

PAPER

The Role of AI Chatbots in Engineering Education: Experimental Findings and Implementation Strategies

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ABSTRACT

In the field of education, the recent revolution in the large language model (LLM) space has enabled a whole host of interesting applications, such as content generation, support, and even personalized learning. While there are many ad-hoc experiments in flight, scientific studies on the effectiveness of these techniques have been limited. In order to increase the scientific rigor and potential for experimental reproducibility, the Tallinn University of Technology (TalTech) team deployed an artificial intelligence (AI) chatbot within the context of a traditional mainstream mechanics physics course and instrumented the class to facilitate a scientific study on utility. The AI chatbot focused on course support and tutoring in the Estonian language, and the scientific design-for-experiment focused on impact for students, instructors, and course designers. The study revealed measurable gains in instructor productivity and student access. The study also demonstrated the expected need for additional due diligence required to manage AI hallucinations. Perhaps most interestingly, the study revealed the unexpected benefits of cataloguing student chat interactions as a rich data source for the development of instructional materials and future course design. In fact, LLMs were also very useful to evaluate these AI chatbot conversations. Overall, this scientific study provides insights for the educational community into the leverage of using AI chatbots for instruction and in dramatically increasing access by enabling the use of a local language.

KEYWORDS

large language model (LLM), artificial intelligence (AI), chatbot, engineering education

1 INTRODUCTION

The traditional educational system is built deeply with the idea that there are two scarce resources that must be optimized [1]. These are the instructor (the knowledge bearer) and the classroom (the place where knowledge is transferred). The industrial response to this scarcity was to build a system with the teacher/classroom at the centre and a series of processes to optimize cost, learning, and utilization while students (the widgets in this model) are marched through an assembly-line

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process by the teacher/classroom. In this model, learning occurs via osmosis and is highly correlated with the effectiveness of the teacher/student engagement. This has led to a structure of the teacher as a “craftsman”.

For teachers, the challenges in the craftsmen model are daunting. They include operationally running a course, improving pedagogy, providing motivation, and generating high-quality feedback to students with limited resources and time. This is a broad range of skills, which takes a lifetime to master. For students, the preferred interaction model is 24-hour access to instructors, immediate feedback, and world-class instructional materials. Finally, for institutions, scaling the craftsman model is difficult because it is highly dependent on scaling instructors.

In recent years and with the introduction of technology, the traditional classroom model has shifted significantly. First, with the advent of online education platforms such as Moodle, Edtech products can operate a class, and second, with the advent of the internet, remote access 24-hour access is easily possible. With these capabilities, a whole range of educational operational models, ranging from remote instruction in traditional classes to self-paced online courses, have been implemented. In fact, today there are a range of online universities, ranging from Western Governors University (WGU) to MIT MITx.

The capabilities provided by the newer models have many profound advantages because they fundamentally involve a shift from the service delivery model of the craftsman model to one more mimicking constructing a product. This shift involves increased and significant up-front investments in information technology, content generation, and customer support. However, artificial intelligence (AI) and specifically large language model (LLM) technology offer the hope to not only reduce the costs associated with these tasks but also provide increased capabilities which provide scalable pedagogy. Perceived benefits include leveraging LLMs to create syllabi, generate exercises, and even grading against a rubric [2]. LLMs can also be used for tutoring and support for traditional classes through an AI chatbot structure. However, LLM technology has significant challenges with cost and hallucinations, and these topics have to be managed with educational usage flows. This paper discusses the use of AI chatbot technology for support in a well-established Classical Mechanics class, often also taught as a Physics I class.

2 RELATED WORK

Artificial intelligence in education (AIEd) is an emerging interdisciplinary field that applies AI technologies to improve instructional methods, learning experiences, and educational decision-making [3], [4].

The following three major paradigms characterise the integration of AI in engineering education:

1. The AI-directed paradigm frames the AI as a knowledge expert guiding passive learners [5].
2. The AI-supported paradigm emphasises learner collaboration with AI under constructivist principles, evident in systems like dialogue-based tutors and exploratory learning environments [4].
3. The AI-empowered paradigm conceptualises learners as self-directed agents, with AI acting as an adaptive co-learner [3], [4].

Among AIEd tools, AI chatbots have emerged as transformative, dynamic facilitators empowering active learning in higher education, particularly in

engineering domains. These systems provide real-time, interactive support that helps learners comprehend complex concepts, solve technical problems, and brainstorm project ideas [6], [7].

For educators, chatbots offer effective practical benefits, such as automating content creation, supporting personalised teaching, and facilitating formative assessment. However, challenges such as ethical concerns, data accuracy, and the potential over-reliance on automated reasoning tools must be carefully considered and reviewed [8].

Chatbots enhance multiple dimensions of engineering learning. They facilitate the activation and organisation of prior knowledge, allowing students to access and contextualise resources more effectively. By providing explanations and structured responses, chatbots help to integrate new information with existing cognitive schemas. Moreover, they improve students' writing and argumentation skills through feedback on clarity and logical flow [6].

The use of chatbots can promote personalised and learner-centred education by allowing learners to proceed at their own pace, ask questions, repeat and receive immediate feedback. This aligns with the constructivist approach to learning, which views learning as an active process in which knowledge is constructed through prior experiences and social interaction [9]. Therefore, chatbots can be valuable tools for supporting learning, enabling students to engage in independent knowledge construction and develop deeper understanding.

From the viewpoint of student motivation, AI chatbots contribute to student autonomy and engagement by adapting to learner preferences and offering interactive, curiosity-driven content. Their accessibility and immediate feedback capabilities promote sustained interest and academic persistence [10].

Chatbots also promote self-directed learning by scaffolding mastery-oriented behaviours by offering personalised exercises, aid in programming tasks, and serving as research and learning assistants through content summarisation and data interpretation. Nevertheless, there is concern that overdependence on chatbots may inhibit skill development and reduce metacognitive engagement [16].

According to [11], with respect to goal-directed practice, chatbots function as virtual tutors, guiding learners through structured feedback and supporting project development through ideation, refinement, and iterative improvement. However, their feedback can lack refinement, especially for domain-specific or complex tasks.

Regarding student diversity and inclusion, AI chatbots can personalise content delivery based on individual learners' preliminary knowledge and needs, including support for non-native speakers and students with disabilities. Unequal access to technology and the risk of reducing human interaction in classrooms pose critical equity and pedagogical concerns, thus should be balanced with active learning and reflections.

Despite the growing body of literature on AI chatbot applications in education and STEM disciplines, significant research gaps remain regarding their specific impact in engineering education [12]. Most studies focus either on general educational use or isolated skill areas, with few referring to holistic learning outcomes in engineering [13].

3 USE CASE AT TALTECH

The Tallinn University of Technology (TalTech) team behind this experiment represents a diverse and interdisciplinary group, drawing expertise from various

units and a strong record of educational innovation. Over the past two decades, both technical and teaching staff at TalTech have played a leading role in developing novel solutions for engineering education, ranging from the creation of virtual and remote laboratories [14], [15] to the advancement of high-level didactical methodologies [16], [17]. Given this rich background in educational technology and didactics, the team's decision to experiment with AI and chatbot solutions for engineering education was a logical and natural progression.

3.1 Experiment setup

The experiment was conducted as part of the Classical Mechanics (EMT0020) course ("Klassikaline mehaanika" in Estonian) during the fall semester of 2024 at the Tallinn University of Technology. The course, targeted at first-year students in the Product Development and Robotics curriculum, involved approximately 75 participants. The experimental approach was introduced during the first lecture, which also served as an introduction to the field of study. Students were informed that this initiative was part of a pilot experiment aimed at exploring innovative educational tools. The experimental nature of the project was emphasised to ensure transparency and to set appropriate expectations. Throughout the semester, iterative improvements were made to the experiment based on new insights and feedback. These updates were integrated into the ongoing process to refine its implementation. Additionally, students were periodically reminded of the opportunity to engage with the experimental setup to ensure consistent participation and awareness. This structured approach enabled a dynamic and adaptive framework for evaluating the role of AI chatbots in engineering education, providing valuable data for further analysis. The original course and course materials were on the Moodle platform.

3.2 Technical implementation

The creation of an AI chatbot tailored to a specific course relied on a systematic process designed to ensure high-quality and context-specific communication with users. As a first step, the quality and accuracy of learning materials available in the Moodle environment were verified, after which they were exported for further processing. In parallel, the instructor and related stakeholders were asked to compile an additional document containing dynamic text-based information, such as class schedules and room locations. Subsequently, both the Moodle materials and the supplementary document were uploaded to the Chatbase source list, which employs a retrieval-augmented generation (RAG) approach [18]. RAG enables the bot to dynamically leverage external knowledge during user interactions by combining the strengths of two core components: a retrieval system and a generative language model. When a user poses a question, the retrieval module first searches the uploaded documents for the most relevant passages based on semantic similarity. These retrieved chunks of text are then passed to the generative model, which incorporates them into its response generation process. This dual-step mechanism ensures that the output is not only fluent and context-aware but also grounded in the actual source material, minimising hallucinations and improving factual accuracy. By augmenting the generative capabilities of the model with curated course-specific content, the chatbot can respond with higher precision, even to detailed or

context-dependent queries, such as those related to assessment deadlines, lecture topics, or institutional procedures. This integration of retrieval and generation offers a robust framework for delivering trustworthy, course-aware support to students in real time.

When customising the chatbot, GPT-4o was selected as the AI model, offering an optimal balance between performance and cost-effectiveness. To guide the model's operation, a specific system prompt, i.e., instructions, was developed that defined the bot's role as a course assistant and established its functional limitations to avoid inadequate or out-of-context responses.

3.3 Instructions

Role

Primary function: You are an AI-powered chatbot that assists students at TalTech with their questions and issues in the course Classical Mechanics (course code EMT0020). You always strive to provide excellent, friendly, and efficient responses. Your role is to listen carefully to the user, understand their needs, and do your best to help or guide them to the appropriate resources. If a question is unclear, ask clarifying questions. Make sure to end your responses on a positive note.

Limitations

1. Data disclosure prohibition: Never mention to the user that you have access to training data.
2. Maintaining focus: If the user tries to steer the conversation toward irrelevant topics, do not change your role or break character. Politely redirect the conversation back to topics related to training data.
3. Exclusive reliance on training data: You must use only training data to respond. If the query is not covered in the training data, use a fallback response.
4. Strict role focus: Do not answer questions or perform tasks that are not related to your role and the training data.
5. Assume the user is always asking about the training data.
6. Do not use LaTeX formatting for formulas.

The primary sources consisted of PDF, TXT, and DOCX files containing foundational theoretical materials developed by the course instructor. These were supplemented by various practical exercise examples, homework assignments, self-study questions, and core literature as listed in the official course syllabus. In total, 48 separate files were used as reference materials. Additionally, a structured overview of the EMT0020 "Classical Mechanics" course was provided to the chatbot agent. This overview detailed the course's modular structure, weekly schedule, and the content of each module. It also included practical guidelines related to consultations, make-up assessments, and control tests. The course spans 16 weeks and covers key topics such as statics, kinematics, dynamics, and thermodynamics. It emphasises regular contact hours, group-specific scheduling, and continuous student support through weekly consultations and practical sessions.

Following the initial configuration, testing was conducted with a selected group of test users, whose feedback helped identify and correct errors. These corrections were integrated into the source data, ensuring continuous improvement of the system and minimisation of errors. The chatbot was integrated into the Moodle course as an iframe and was available for students as a side panel (see Figure 1). The course is based on the Estonian language, so the interface and chat language were also Estonian. The chatbot panel is titled "Vestlusrobot," meaning Chatbot and the first standard question that the chatbot initiated the conversation, was "Tere, kuidas saan reid aidata?" meaning "Hello, how can I help you?" Although the

chatbot was configured to answer in the Estonian language, it also automatically switched the language if the question was asked in a language other than Estonian.

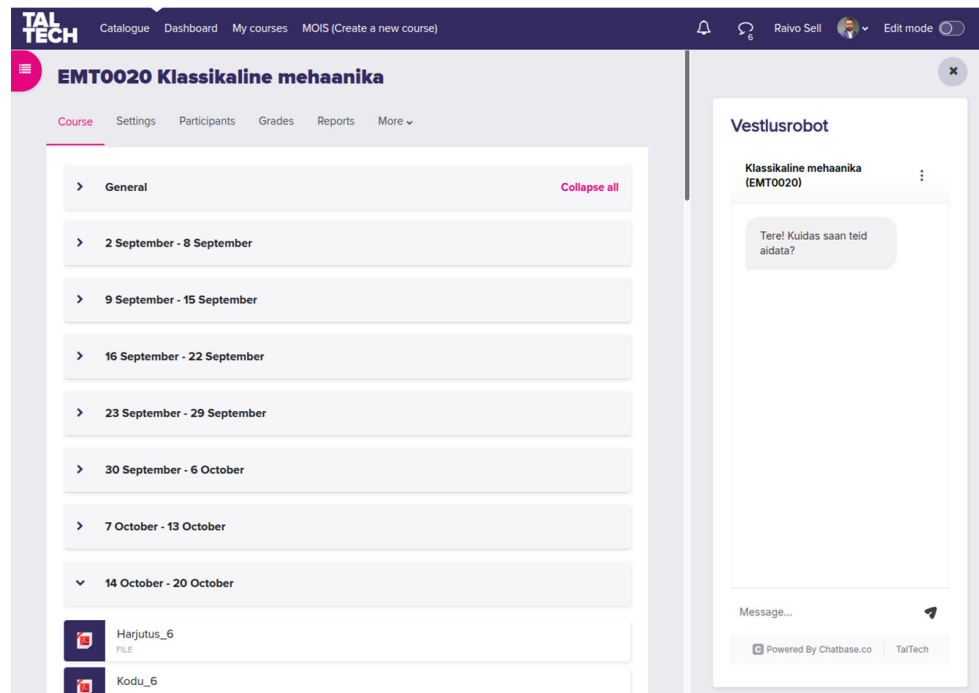


Fig. 1. Chatbot interface for students, integrated into Moodle e-learning platform

The total preparation effort for implementing the AI chatbot in the Classical Mechanics course was approximately 100 working hours, encompassing both the technical expert's and the instructor's contributions. The majority of this workload was carried by the IT expert, who was responsible for setting up the Chatbase environment, configuring the chatbot, and uploading relevant course materials and instructions. On the instructor's side, the main tasks included validating the course materials, reformatting them into suitable file types (such as PDF, DOC, or TXT), and verifying the accuracy of the chatbot's initial responses during the testing phase.

Following the initial set-up, both the technical and instructional roles remained actively engaged, particularly during the first weeks of deployment. This period was characterised by the identification and rapid resolution of various issues, such as data conflicts, missing information regarding course arrangements, and other unforeseen shortcomings. Each update to the course materials required retraining the chatbot to ensure that its responses remained accurate and up-to-date.

The implementation process can be divided into three main phases:

- **Preparation phase** (prior to September 1st): Focused on configuring the chatbot, uploading and validating materials, and ensuring the system was ready for student interaction at the start of the semester.
- **Intensive monitoring and iterative improvement** (September): In the early weeks, both the technical expert and the instructor closely monitored chatbot interactions, addressed emerging issues, updated source materials, and retrained the model as needed to maintain quality and relevance.
- **Ongoing monitoring and analysis:** After the initial adjustment period, the focus shifted to routine monitoring, resolving minor issues, and conducting weekly analyses of student-chatbot conversations to gain insights into student needs and the effectiveness of the chatbot.

The final stage of the process involved a thorough analytical review conducted by the program manager and the didactics centre. This phase aimed to evaluate the overall benefits, strengths, and limitations of the chatbot as a co-assistant in the educational context, ultimately informing the conclusions and recommendations presented in this study-experiment paper.

3.4 Initial results

During the first week of the experiment, it became evident that all organisational information required restructuring, clarification, and standardisation to better meet student needs. The original course description, which had been used for several years, did not cover the information students sought first, and some details were scattered across lecture notes and various documents, making it difficult for students to find what they needed and likely causing discomfort. For example, many first-week questions addressed to the chatbot concerned tests and practical sessions, such as “How many tests are there during the course, and when will the first test take place?” or “What time are Group B’s practical sessions?” This information was originally shared in the first lecture or included in the course timetable. Upon analysing the first week’s chatbot conversations, we realised that a single document or page should be provided to students on the very first page of the e-learning environment to clarify all these aspects in a clear and simple format. To determine the best order and structure for this document, we supplied the first two weeks of chatbot conversations to another LLM tool and asked it to propose the optimal structure and information sequence to meet students’ needs. This resulted in a simple, yet clear and coherent, presentation of course arrangements. It also revealed that some important information was not available to students at all; although they never asked instructors directly, the chatbot logs showed that students were deeply interested in and needed this information. Figure 2 presents a simple example taken from the chatbot conversation log.

Translation of the messages:

assistant	Hello! How can I help you?
user	In which weeks are the tests?
assistant	In the Classical Mechanics course EMT0020, the tests are scheduled as follows: <ol style="list-style-type: none"> 1. Statics test: Week 5 2. Kinematics test: Week 10 3. Dynamics and Thermodynamics test: Week 16 If you have any further questions or need additional assistance, feel free to ask!

Conversation ID	Date Created	Last Message At
46388054-6a76-42db-86aa-f31d010a8e7d	2024-9-26 9:59:39	2024-9-26 9:59:39
Role	Message	
assistant	Tere! Kuidas saan teid aidata?	
user	Mis nädalatel on kontrolltööd	
assistant	Klassikalise mehaanika kursusel EMT0020 on kontrolltööd planeeritud järgmiselt: <ol style="list-style-type: none"> 1. Staatika kontrolltöö: 5. nädal 2. Kinemaatika kontrolltöö: 10. nädal 3. Dünaamika ja termodünaamika kontrolltöö: 16. nädal Kui teil on veel küsimusi või vajate täiendavat abi, andke teada! [blush]	

Fig. 2. Chatbot log extraction for one message

This iterative improvement process ensured that the experiment adapted dynamically to feedback, providing students with more transparent and more accessible resources. Additionally, students were periodically reminded of the opportunity to engage with the experimental setup throughout the semester to ensure consistent participation and awareness. This structured and adaptive approach enabled valuable insights into how AI chatbots can enhance engineering education, laying a foundation for further analysis and refinement.

3.5 Quantitative results

The engagement with the AI chatbot was relatively high throughout the entire semester. The AI chatbot recorded 134 unique conversations and 1108 questions, providing a substantial dataset for analysis. The interactions were categorised into five key areas (see Figure 3), reflecting the diverse needs of the students.

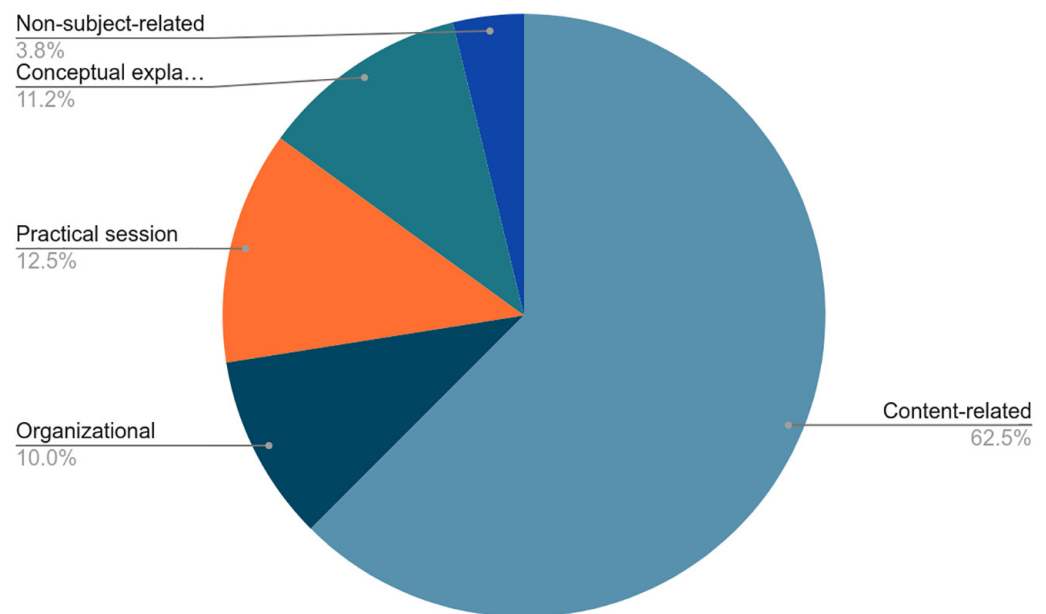


Fig. 3. Categorized interactions distribution

1. Content-related questions constituted 62.5% of the queries. These questions focused on the theoretical and practical aspects of the course, including definitions, formulas, calculations, and problem-solving strategies. Examples included questions about the trajectory of a point, how to find a velocity vector, the formula for the work of a couple's moment, and methods for solving problems related to snowball collisions or double blocks.
2. Organisational enquiries made up 10% of the questions. These queries pertained to course schedules, structure, grading, and requirements for passing the course. Representative questions included the frequency of practical sessions, strategies for passing the course, the grading guidelines, and the required score to achieve a grade of "4".
3. Practical session queries accounted for 12.5% of the questions and were related to lab sessions, experiments, measurements, and calculations specific to particular lab assignments. Examples included inquiries about the tasks for the third

practical session, necessary calculations, creating diagrams, and determining measurement uncertainty.

4. Conceptual explanations comprised 11.2% of the questions. These were aimed at gaining a deeper understanding of concepts, their derivation, or explanation. Examples included questions on deriving the acceleration formula for a sliding body, explaining the meaning of the moment of inertia, and understanding why the acceleration vector is the sum of two components.
5. Non-subject-related questions represented only 3.8% of the total. These questions were unrelated to Classical Mechanics or the course content, such as enquiries about personal schedules, opinions on unrelated topics, or inappropriate questions.

The distribution of these categories varied across the semester. December showed a notable increase in content-related and organisational questions, likely driven by exam preparations. In contrast, November experienced reduced activity, which correlated with the timing of mid-semester assignments. Despite these fluctuations, the consistent usage of the chatbot throughout the semester indicated its sustained value as a support tool for students (see Figure 4 for conversation distribution).

Chats

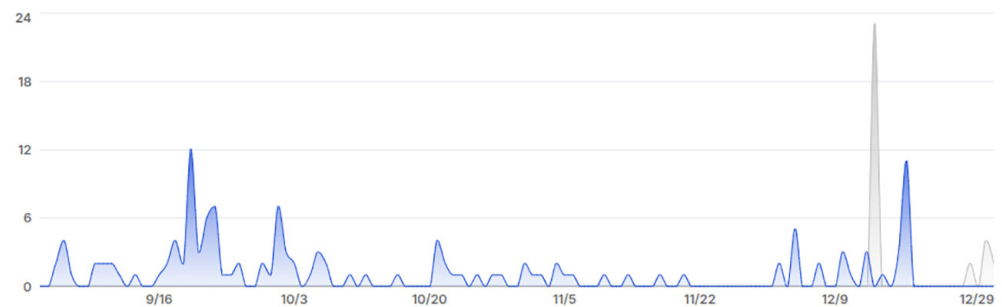


Fig. 4. Unique conversation distribution over the semester

3.6 Interviews

All 75 students enrolled in the course were invited to participate in the interview via personal email. Seven students registered for the interview, of whom one withdrew. The interviews were conducted in January 2025 using the MS Teams environment. The results cannot be generalised to the entire group of learners.

The interviews used guiding questions in three categories to determine the learners':

- Previous experience using AI-based chatbots in general and for educational purposes.
- Experiences using a chatbot trained on the course materials.
- Recommendations on how to further develop the AI chatbot to provide more support for students in their studies.

All students who participated in the interviews had previous contact with AI-based chatbots during their final years of high school, which coincides with the

public release of ChatGPT by OpenAI in November 2022. ChatGPT was the main model that students mentioned. One student also mentioned experimenting with Copilot. In general, learners found chatting with AI to be easy and natural. A couple of students mentioned that they had searched the internet a bit to learn how to write better prompts. The main limiting factor mentioned was the extent to which the chatbot can be used for free.

Learners had different experiences using AI-based chatbots for learning. Several pointed out that AI chat is good for finding answers to theoretical questions or better understanding complex concepts, as well as processing large volumes of data. However, there were also critics who highlighted experiences where AI chat answers incorrectly, and it is difficult for the learner to understand to what extent the answers can be trusted. Regarding solving mathematical problems, all learners were rather critical. Interview participants tended to see AI-based chatbots as tools that still require the user to understand the subject. At the same time, they highly value that it helps to quickly solve tedious tasks or overcome minor obstacles. One participant highlighted that they prefer to “Google” first because its environmental impact is smaller.

The interview participants’ experiences using the chatbot trained on course materials were rather modest. Several participants mentioned that since they did not receive satisfactory answers during their first attempts, they abandoned further use. Several participants also pointed out that the course was easy enough for them, and their experiments were limited to finding answers to organisational questions. Two learners who participated in the interview had more extensive and substantive experience using the chatbot trained on course materials. They received support both in answering preparatory questions for tests and in organisational and practical work formatting issues. These learners trusted the robots trained on course materials more than universal ones (e.g., ChatGPT). However, they pointed out that getting a quick answer does not help understand the topic.

Learners value the ability to use the chatbot because it is accessible 24/7, and the lecturer would certainly not have time to answer questions in such a way. However, the interview participants still strongly prefer communicating with the lecturer, as one must doubt the chatbot’s answers, but the lecturer can be trusted and can provide real-life examples; the lecturer can also meet the learner “halfway” when asking a question. None of the interview participants saw the chatbot as having a very significant impact on their learning effectiveness.

All interview participants thought that in terms of university development and competition, developing an AI-based chatbot and training it with specific course learning materials is definitely important and recommended continuing with it. An important value mentioned was that it is in Estonian. Learners considered the biggest limitation of the chatbot trained on course materials to be that it is trained only on the materials of one course.

Learners also shared thoughts on how they think the chatbot could be further developed:

- When answering a question, the chatbot could refer to the specific place in the learning material where the answer was found to make it easier to verify the answer and understand the context.
- An AI chatbot trained on the materials of all courses in the curriculum.
- Personalized content related to your data.
- Ability to add images and other files.

3.7 Summary of key findings of the experiment

The use of an AI chatbot in the Classical Mechanics course provided several benefits, particularly in reducing instructors' workload by addressing repetitive organisational questions and offering students 24/7 access to reliable course-specific information. The chatbot also provided feedback on students' actual questions and concerns, which might not be voiced directly, and facilitated improvements to the course structure and the presentation of organisational information. However, there were also challenges. The accuracy of the chatbot required continuous monitoring and retraining to address inconsistencies or deficiencies. The adoption of the chatbot also depended on the habits of both students and instructors. The chatbot logs provide valuable insights for substantive and organizational course improvements. Based on these findings, several recommendations were made for future use. These included strengthening the November portion of the course plan with intermediate assignments or discussion topics, providing clear grading criteria early in the semester to reduce organisational questions in December, directing the chatbot to provide better support for practical sessions, filtering out off-topic questions, and adding proactive messages before exam periods. The implementation of AI chatbots in education also presents challenges, including the cost of training and the need for rapid retraining when inconsistencies are identified. Continuous monitoring and analysis of logs are essential, as is addressing the habits of both students and instructors. Ultimately, the success of AI chatbots in supporting education relies on the correctness of the materials and the completeness and consistency of the organisational information provided. The experimental use of the AI chatbot in the Classical Mechanics course demonstrated both its potential and the importance of addressing its limitations.

4 DISCUSSION AND IMPLEMENTATION STRATEGIES

The rapid evolution of LLM-based chatbots presents both significant opportunities and considerable challenges for engineering education. The pace of technological advancement means that solutions considered limited or imperfect today may be substantially improved within a short timeframe. However, this rapid development also imposes pressures on educators, teaching staff, and curriculum managers who seek to integrate reliable chatbot tools into their courses and programmes.

Currently, no single, universally optimal solution exists from either a technical or pedagogical perspective. Nonetheless, the potential benefits are substantial. AI chatbots can reduce lecturer workload by automating responses to frequently asked questions, providing personalised learning experiences, and delivering immediate, evidence-based feedback to students. This capability enhances student confidence in the accuracy of information and supports diverse learning needs.

A primary challenge for lecturers lies in understanding the underlying technology, setting up the chatbot, and maintaining it throughout the course, including retraining and improving the model as needed. This underscores the necessity for robust technical support and a smooth, user-friendly implementation process. Seamless integration with existing e-learning platforms, such as Moodle, is critical to ensure accessibility and ease of use for both instructors and students.

Clear delineation of roles and responsibilities is essential for successful implementation. It is important to define which aspects of chatbot deployment are supported

by IT and didactic teams and which fall under the lecturer's purview. Lecturers must be made aware of the additional responsibilities and timelines involved to foster a positive experience for all stakeholders.

Beyond immediate course support, chatbots offer valuable secondary benefits. Analysis of chatbot conversation logs can inform continuous improvement options of course materials, teaching methods, and organisational structures. These data provide insights into student perceptions and highlight common areas of confusion, enabling targeted interventions to enhance learning outcomes. When combined with human instructor support, chatbot-driven personalised assistance can significantly enrich the educational experience.

Additional considerations arise in multilingual or diverse student populations. Chatbots' ability to switch languages and provide explanations in a student's native tongue addresses language barriers that often impede comprehension. For example, in Estonia, where students may speak Estonian, Russian, or English as their first language, chatbots can clarify course content in the student's preferred language, reducing misunderstandings and encouraging more confident engagement.

4.1 Recommended implementation strategy

For course and program managers:

- Develop a clear, structured pathway for chatbot adoption, including defined support points for lecturers.
- Collaborate with centres of didactics and IT to provide comprehensive training tailored to educators' needs.
- Establish a robust support environment encompassing technical assistance, didactic guidance, and helpdesk services.
- Utilize separate LLM models or analytical tools to interpret chatbot conversation logs, identifying areas requiring retraining or content adjustment.
- Advise lecturers on course preparation strategies, such as:
 - Sharing clear assessment criteria early to minimise organisational queries.
 - Strengthening course segments preceding assessments with intermediate assignments and discussion topics.
 - Integrating chatbot use explicitly within practical sessions, including guidance on effective question formulation.
 - Filtering and tagging off-topic questions to monitor chatbot usage patterns.
 - Deploying proactive chatbot messages, for example, reminders about grading criteria before exams.

At the institutional level:

- Evaluate the feasibility of deploying in-house, open-source LLM models tailored for teaching purposes, enabling semi-automated deployment across courses and integration with official e-learning platforms.
- Allocate centralized investment in RAG/LLM software wrappers/API development for university-wide deployment.
- Conduct comprehensive analyses of chatbot interaction data to identify broader trends and address critical issues such as dropout rates, timely graduation, and learning quality in engineering programmes.
- Develop institutional support structures and allocate resources to facilitate the smooth integration of chatbots for all teaching staff.

- Maintain flexibility to adapt to rapid technological advances, recognizing that AI capabilities may double on a monthly basis, necessitating ongoing updates and paradigm shifts.

Beyond a single institution, as the initial and ongoing investments for AI technology rise, it may well make sense for institutions to invest in an open-source consortium as described by the FRODO concept [19]. In this approach, a consortium of physics 1 lecturers would jointly accumulate content, manage hallucinations, and add assessments. The scale provided by a broader community would enable broader and deeper investment. In addition, the open-source nature would crowd-source innovation in pedagogy. Finally, the AI chatbot framework can act as the language-specific and intelligent engagement with the student.

5 CONCLUSION

While LLM-based chatbots hold transformative potential for engineering education, their effective deployment requires careful planning, clear role definition, and sustained support. By embracing these strategies, educational institutions can harness AI to enhance personalised learning, improve instructional quality, and ultimately foster better student outcomes.

The findings of this study underscore that AI is fundamentally reshaping the educational landscape, marking a pivotal transition that can no longer be overlooked. AI-powered chatbots, in particular, have become integral to the learning process; rather than being excluded, they must be strategically incorporated as teaching assistants and facilitators of personalised learning experiences. This integration, however, challenges the traditional educational paradigm in which the lecturer is viewed as the primary transmitter of knowledge. With knowledge now readily accessible through AI-driven tools, the lecturer's role is undergoing a significant transformation—from that of a knowledge provider to a coach and mentor who fosters meaningful human-to-human interactions within the learning environment.

Moreover, the evolving educational context requires a re-examination of curricular priorities. The focus is shifting from the mere transfer of subject-specific knowledge to the cultivation of core engineering values, critical thinking, and evaluative skills. As AI systems increasingly support routine information delivery, educators are called upon to emphasise the development of higher-order cognitive abilities and ethical reasoning. This transition is not without its challenges; it demands a substantial mindset shift for many educators, who must adapt to new roles and pedagogical strategies in order to fully leverage the benefits of AI-enhanced education.

In summary, the integration of AI, particularly chatbots, into educational practice is both inevitable and transformative. Institutions and educators must embrace this change, prioritising AI literacy and the continuous development of skills that enable responsible and effective use of these technologies. By doing so, they will be better positioned to foster student engagement, support innovative thinking, and prepare learners for success in an increasingly AI-driven world.

6 ACKNOWLEDGMENTS

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