



Attempt of integrating ChatGPT into exercise classes of Theoretical Physics

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Abstract

Integrating artificial intelligence (AI) at universities opens up new avenues for accessing and acquiring contents and methodological knowledge, as well as for managing academic work. We investigate the use of ChatGPT, an AI-powered chatbot, in the context of physics studies. Specifically, we focus on experiences in the exercise course for the introductory lecture on Theoretical Mechanics in the Physics Bachelor study program. Aspects beyond this course are addressed as well. Our approach includes additional exercises supporting the lectures that illustrate to students the potential and current limitations of ChatGPT in its freely available version. For this purpose, we used two different types of tasks. On the one hand, this involved using ChatGPT to solve computational exercises, and on the other hand, utilizing the chatbot for conceptual explanations of physical phenomena, definitions, and everyday examples. Additionally, we conducted an online survey among the students. The results show that students found the provision of conceptual explanations and examples by ChatGPT to be helpful. However, the support for computational tasks in the freely available version of ChatGPT at that time was perceived as unreliable and weak. Our framework contributes to the discussion on the meaningful use of AI technologies in university teaching and provides insights into students' perceptions and use of these technologies.

Die Integration von künstlicher Intelligenz (KI) in Forschung und Lehre an Universitäten eröffnet neue Wege für den Zugang zu und den Erwerb von inhaltlichem und methodischem Wissen sowie für die Bewältigung akademischer Arbeit. Wir untersuchen den Einsatz von ChatGPT, einem KI-gestützten Chatbot, im Kontext des Physikstudiums. Speziell konzentrieren wir uns auf Erfahrungen im Übungsbetrieb zur Physik-Bachelor-Grundvorlesung Theoretische Mechanik. Auch weitergehende Aspekte werden erfasst. Unser Ansatz beinhaltet die Einbindung von zusätzlichen, vorlesungsbegleitenden Übungsaufgaben, um den Studierenden das Potenzial sowie die aktuellen Limitationen von ChatGPT in der frei verfügbaren Version zu verdeutlichen. Hierfür setzten wir zwei verschiedene Arten von Aufgaben ein. Einerseits war dies die Verwendung von ChatGPT zur Lösung rechnerischer Übungsaufgaben, andererseits die Nutzung des Chatbots für konzeptionelle Erklärungen physikalischer Phänomene, Definitionen und Alltagsbeispiele. Zusätzlich führten wir eine Online-Umfrage unter den Studierenden durch. Die Ergebnisse zeigen, dass die Studierenden die Bereitstellung von konzeptionellen Erklärungen und Beispielen durch ChatGPT als hilfreich empfanden. Allerdings wurde die Unterstützung bei rechnerischen Aufgaben in der zu diesem Zeitpunkt frei verfügbaren Version von ChatGPT als unzuverlässig und schwach empfunden. Unser Ansatz trägt zur Diskussion über den sinnvollen Einsatz von KI-Technologien in der universitären Lehre bei und liefert Einblicke in die Wahrnehmung und Nutzung dieser Technologien durch Studierende.

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1. Introduction

The development of AI-powered chatbots marks a significant technological milestone. When OpenAI released its chatbot, ChatGPT, to the public for free on November 30, 2022, one million users worldwide registered within a few days. Since its launch, a remarkable transformation has been felt in various areas of our society, including education. AI-powered chatbots have the potential to support and improve the teaching and learning process.

At universities, especially in teaching and studying, the integration of such technologies holds both great potential and some challenges. On one hand, the use of ChatGPT provides students with new access to knowledge, both in terms of content and methodology, and facilitates the completion of academic tasks through the immediate availability of information and explanations. On the other hand, there are also risks, such as the possibility of dependence on the technology and the danger of spreading inaccurate or even false information. Physics, and theoretical physics in particular, uses mathematical expressions to quantitatively describe content. The question arises to what extent this can currently be represented by ChatGPT.

Our approach in the first attempts to integrate ChatGPT into the teaching and learning of theoretical physics includes the integration of the chatbot into additional, lecture-accompanying exercises. We aim to show students both the potential and the limitations of this technology in its current state at the time of use. To this end, we focus on two types of exercises. On one hand, ChatGPT will be used to solve computational exercises. On the other hand, the chatbot will be employed to find conceptual explanations of physical phenomena, definitions, and everyday examples.

The structure of this article is as follows. First, we explain in detail how ChatGPT was integrated into the exercise class and which different types of exercises were set. We then present the results of an online survey conducted among the students to evaluate their experiences and perceptions regarding the work with ChatGPT. Finally, we summarize and draw con-

clusions about the effectiveness and challenges of using ChatGPT in physics studies. Finally, we give an outlook on possible future developments and improvements in the integration of AI-based technologies within the framework we have described.

2. Use of ChatGPT in the study of theoretical physics

We investigate the use of ChatGPT, an AI-supported chatbot, in the context of physics studies, specifically in the field of theoretical physics. Our approach includes the integration of lecture-accompanying exercises to show students both the potential and the limitations of ChatGPT in the version freely available at the time of the report. We gained our experience during the lecture on theoretical mechanics in the winter semester 2023/2024, when students had free access to ChatGPT version GPT-3.5 [1]. We did not require students to register with ChatGPT. The course on theoretical mechanics, to which we refer, is part of the bachelor degree program in physics at Otto von Guericke University Magdeburg [2] and is a compulsory course in the third semester.

In the lecture (four hours per week during teaching periods) the basics of theoretical mechanics are developed. The course content and associated calculation techniques are introduced and taught step by step. An essential component of the courses is given by the accompanying exercises. Here, students learn and practice how to carry out complex calculations independently. Each week, students receive an exercise sheet with four calculation exercises, parts of which are corrected and assessed after being submitted online. We use a digital process via an e-learning platform [3] for submission of the solutions to the exercises and to correct them. The discussion takes place in person. In the associated course (two hours per week during teaching periods), the solutions to the exercises on each exercise sheet are discussed.

In addition to the regular analytical calculation exercises described above, we added a short, fifth ChatGPT exercise to each exercise sheet. This exercise referred either to the current ex-

ercises on the sheet or to the current lecture content. We used two types of exercises. On one hand, students were asked to solve simple problems of calculation related to the lecture. First, they solved this exercise independently by themselves, then they asked for help by ChatGPT. On the other hand, the students were asked to use the chatbot to obtain conceptual explanations of physical phenomena, definitions, and everyday examples. To briefly summarize the result: while the chatbot can provide reliable explanations of physical phenomena and concepts, errors regularly occurred when processing calculation exercises in the described framework in the version freely available at the time of report. Explanations were imprecise so that misunderstandings were virtually unavoidable. In some cases, it was very difficult or practically impossible to obtain correct calculation solutions, even with intensive discussion and assistance. The ChatGPT exercises were completed on a voluntary basis and were not included in the assessment of the students' performance in the corresponding module.

In the following, we present examples of the two types of exercises. The functionality of the chatbot in this context is discussed on the basis of its output.

We start with an example for a calculation exercise. The ChatGPT exercise refers to another exercise on the first exercise sheet that the students beforehand solved by conventional, analytical calculation (e.g. with paper and pencil). In the following, we first reproduce the wording of the **conventional calculation exercise** and then the wording of the related **ChatGPT exercise**. We then insert a typical **user input** to obtain the solution to this exercise using ChatGPT. We reproduce the **chatbot output**. Later, we classify the result under **Conclusion/Criticism**.

Wording of the conventional calculation exercise 4(d) (translated from German): Use index notation (including Einstein's summation convention) and the totally antisymmetric third-rank tensor with components ε_{ijk} to compute the following expression:

$$\vec{a} \cdot (\vec{b} \times \vec{a}) \quad (1)$$

Wording of the related ChatGPT exercise (translated from German): Try to elicit the

calculation of exercise 4(d) from ChatGPT. Then check the calculation. Please upload your chat history for solving exercise 4(d) together with the solution of the exercise sheet to the e-learning portal.

User input (translated from German): Please calculate and simplify $\vec{a} \cdot (\vec{b} \times \vec{a})$ using Einstein's summation convention.

Chatbot output (translated from German): To calculate and simplify the expression $\vec{a} \cdot (\vec{b} \times \vec{a})$ using Einstein's summation convention, we proceed as follows: First, we use the identity for the cross product in vector form:

$$(\vec{b} \times \vec{a}) = \varepsilon_{ijk} b^j a^k \hat{e}_i \quad (1)$$

Here ε_{ijk} is the Levi-Civita symbol and $\hat{e}_i$ are the unit vectors. Now we multiply $\vec{a}$ by the result of the cross product:

$$\vec{a} \cdot (\vec{b} \times \vec{a}) = a^i (\vec{b} \times \vec{a})_i \quad (2)$$

Let us insert the cross product:

$$(\vec{b} \times \vec{a})_i = \varepsilon_{ijk} b^j a^k \quad (3)$$

Then we get:

$$\vec{a} \cdot (\vec{b} \times \vec{a}) = a^i \varepsilon_{ijk} b^j a^k \quad (4)$$

Since ε_{ijk} is antisymmetric (i.e. $\varepsilon_{ijk} = -\varepsilon_{ikj}$), we can rearrange:

$$\vec{a} \cdot (\vec{b} \times \vec{a}) = \varepsilon_{ijk} a^i a^k b^j \quad (5)$$

Now we use Einstein's summation convention to sum over i and k :

$$\vec{a} \cdot (\vec{b} \times \vec{a}) = \varepsilon_{ijk} a^i a^k b^j = a^i a^k \varepsilon_{ijk} b^j \quad (6)$$

Since $\varepsilon_{ijk} a^i a^k = 0$ (because ε_{ijk} is only nonzero if i, j, k are different indices), it follows that

$$\vec{a} \cdot (\vec{b} \times \vec{a}) = 0 \quad (7)$$

Therefore, the simplified formula for $\vec{a} \cdot (\vec{b} \times \vec{a})$ using Einstein's summation convention is 0.

Conclusion/Criticism: This issue is a prime example of the problems that can arise when using ChatGPT for calculation tasks. In this case, the AI-supported chatbot arrives at the correct final result, but the reasoning is incorrect and therefore not reliable.

In the fourth calculation step (between equations 4 and 5), ChatGPT justifies the rearrangement of the terms by the Levi-Civita symbol being antisymmetric. However, the actual reason lies in the fact that a^i, a^k , and b^j are individual indexed vector components, that is, simple numbers in this specific case. The multiplication of simple numbers is commutative, which

means that we can change the order of multiplication at will.

Another problem can be found in the last calculation step (between equations 6 and 7). The chatbot statement is that the expression $\varepsilon_{ijk}a^i a^k$ becomes zero because the Levi-Civita symbol is only nonzero if all indices are different. However, recalling Einstein's summation convention, contributions containing different indices actually do occur in this expression. In general, these contributions do not vanish. The actual reason for the result being zero is that the contributions pairwise cancel each other. Now, the background is that the Levi-Civita symbol is antisymmetric, which is the reasoning that was incorrectly used between equations 4 and 5.

To summarize, the chatbot has managed to list the definitions of the expressions correctly. It also reproduces the correct result. However, the calculation is not correct if one follows the logic of the incorrectly displayed justifications. Errors occur when it comes to correctly combining individual properties of the employed variables and generating a logical justification and derivation.

Next, we present an exemplary ChatGPT exercise on conceptual explanations following the same pattern:

ChatGPT exercise (translated from German): Have ChatGPT list the defining characteristics of conservative force fields. Then evaluate the outputs. Please upload your chat history together with the solution of the exercise sheet to the e-learning portal.

User input (translated from German): Please list all required/defining characteristics of conservative force fields.

Chatbot output (translated from German): A conservative force field has several characteristics that distinguish it from nonconservative force fields. Here are the most important characteristics:

1. Conservative forces depend only on position: In a conservative force field, the force acting on a particle depends only on its position and not on its velocity or time. This means that the force is independent of the movement of the particle.
2. Work is independent of the path: The work performed by a conservative force on a parti-

cle depends only on the initial and final positions of the particle and not on the exact path that the particle takes between these two positions. This is called path independence.

3. Conservation of energy: In a conservative force field, the mechanical energy of a particle is conserved. This means that the sum of kinetic energy (energy due to velocity) and potential energy (energy due to position in the field) remains constant as long as no nonconservative forces (such as friction) are acting.

4. Potential energy: A potential energy can be defined in a conservative force field. This potential energy depends on the position of the particle in the field and can be used to calculate the work performed by the force on the particle as it moves between different positions.

5. Closed paths: In a conservative force field, the work performed along a closed path (a closed loop) is always zero. This means that energy is conserved when a particle moves along a closed path.

These characteristics are crucial for understanding conservative force fields in physics. They make it possible to understand the conservation of energy and the relationship between forces, potentials, and paths in conservative fields.

Conclusion/Criticism: In this case, ChatGPT manages to provide a comprehensive and detailed answer. If further questions are asked, the individual points are also presented as formulas. One point of criticism could be the failure to mention the vanishing curl of the force field, at least if the force field is defined in a simply connected space. ChatGPT does not list these points in the first answer. However, they can be generated upon further inquiry. Furthermore, it is not clear which properties are actually defining. For example, point 1 describes a property, but does not define a conservative force field. In contrast, point 2 is sufficient in itself as a definition of a conservative force field. Without wishing to criticize the user at this point, the above observation also allows us to draw possible conclusions about how to improve the design of the input. The combination of the not completely synonymous terms "required" and "defining" with the help of the slash "/" may suggest a synonymity that is not

completely true and influences the less differentiated output of the results.

In summary, we may say that ChatGPT can well be used to provide explanations of physical phenomena and concepts. This is especially true when no indepth description using mathematical formulas and logical linking of calculation steps is required. In contrast, errors, imprecise reasoning, and misunderstandings regularly occur when working on calculation problems in theoretical physics. This trend was observed across all ten ChatGPT exercises set during the semester. Half of them contained calculation problems, while the other half required conceptual points and explanations.

3. Assessment by the students

In order to obtain more detailed feedback and assessment of the results from the students, we conducted an anonymous online survey at the end of the lecture period of the winter semester 2023/2024 via the e-learning platform [3] of the Otto von Guericke University Magdeburg. Responses were provided by nine participants. The trends resulting from this survey are presented and discussed below.

Questions were asked about the frequency of previous and expected future use and the estimated usefulness of ChatGPT for various tasks and requirements. Some of these questions related specifically to the study of theoretical physics, some related to the study of physics in general, and some went further beyond. All questions could be rated on a scale from 1 to 8. The two end points of the scales were verbalized, according to the question. The value 1 expressed the minimum in terms of the lowest level of agreement, most negative attitude, or minimum frequency. The value 8 corresponded to the maximum in terms of the strongest agreement, most positive attitude, or maximum frequency. The students were informed that our scale does not have an indifferent mean value, so that the rating 4 tends slightly towards 1, and the rating 5 tends slightly towards 8.

In general, our aim in including the ChatGPT exercises was to motivate students to experience the possibilities and current limitations of the new technology. On one hand, this relates to the context of their studies. On the other

hand, we also wanted to stimulate them in general to keep an eye on technological developments and to engage with them. Accordingly, the aim of our survey was not only to find out how the students perceived the usefulness of ChatGPT in the narrow technical and methodological context of the ChatGPT exercises described above. We also wanted to find out whether we had succeeded in sensitizing the students in general with regard to possible further use of ChatGPT in physics studies and beyond. We also intended to find out in general how much the students liked our approach of introducing them to the technology in this way. Out of the participating students, all stated that they had used ChatGPT occasionally to frequently in the past. None of them used ChatGPT for the first time.

With regard to the two different types of ChatGPT exercises presented above, we asked the students to rate the usefulness of ChatGPT, see Fig. 1. At the time of processing and survey, version GPT-3.5 was available free of charge.

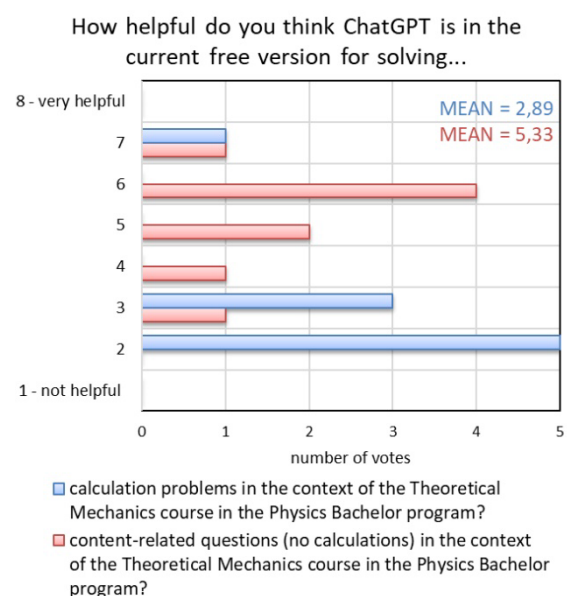


Fig. 1: Students' assessment of the usefulness of ChatGPT for solving calculation problems and clarifying questions referring to the compulsory course Theoretical Mechanics in the bachelor degree program in physics. At the time of the survey, version GPT-3.5 was freely available.

The majority of students found the use of ChatGPT for solving calculation problems to be less helpful, see the blue bars in Fig. 1. In contrast, the majority of participating students rated its use for clarifying content-related

questions as positive, see the red bars in Fig. 1. These two trends are consistent with our own experience of using the version GPT-3.5.

Next, we wanted to determine to what extent the students plan to use ChatGPT in the future as part of their further physics studies after dealing with ChatGPT when working on our exercises, and in other, for example private contexts, see Fig. 2. Unsurprisingly, based on the described experiences, uniformly the students rarely plan to consult the chatbot for help with calculations in theoretical physics, see the blue data in Fig. 2. With regard to assistance with general physics content, students are slightly more likely to consider future use in theoretical physics, see the red bars in Fig. 2.

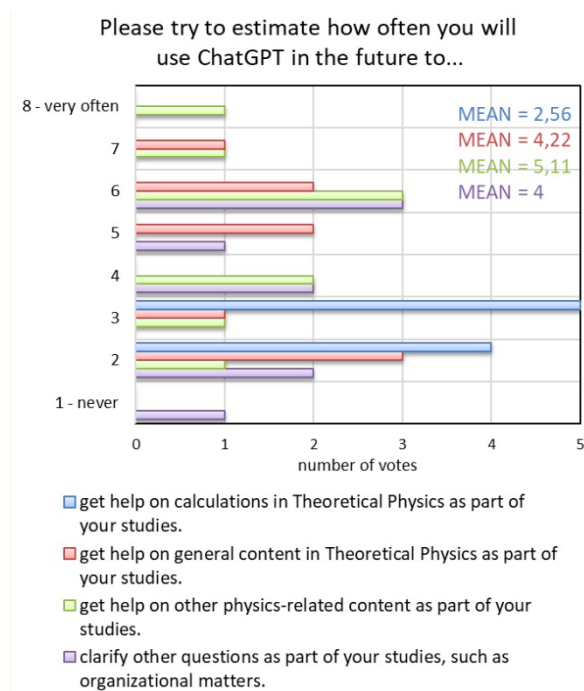


Fig. 2: Students' assessment of the frequency with which they would use ChatGPT in the future as part of their studies. We distinguish between calculation exercises and content-related questions in theoretical physics, as well as content-related and organizational questions in the remaining context of their studies.

In contrast, there is a more positive attitude towards use concerning more general aspects of their studies, see the green bars in Fig. 2. We suspect that theoretical physics occupies a different position here with regard to the prevailing mathematical language and expressions than subject areas that are primarily communicated in a verbal way. This is also consistent

with our earlier finding that, mostly, students in theoretical physics still prefer a handwritten approach [4]. It may suggest that students are more likely to consider the technology in other areas such as experimental physics. The future tendency of referring to ChatGPT was rated as moderate on average concerning other questions within the context of the courses, for example, organizational issues, see the purple bars in Fig. 2.

In contrast to skills of calculation, at the time the online survey was evaluated, AI-supported chatbots had great potential in processing and writing texts. Accordingly, ChatGPT could be a great help, particularly when writing academic texts, especially in seminar tasks, bachelor and master theses.

In this context, it was interesting for us to find out how often the students expected they would use ChatGPT in the future when writing such academic texts, see Fig. 3. It is very surprising to us that, on average, the students can only imagine using ChatGPT with moderate frequency as support for academic writing, see the red bars in Fig. 3.

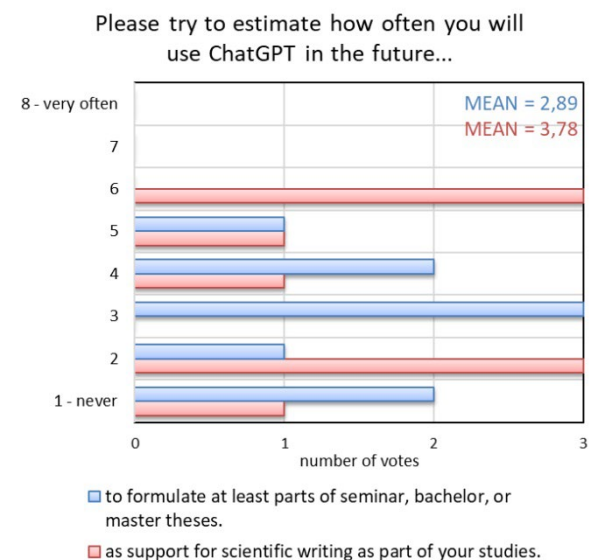


Fig. 3: Students' assessment of the expected frequency of using ChatGPT when writing scientific texts as part of their studies. The results distinguish between academic writing specifically in the context of seminar tasks, bachelor and master theses on one hand, and remaining, more general writing on the other hand.

In the context of physics studies, this category could include, for example, the writing of parts

of lab reports or descriptions and evaluations of experiments. This is all the more surprising as students repeatedly report in personal discussions about the high workload associated with writing such texts.

The intention to use ChatGPT specifically for formulating parts of seminar tasks and theses is even less apparent, which in the context of physics studies particularly concerns bachelor and master theses, see the blue bars in Fig. 3. On one hand, this may be due to third-semester students still feeling that writing their bachelor thesis is a long way ahead. On the other hand, it could result from fear and uncertainty about violations of declarations of independence, that is, the declaration that the thesis was written without any aids other than those specified. This context generally points to the urgency of clarifying the relevant facts and making them widely known, if possible using concrete examples. In other words, clear regulations are required in this case as to when the use of AI-supported tools is permitted, in what form, and under which circumstances. Teachers can use such regulations to educate students how to use new technologies and gain confidence in assessing their performance. Students can learn how to use the technologies profitably within this framework.

Another area of potential use concerns the general linguistic capabilities of ChatGPT in the context of writing computer programs and translating texts. These tasks apply to the learning of foreign and programming languages. ChatGPT can be helpful in creating simulation code and in finding and correcting programming errors. In contrast to conventional translation software, ChatGPT can potentially provide more coherent translations for longer texts. In the context of the lecture on theoretical mechanics, these applications are only marginally relevant. However, the chatbot could support the writing of research-relevant simulation code during the master thesis at the latest. It could also be helpful for better understanding of scientific literature when translating it from English, or when writing the bachelor or master thesis in English. Accordingly, in Fig. 4 we show the frequency with which students estimate they have consulted the chatbot in the past and will consult it in the future

for these and similar purposes. It can be clearly seen that the majority of participants have rarely or never used ChatGPT for programming assistance, see the blue bars in Fig. 4.

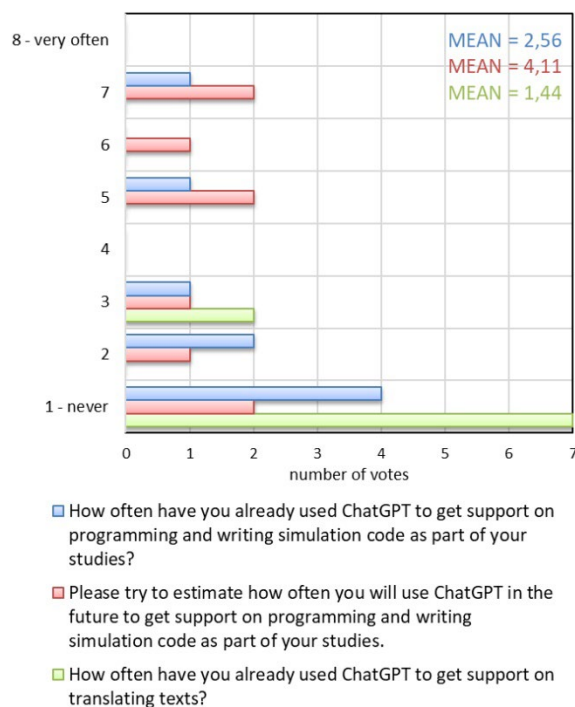


Fig. 4: Students' assessment of the frequency of use of ChatGPT for support in programming and creating simulation code as well as translating texts into and from foreign languages. The students were asked about the amount of their expected future use of ChatGPT for programming as well.

The situation is similar concerning the use of ChatGPT for translating texts, see the green bars in Fig. 4. However, on average, students assume that this will change, at least with regard to programming activities, see the red bars in Fig. 4.

Finally, we wanted to find out how well our approach was received by the students, see Fig. 5. How did the students rate our efforts to motivate them to familiarize themselves further with the new technology in the described way and to think about its possible future use? A significant majority was positively inclined towards our approach, see the blue bars in Fig. 5. For us, this is surprising in a positive sense. After all, the ChatCPT exercises meant additional work for the students. When asked whether their experience with ChatGPT during the semester had led them to use the technol-

ogy in general as part of their studies, the students gave a roughly neutral assessment on average, see the red bars in Fig. 5. The situation is similar with regard to general use outside of their studies, see the green data in Fig. 5.

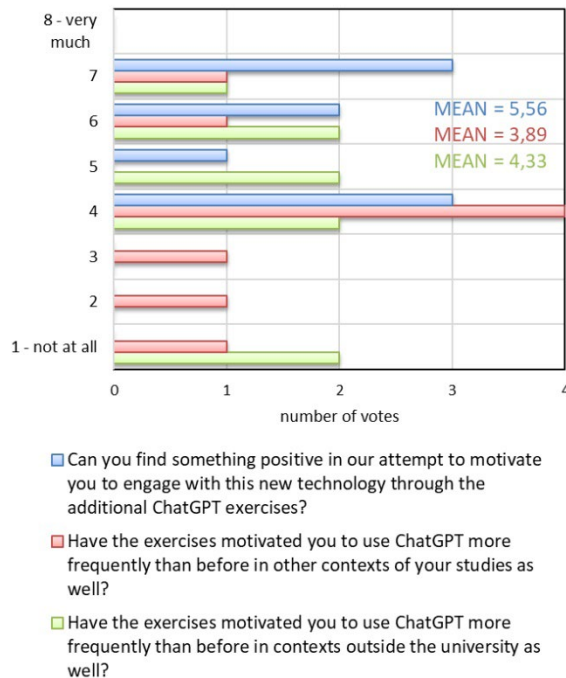


Fig. 5: Students' assessment of the impact of our attempt of involving ChatGPT exercises to encourage them to use the new technology more frequently. We differentiate between use in their study context and in a nonuniversity context. The average feedback on our attempt of motivating students to engage with ChatGPT was positive.

The spectrum is broadly distributed. Apparently, we were able to stimulate a significantly stronger engagement with the chatbot among individual students through our ChatGPT exercises. For others, this effect was only moderate. In a nonuniversity context, the use of ChatGPT increased slightly more than in the context of physics studies, at least among the few participants in this survey. This is shown by the comparison between green and red bars in Fig. 5.

4. Lessons learned

In summary, we investigated the extent to which the AI-supported chatbot ChatGPT can be used in physics studies in regular university

exercise classes in theoretical physics. Specifically, this attempt to integrate ChatGPT took place in the lecture-accompanying exercises on Theoretical Mechanics, a compulsory course in the third semester of the bachelor degree program in physics [2] at Otto von Guericke University Magdeburg. The time period corresponded to the lecture period of the winter semester 2023/2024. Accordingly, the students had free access to ChatGPT version GPT-3.5 [1]. They used the chatbot to work on additional exercises set for this purpose, both of calculation and conceptual, content-related nature. We did not encourage the students to register to use ChatGPT. Our aim was to motivate them to familiarize themselves with the new technology and to explore its capabilities, if necessary beyond the context of our exercises. At the same time, we wanted them to experience the opportunities it offers, but also the limitations that still exist. With the help of an online survey, we received feedback on the students' impressions.

Our test showed that ChatGPT version GPT-3.5 is capable of providing comprehensive and detailed explanations of physical phenomena and concepts. However, errors and inaccurate reasoning regularly occur when working on calculation tasks. This is reflected in the feedback from the students. On average, they found the use of ChatGPT to solve calculation problems not to be helpful, at least in the version that was freely available at the time of use. The opportunity to clarify content-related questions was rated much more positively.

In addition to these points, the online survey at the end of the semester showed that students used ChatGPT occasionally to frequently and would also consider using it in the future to clarify general physics content and questions. Interestingly, the willingness to use ChatGPT at least as an aid in writing scientific texts was low. Surprisingly, the students also gave little consideration to using ChatGPT for programming and creating simulation codes, or for translating texts.

For us, the findings from our study provide important hints for the future integration of AI-supported chatbots in university teaching. Based on the results, we see several approaches to further optimize and expand the

use of ChatGPT in physics studies. We should explain to students that ChatGPT can be a helpful tool for clarifying content-related and conceptual issues. In particular, we should convey to students that it is a very valuable tool when it comes to learning programming and creating individual program modules. It may not be enough to simply refer to the capabilities of ChatGPT. At the very least, students should be given a live demonstration of its use for creating program blocks or learning programming languages. The same applies to translating texts. ChatGPT is generally an excellent translation tool, which should be adequately communicated to students.

In addition, and surprisingly, we noticed a clear reluctance among students to use ChatGPT when writing lab reports, theses, or other academic texts. Above all, we see this as an indication that clearly formulated guidelines need to be established in academia in general, universities, and departments. These guidelines should be comprehensible and practicable for students, providing concrete examples. Above all, they must be clearly communicated and students must be actively made aware of them. It must be specified when AI-supported tools may and may not be used, how this is to be indicated, and how this is to be taken into account in evaluations and assessments. This would help students to take advantage of potential benefits without worrying about violating academic standards. It would also make it significantly easier for teachers to educate students how to use the tools. Students, and therefore our society, should not suffer any disadvantages in international competition as a result of limited experience with future standard tools, which could result from bans on their use.

In this context, it would be interesting to see in future studies whether students' attitudes towards the use of ChatGPT for writing lab reports, theses, or other academic texts change over the course of their studies. Simultaneous surveys involving students in different academic years could provide corresponding information. Such simultaneous data collection across different academic years over the course of the degree program could possibly reduce the influence of the rapid development of AI-supported tools on student feedback.

We would like to point out that the scope of possible applications will also grow with the further development of AI-supported chatbots. Since the first release of ChatGPT in version GPT-3.5 by OpenAI on November 30, 2022, there have been numerous innovations. These include optimized speech understanding and the recognition of images and videos since version GPT-4 [5]. Unlike the previous GPT-4, version GPT-4o, which is available at the time of writing this manuscript, is accessible free of charge. In this latest version, the chatbot can be connected to a number of plugins. In particular, the Wolfram Alpha plugin, for example, allows calculation exercises to be evaluated much more reliably. Here, arithmetic operations are passed to the Wolfram Alpha symbolic solver. For data protection and privacy reasons, we confined ourselves to working with a free version in our approach. We did not ask the students to register.

We assume that a repetition of the study in the future would already lead to different results due to the rapid development of the technology. The number of participants in our survey is relatively small. An increased number would certainly be helpful in future evaluations. In parallel to introducing measures to increase the number of participants, the investigation of other models could be considered in order to increase the informative value. Nevertheless, we believe that qualitative trends can be identified from the present survey and would like to thank the students for their participation. Their feedback provided us with valuable information for possible future designs.

Ultimately, our study shows that ChatGPT can be a valuable tool in physics studies if used correctly. Continuous improvements and additions to the possible applications will significantly expand the potential of this technology in the future. We are convinced that teaching and learning processes can be significantly improved if used rationally in order to exploit the potential of the new technology. Our attempt shows that, on average, students rate it positively when they are introduced to the technology in the context of specific tasks.

Acknowledgements

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