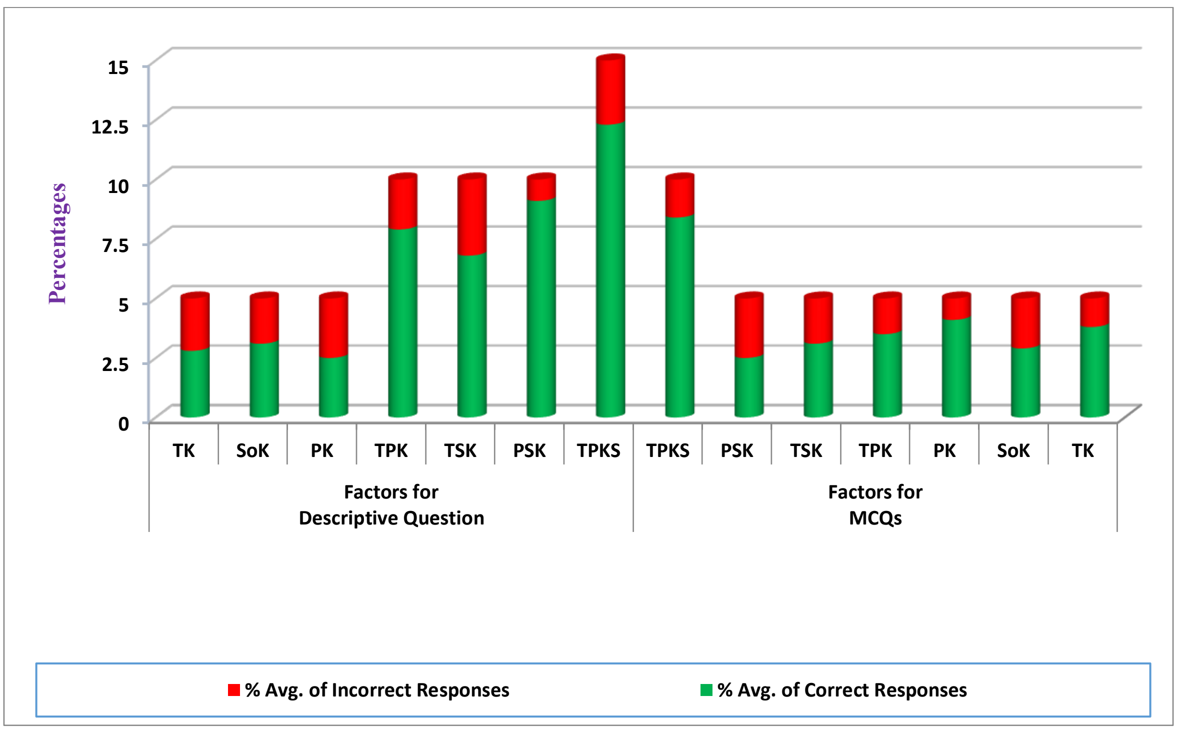

Fig. 4 % Average Responses of Engineering Students based on TPKS Framework

As illustrated in the above graph, the responses of engineering students are thoroughly analyzed using the TPKS (Technological Pedagogical Knowledge and Skills) framework. This graphical representation enables a structured evaluation of students' performance by categorizing their responses according to the four key elements: TK, PK, PSK, and TPKS. Among these, the descriptive questions aligned with the TPKS element received the highest overall weightage, emphasizing the significance of integrating technological and pedagogical knowledge in applied contexts. Furthermore, when analyzing the percentage of correct responses within each section, it is observed that the PSK (Pedagogical Skills and Knowledge) element within the descriptive question category garnered the highest average of correct responses, indicating that students demonstrated a relatively stronger ability to reflect on and articulate pedagogical practices in descriptive formats. Similarly, within the multiple-choice questions (MCQs) section, the PK (Pedagogical Knowledge) element recorded the highest average of correct responses, suggesting that students were more confident in identifying fundamental pedagogical concepts when presented with structured answer options. On the other hand, across the entire dataset, the average percentage of correct responses exceeds the average percentage of incorrect responses, reflecting an overall satisfactory level of understanding and preparation among the engineering students. This trend signifies that while there are variations in the strengths across different knowledge domains, the students generally performed well above the guesswork or random response level.

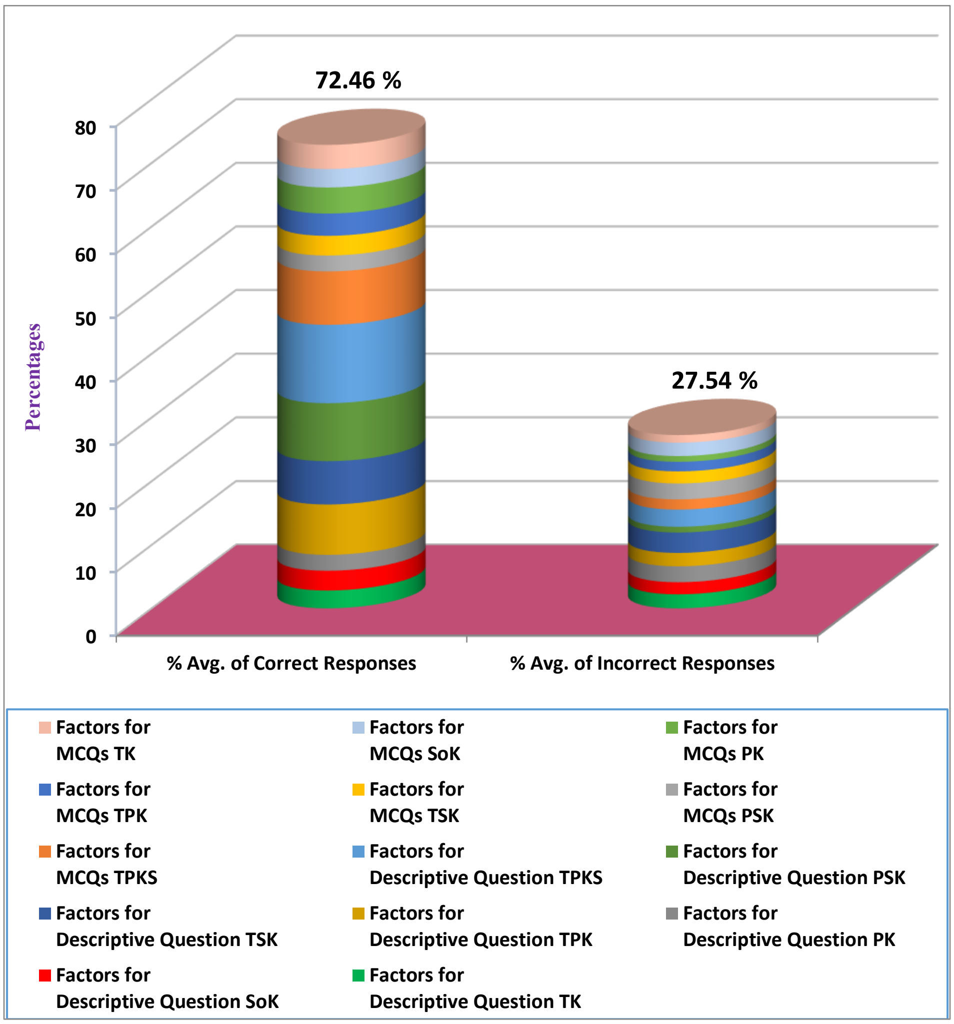

Fig. 5 % Results of Engineering Students

As per above graph, focusing on the percentage-based results of the engineering students as a whole, it is evident from the graphical data that the overall correct response rate stands at 72.46%**,** while the incorrect response rate is 27.54%**,** yielding an average overall performance result of approximately 73%. This demonstrates a commendable level of engagement and comprehension by the student group within the structured TPKS evaluation model.

3.2 Case II: Same test given by ChatGPT:

In this case, a similar standardized test was conducted using ChatGPT to evaluate and compare its performance with that of the engineering students. The entire question set, including both descriptive and multiple-choice questions (MCQs), remained the same as in the previous test taken by students. This consistency ensures a fair and unbiased comparison between human and AI performance based on identical evaluation parameters. Upon analyzing the results, it became evident that ChatGPT demonstrated enhanced performance, providing a greater number of accurate and contextually appropriate responses across both descriptive and objective formats. The assessment was again carried out using the TPKS framework, which categorizes knowledge into Technological Knowledge (TK), Pedagogical Knowledge (PK), Pedagogical Skills and Knowledge (PSK), and the integrated Technological Pedagogical Knowledge and Skills (TPKS). As illustrated in the graph below, the percentage average of correct responses in the case of ChatGPT is significantly higher than the percentage average of incorrect responses**,** highlighting the model's consistency, accuracy, and capacity to retrieve and apply relevant information effectively. When the data is examined more closely through the TPKS framework, it becomes clear that the descriptive questions associated with the TPKS element received the highest weightage in terms of both number and complexity. Interestingly, ChatGPT not only handled this high-weightage section efficiently but also delivered the most accurate responses in this category, indicating its proficiency in dealing with questions requiring integrated knowledge and critical reasoning.

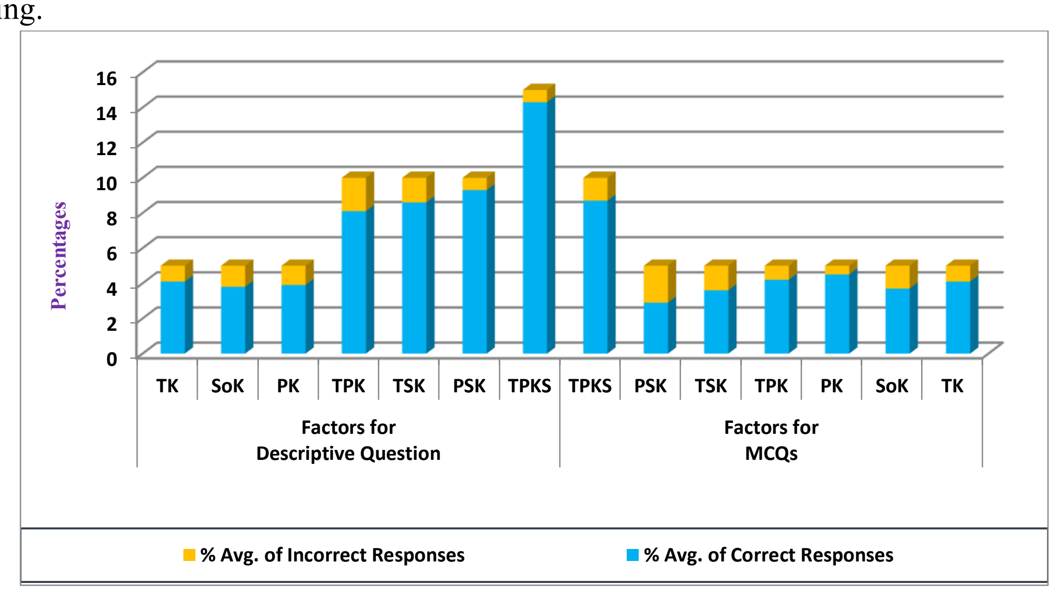

Fig. 6 % Average Responses of ChatGPT based on TPKS Framework

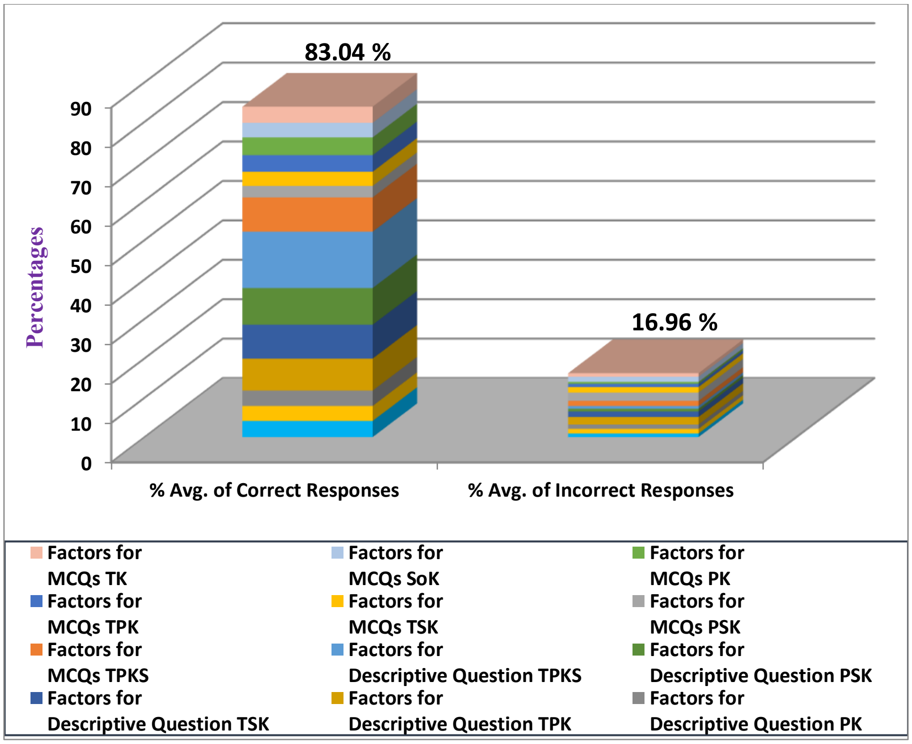

Fig. 7 % Results of ChatGPT

Other side, highest % average of correct responses goes to TPKS element in the descriptive question factor. Same way highest % average of correct responses goes to PK element in the MCQs factor. Moreover, highest % average of incorrect responses goes to TPK element in the descriptive question factor. Same way highest % average of incorrect responses goes to PSK element in the MCQs factor. Now move on to the % results of ChatGPT.

In this case compare to engineering students the % results are more and ChatGPT get more correct answers because of accurate database storage and implementation. As per above graph, % average of correct responses is 83.04% and incorrect responses are 16.96%. Hence % result is around 83% for the ChatGPT.

3.3 Comparative analysis of both the cases:

In this comparative section, both the factors (descriptive question and MCQs) are compared to each other and both the factors are also compared for the case I and case II.

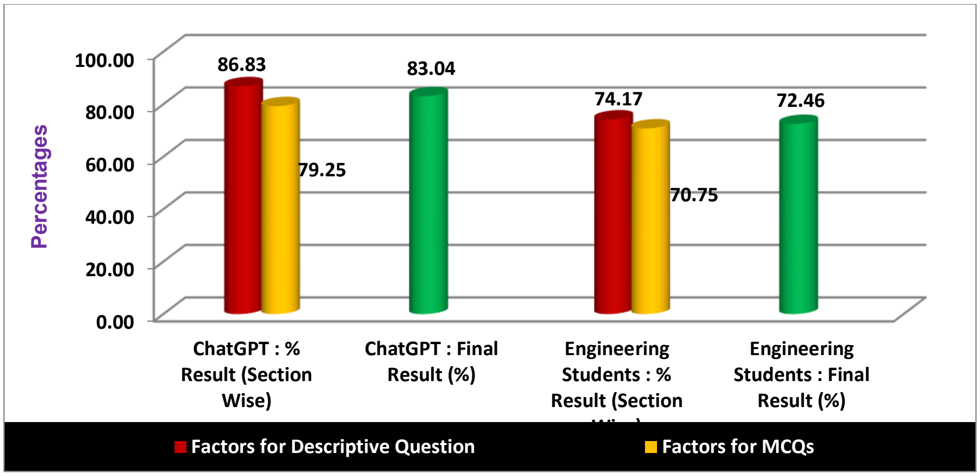

Fig. 8 Comparative investigation between ChatGPT & Engineering Students

As per above graph, in the case of ChatGPT descriptive question got more result compare to MCQS. Same scenario is made in the case of engineering students. Now, if we talk about result than ChatGPT received 83.04% and engineering students got 72.46 %. The reason behind this is because of excellent database management by Open AI and ChatGPT.

4. DISCUSSION ON RESULTS

This study compares the performance of 46 engineering students from RK University with ChatGPT on a standardized test structured around the TPKS (Technological Pedagogical Knowledge and Skills) framework. The two-hour, 100-mark test included both descriptive and multiple-choice questions (MCQs). The same test was later administered to ChatGPT for benchmarking. The engineering students achieved an average correct response rate of 72.46%, with 27.54% incorrect answers. Descriptive questions received the highest weightage, especially those focused on the TPKS element. In this section, PSK (Pedagogical Skills and Knowledge) had the highest correct responses, while in the MCQs, PK (Pedagogical Knowledge) was most accurately answered. Overall, the students showed a solid grasp of core concepts, as the average correct responses exceeded the incorrect ones. ChatGPT, when evaluated on the same test, scored 83.04% correct and 16.96% incorrect, outperforming the students by around 10.58%**.** Like the students, ChatGPT performed best in descriptive questions under the TPKS element and in MCQs under the PK element. However, the model showed weaknesses in descriptive responses under the TPK element and in MCQs related to PSK [20]**.**

Both groups performed better in descriptive questions than MCQs, indicating that applied knowledge and analytical reasoning are better captured in open-ended formats. ChatGPT's superior performance can be attributed to its robust knowledge base, quick information processing, and consistent logic—factors that give it an edge over students under exam conditions [21]. This comparative analysis highlights not only the effectiveness of the TPKS framework in assessing knowledge but also the potential of AI tools like ChatGPT to complement traditional learning, helping students improve conceptual clarity and test performance in higher education.

5. CONCLUSION

It is noteworthy that ChatGPT performed well on the Engineering Education 4.0 exam; however, it is important to understand the limitations and broader context of these results. Education extends beyond simply providing correct answers it involves deep understanding, critical thinking, problem-solving, and hands-on application of knowledge. While AI tools like ChatGPT can serve as valuable learning aids by offering quick information, explanations, and support, they cannot replicate the human elements of teaching, mentoring, and experiential learning. Therefore, AI should be viewed as a complementary resource in education rather than a replacement. The true essence of learning still depends on students' active engagement, curiosity, and the guidance of skilled educators who foster meaningful understanding and personal growth.

Author Bio

I am Dr. Riaz K. Israni, an accomplished academic and researcher, currently serving as an Associate Professor in the School of Engineering at RK University, Rajkot, India. I hold a Ph.D. in Electrical Engineering, which I completed at RK University, Rajkot, where I have also been actively engaged in the academic and research community. With over 12 years of extensive teaching experience, I have had the privilege of shaping and mentoring countless students, guiding them through the complexities of electrical engineering. In addition to my academic role, I bring with me 3 years of valuable industrial experience, which has provided me with a well-rounded perspective on the practical applications of engineering principles. Throughout my career, I have been deeply committed to research and scholarship. I have published 15 research and review papers in prestigious international journals, contributing to the global body of knowledge in electrical engineering. I have had the opportunity to present 18 researches and review papers at various international conferences, where I have engaged with fellow researchers and professionals, sharing insights and advancing discussions in the field.

Mr. Yuvraj Jani holds a Master of Technology (M.Tech) degree in Power Systems and a Bachelor of Engineering (B.E.) in Electrical Engineering. He is currently serving as a faculty member at the Unitedworld Institute of Technology (UIT), Karnavati University, Gandhinagar. With over a decade of teaching experience, he has consistently demonstrated a strong commitment to academic excellence and student development in the field of electrical engineering. His dedication to advancing knowledge in these domains is evident through his active engagement in academic research and publications. He has presented and published two research papers at international conferences, contributing valuable insights to the global electrical engineering community. He is also involved in mentoring students, developing innovative lab practices, and participating in curriculum design and academic quality enhancement initiatives at UIT. His professional journey reflects a balanced blend of theoretical knowledge and practical application, making him a respected educator in the field.

References

Awati, J. S., Desai, S. S., & Tope, S. (2020). Mind Mapping: An Effective Teaching Learning Evaluation Tool in Engineering Education. *Journal of Engineering Education Transformations, 33(Special Issue).*

Lathigara, A., Gupta, L., Binu, K. G., & Kumar, V. (2021). Sustaining motivation of engineering students in india by managing their academic & affective needs. *Journal of Engineering Education Transformations, 34.*

Richter, O. Z., Juarros, V. I. M., Bond, M., & Gouverneur, F. (2019). Systematic review of research on artificial intelligence applications in higher education: where are the educators? *International Journal of Educational Technology in Higher Education, (16), 6.*

Mirzana, I. M., & Lal, M. R. (2020). Engineers for the Future. *Journal of Engineering Education Transformations, 33(Special Issue).*

Tanna, P., Bhatt, N., & Patel, S. (2020). An Innovative Approach for Learning and Evaluating Programming-Oriented Courses. *Journal of Engineering Education Transformations, 33(3), 62-74.*

Jiao, P., Ouyang, F., Zhang, Q., & Alavi, A. H. (2022). Artificial intelligence-enabled prediction model of student academic performance in online engineering education. *Artificial Intelligence Review*, *55*(8), 6321-6344.

Pavlik, J. V. (2023). Collaborating with ChatGPT: Considering the implications of generative artificial intelligence for journalism and media education. *Journalism & Mass Communication Educator, 78(1), 84-93.*

Rahaman, M. S., Ahsan, M. T., Anjum, N., Terano, H. J. R., & Rahman, M. M. (2023). From ChatGPT-3 to GPT-4: a significant advancement in ai-driven NLP tools. *Journal of Engineering and Emerging Technologies, 2(1), 1-11.*

Topsakal, O., & Topsakal, E. (2022). Framework for a foreign language teaching software for children utilizing AR, voicebots and ChatGPT (Large Language Models). *The Journal of Cognitive Systems, 7(2), 33-38.*

Alghazo, M., Ahmed, V., & Bahroun, Z. (2025, February). Exploring the applications of artificial intelligence in mechanical engineering education. In *Frontiers in Education* (Vol. 9, p. 1492308). Frontiers Media SA.

Celik, I. (2023). Towards Intelligent-TPACK: An empirical study on teachers' professional knowledge to ethically integrate artificial intelligence (AI)-based tools into education. *Computers in Human Behavior, 138, 107468*.

Valtonen, T., Sointu, E., Kukkonen, J., Kontkanen, S., Lambert, M. C., & Mäkitalo-Siegl, K. (2017). TPACK updated to measure pre-service teachers' twenty-first century skills. *Australasian Journal of Educational Technology, 33(3).*

Sumathi, R., Savithramma, R. M., & Ashwini, B. P. (2023). Curriculum Compliance Improvement Model for Addressing Program Outcomes in Engineering Education. *Journal of Engineering Education Transformations, 37(1).*

Nuthanapati, F. A. A. K., Cherukuri, S. B. K., & Dukkipati, T. C. N. R. (2022). Education Process Re-engineering through Spectral Pyramid Framework to Achieve Excellence in Engineering Education. *Journal of Engineering Education Transformations, 35 (Special Issue 1).*

Riaz Kurbanali Israni. (2024). Inter-retaliatory Student Projects as Part of Evaluating Practical Knowledge with the Assist of Novel Assessment Technique. *Journal of Effective Teaching and Learning Practices, 1(1):31-40*

Fuchs, K. (2023, May). Exploring the opportunities and challenges of NLP models in higher education: is ChatGPT a blessing or a curse? *In Frontiers in Education (Vol. 8, p. 1166682). Frontiers.*

Bosman, L., Kotla, B., Madamanchi, A., Bartholomew, S., & Byrd, V. (2023). Preparing the future entrepreneurial engineering workforce using web-based AI-enabled tools. *European Journal of Engineering Education*, *48*(5), 972-989.

Rithvik, M., & Haritha, D. (2020). Student Learning Centric Methodology: An aid to Innovative Teaching and Learning Process. *Journal of Engineering Education Transformations, 33 (Special Issue).*

Baalsrud Hauge, J., & Jeong, Y. (2024). Does the improvement in AI tools necessitate a different approach to engineering education? In *Sustainable Production through Advanced Manufacturing, Intelligent Automation and Work Integrated Learning* (pp. 709-718). IOS Press.

Fitria, T. N. (2021, December). Artificial intelligence (AI) in education: Using AI tools for teaching and learning process. In *Prosiding seminar nasional & call for paper STIE AAS* (pp. 134-147).

Pham, T., Nguyen, T. B., Ha, S., & Ngoc, N. T. N. (2023). Digital transformation in engineering education: Exploring the potential of AI-assisted learning. *Australasian Journal of Educational Technology*, *39*(5), 1-19.