ChatGPT and Sustainability in Universities: Exploring Environmental and Educational Impacts

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While capable of solving university assignments and consuming almost ten times more energy than a Google query, ChatGPT's impact on universities' environmental and educational sustainability remains largely unexplored. Therefore, this research assesses ChatGPT's influence on deeper learning and the increase in energy consumption resulting from the usage of ChatGPT by students. To establish an empirical base for the research, an anonymous survey among 50 students was conducted to learn about their perceptions and usage patterns of ChatGPT. The research reveals an adoption rate of 54%, with a mild positive influence on deeper learning accompanied by a 5.4 times increase in the cumulative energy required by students to complete their university assignments. Furthermore, patterns of lack of trustworthiness and independent thinking concerning the usage of ChatGPT were detected alongside a considerable impact on the ease of assignments. Consequently, while having a mild positive effect on deeper learning, the potential of ChatGPT to be misused might eventually negatively alter students' learning process.

Additional Key Words and Phrases: ChatGPT, university, education, sustainability, deeper learning

1 INTRODUCTION

In recent years, almost every aspect of society has been influenced by the proliferation of Artificial Intelligence (AI), including university education. However, in this context, the emergence of ChatGPT can be defined as the turning point in the relationship between university education and AI. Upon registration, ChatGPT provides any individual, including students, advanced capabilities that many have yet to encounter, including the ability to solve different types of university-level assignments [22, 28]. Consequently, while offering potential positive and negative effects, placing universities in an unprecedented situation.

Apart from capabilities that could be leveraged to improve tutoring and learning processes, ChatGPT has also raised concerns related to academic integrity and misuse by students. According to Baidoo-Anu and Ansah (2023), by offering alternative explanations that match the student's level of understanding, ChatGPT can provide students be used as a personalized tutor [1]. Moreover, due to enhanced writing and analysis skills, it can be used in the development of such skills among students [23]. However, all that glitters is not gold. ChatGPT's ability to collect information from various sources, summarize it, and generate a concise but well-written text could readily transform the learning opportunity into a threat to academic integrity [5]. Furthermore, ChatGPT inherent biases and inability to distinguish between right and wrong and true or false, might result in a structured, well-written text that might ultimately prove to be incorrect [3, 24, 26]. Therefore, the usage of ChatGPT must be responsible and its output must be taken with a grain of salt.

Consider potential misuse of ChatGPT by students to complete assignments, a question can be raised whether the current university education model is still sustainable. To graduate from university, students are expected to achieve learning goals and master various academic topics, this is also known as deeper learning. Deeper learning is an umbrella term for competencies, such as critical thinking and problem-solving, that students must possess to succeed in the 21st century [10]. However, as ChatGPT is a relatively new tool, its effect on students' deeper learning has yet to be fully explored. Therefore, this research aims to assess ChatGPT's impact on deeper learning. Consequently, facilitating a discussion on the sustainability of the current university education in the era of ChatGPT.

Beyond the educational model's sustainability, the study will also investigate ChatGPT's impact on the environmental sustainability of the current educational model. As ChatGPT consumes roughly 0.0029 Kilowatt-hours (kWh) per prompt, nearly 10 times more than a traditional Google search query (0.0003 kWh), it can be assumed that wide adoption among students increases the energy consumption required to address students' queries, consequently; increasing the environmental footprint of university education [6, 12]. Therefore, the research will assess ChatGPT's influence on the cumulative energy consumption required by students to complete their assignments, as well as address the question of whether university guidelines play a role in promoting excessive use of ChatGPT.

To explore ChatGPT's influence on universities' environmental and educational sustainability, the research included the following research questions:

(1) To what extent does the usage of ChatGPT by university students impact environmental and educational sustainability?
   (a) What are the guidelines for Generative AI usage by students?
   (b) To what extent does ChatGPT affect the environmental sustainability of university education?
   (c) To what extent does ChatGPT impact the educational sustainability of university education?

2 THEORY

To frame this research, this section introduces the Diffusion of Innovation, the concept of Chasm, and deeper learning. First, the section will explore the diffusion of innovation and the Chasm that illustrate the adoption lifecycle of new technologies. Next, deeper learning will be discussed, focusing on what it is and which competencies it entails.

2.1 Diffusion of Innovation and Chasm

Diffusion of Innovation (DOI) is a framework introduced by Everett Rogers in 1962. It seeks to explain how, why, and at what rate

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new ideas, processes, and technology spread through a population or community [33]. Rogers categorizes individuals into adopter groups based on innovativeness: the Innovators, Early Adopters, Early Majority, Late Majority, and the Laggards. According to Rogers (2003), the groups can be characterized as follows:a) Innovators - pioneers who are willing to adopt the technology, although it might be unsuccessful. b) Early adopters - these are opinion leaders, who are responsible for putting a "stamp" on a new idea [25]. c) Early majority - interested in new ideas but less innovative than the aforementioned groups. Their good interaction with other members of the social system contributes to the innovation-diffusion process. d) Late majority - more conservative and skeptical towards new innovations. Therefore, they should see a substantial value before adopting an innovation. e) Laggards - this group is more skeptical towards a new innovation than the late majority. Their network mainly consists of similar people, possibly eliminating adoption due to peer pressure [27]. Consequently, the more groups that adopt an innovation, the bigger the innovation's market share becomes.

Crossing the 'chasm' is a key element in the diffusion of an innovation. Moore (2003) found a psychological gap between 'Early markets' and 'Mainstream markets', which he defined as the chasm [16]. This point is marked by a significant increase or decrease in adoption rates, constituting a tipping point in the life of an innovation. While it can also occur between a 10% to 40% adoption rate, Johnston (2011) places the Chasm at a 16% adoption rate [13]. Similarly, according to Rogers, the critical mass occurs at a 16% adoption rate. It defines the point at which an innovation becomes self-sustaining and can further spread not through marketing but through interpersonal communication channels [25]. Therefore, crossing the 16% adoption rate constitutes a turning point in a life of innovation, in which, afterward, it becomes rapidly common [18]. Figure 1 contains the diffusion of innovation distribution and the Chasm.

While exploring what makes ChatGPT so successful, apart from the superior algorithm, is outside this project's scope, DOI and the Chasm will be used to assess the adoption rate of ChatGPT among students and determine whether ChatGPT can already be defined as a self-sustain innovation among students.

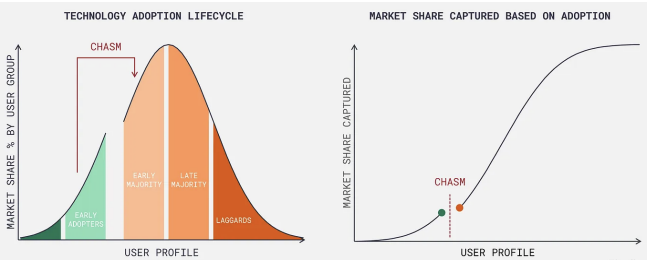

Fig. 1. Chasm and Diffusion of Innovation [7]

The state of adoption might vary depending on the type of study. Non-technical studies might entail more assignments and study materials related to reading, writing, summarizing, and data organization. These are tasks ChatGPT masters and might lead to a difference in the state of adoption once compared to students from technical studies. With that said, ChatGPT has already proved to be able to solve mathematical equations and, although not always fully correct, write code, which are domains usually attributed to technical studies [15, 22]. However, while existing literature on the capabilities of ChatGPT can be found, its state adoption among students based on the type of study was yet to be explored.

2.2 Deeper Learning

Deeper learning is defined as the set of competencies that students are required to develop in order to understand academic content and apply the acquired knowledge in various situations, both in the classroom and on the job [10]. This entails that students must acquire not only factual knowledge but also develop skills and capabilities that will allow them to apply the knowledge in various real-life contexts to solve problems and make decisions [17]. As further defined by the Hewlett Foundation, deeper learning is an umbrella term for the competencies and knowledge that students must possess to succeed in the 21st century.

When considering the competencies deeper learning encompasses, Bitter et al. (2015) provide a comprehensive overview of the competencies associated with deeper learning as identified by the Hewlett Foundation [2]. These competencies are divided into three domains: Cognitive Domain, Interpersonal domain, and intrapersonal domain. They encompass skills such as a deeper understanding of core academic content, people skills, self-management, and more. The full list of competencies and their associated domain can be found in Table 1.

Table 1. Competencies Associated With Deeper Learning [2]

Cognitive Domain	**Deep content knowledge:** Students build a strong foundation in academic content areas and draw on their knowledge to complete new tasks.
	Critical thinking and complex problem solving: Students think analytically and creatively to evaluate information and design solutions to complex problems.
Interpersonal Domain	**Collaboration:** Students learn to work in teams to achieve shared goals.
	Communication: Students clearly organize their data, findings, and thoughts in written and verbal communication.
Intrapersonal Domain	**Understanding how to learn:** Students monitor and direct their own learning.
	Academic mindsets: Students develop positive attitudes and beliefs about their identities as learners and their academic abilities.

3 METHODOLOGY

This section discusses the research methodology, including the survey conducted to obtain data from students, how the adoption rate is determined, the generative AI guidelines review, and the use of SPSS.

3.1 Survey

Using Google Forms, a survey has been conducted to collect data that will allow the mapping of ChatGPT's impact on the sustainability aspects discussed in the introduction. The research, conducted for a week in May 2024, was approved by the ethical committee of

the University of Twente (Request Nr.240918) and collected information about students' usage patterns and perceptions of ChatGPT in academic settings, awareness of university guidelines on AI use, and considerations of the ethical and environmental impacts of using AI tools.

In order to provide a clearer structure to the survey, it has been divided into three sections:

3.1.1 Background questions. To monitor and maintain the diversity of the sample, respondents were asked to fill in their study type, gender, and the start year of academic studies. Ensuring a diverse sample of both technical and non-technical students could shed light on whether there is a link between the study type and the adoption of ChatGPT.

3.1.2 Environmental Sustainability and University Guidelines Questions. Understanding ChatGPT's adoption rate and usage patterns is crucial for exploring its effect on universities' environmental sustainability. Therefore, this section collects data to determine ChatGPT's adoption rate, understand usage frequency, and explore whether university guidelines, in fact, promote excessive use of ChatGPT.

3.1.3 Education sustainability questions. To accurately capture ChatGPT's effect on deeper learning, this section contains a total of twelve questions, where each deeper learning domain described in Bitter et al. (2015) is represented by four questions reflecting the competencies associated with the domain [2]. Using a Likert scale, respondents were then asked to determine their degree of agreement with each statement (Very Negatively, Negatively, No Effect, Positively, Very Positively).

Each answer received a numerical value from 1 to 5, with 1 being Very Negatively and 5 being Very Positively. To conclude whether ChatGPT has a positive, neutral, or non-positive effect on deeper learning, an average of the answers will be calculated. As 3 refers to No Effect, the results could be interpreted in the following manner:

(1) If the average is greater than 3 (>3), a positive effect can be concluded.
(2) If the average is exactly 3, no effect can be concluded.
(3) If the average is lower than 3 (<3), a non-positive effect can be concluded.

Additional questions aim to provide insight into students' perceptions and behavior concerning ChatGPT usage in academic settings, particularly exploring aspects of reliance on ChatGPT, academic integrity, and independent thinking.

3.2 Generative AI Guidelines Review

Due to direct access to the university's policy and regulations, the guidelines to be reviewed are the generative AI guidelines for students at the University of Twente. The direct access ensures a detailed and up to date guidelines review.

3.3 Adoption of ChatGPT

The state of adoption was determined based on the survey's results. As part of the survey, the respondents were requested to fill in how often they used ChatGPT and were given the following options: "Always," "Often," "Rarely," and "Never." As rarely and never do not imply frequent use, a respondent has been considered to have adopted ChatGPT in case the frequency of use is Always or Often. Consequently, respondents who have never used ChatGPT or use it rarely were considered non-adopters. Dividing the respondents into adopters and non-adopters has provided the option to analyze respondents' perceptions based on their affiliation with one of the aforementioned groups.

3.4 SPSS

The data has been coded and analyzed using SPSS to determine the significance of the survey results. With a confidence interval of 95%, Chi-quare and independents sample T-test have been conducted to determine statistical significance.

4 RESULTS

4.1 Guidelines for Generative AI usage by students

As university guidelines might affect the frequency of ChatGPT usage by students, it is essential to conduct a guidelines review. According to Von Garrel & Mayer (2023), research conducted among 6300 students in Germany has discovered that two-thirds of the students use or have used AI-based tools, while half of them explicitly mention ChatGPT as a tool they used [32]. This research provides a glimpse of the extent to which AI-based tools are used in general and ChatGPT in particular. Considering the energy consumption of each ChatGPT query and the infancy of the prompt engineering discipline, a discipline focused on designing and correcting input queries to optimize results, it can be assumed that strict regulations might result in excessive use of ChatGPT, for example by students trying to make the output resemble less to an AI output in order not be accused of academic misconduct. Eventually, this will not only increase the education's environmental footprint but possibly damage aspects of deeper learning and with that the paradigm on which higher education learning is based.

The advent of ChatGPT, with its astonishing capabilities, has introduced a new term - the "educator's dilemma" [11]. This refers to educators' dilemma as to whether tools such as ChatGPT should be completely banned for students' use or should their use be encouraged. Many universities have already introduced guidelines for students using generative AI tools demonstrates the realization of higher education policymakers that student's use of such tools is now part of higher education. Yet, given the rapid development of such tools, the challenge remaining is determining guidelines that will ensure that the use of such tools results neither in academic misconduct nor being used to 'bypass' rather than support deeper learning, for example with respect to academic thinking. As this research aims to gain insight into the usage of ChatGPT by students, it is crucial to first understand the boundaries in which students are expected to operate. Considering the guidelines of the University of Twente (UT), the teacher has the right to determine whether students are allowed to use generative AI [29]. It can be assumed that the motivation behind it is the nature of some assignments, such as writing or literature reviews, as susceptible to being completed by ChatGPT. Moreover, using such tools for completing such assignments might result in an inaccurate assessment of the student's performance. As each assignment might have a different degree

of susceptibility to being complemented by AI tools, the UT has defined four different levels in which AI is allowed to be used by students. Based on the assignment's susceptibility, the teacher could determine to what degree the usage of AI tools is allowed. These levels can be seen in Table 2.

Table 2. various levels of AI usage [29]

Option	Description
No	No use of AI is permitted
Some	AI can be used for the following purposes: ...
Some	The following AI can be used: ...
Yes	The use of any AI is permitted

While the decision regarding using ChatGPT in assignments may have been a specific guideline at UT, it is universally agreed that any use of AI tools by students must be responsible and adhere to the principles of academic integrity. That means committing to the fundamental values of the academy - honesty, scrupulousness, transparency, independence, and responsibility [20]. Such values include being truthful about your work, avoiding copying others' work without permission or acknowledgment, and not using unauthorized aids. To ensure students operate within these boundaries, the UT requires its students to claim responsibility for the submitted content in the form of an author acknowledgment, which indicates that the content has been reviewed and emphasizes the author's full responsibility [29].

However, as the reliability and validity of AI detectors remain uncertain, much of the responsibility for maintaining academic integrity falls on the students themselves [4]. As ChatGPT is constantly improving, it is becoming increasingly difficult to detect whether it was indeed used to complete an assignment, highlighting issues such as the inability to determine whether guidelines were followed, consequently raising concerns related to the university's ability to ensure adherence to academic integrity [14, 21]. Therefore, while academic integrity inherently relies on personal traits, using tools such as ChatGPT requires a higher degree of honesty and responsibility from the students.

An aspect yet to be researched is whether the existing guidelines stimulate students' excessive use of ChatGPT. As the discipline of prompt engineering is yet to be fully developed and with students potentially trying to bypass their university's guidelines, strict guidelines might result in students using more prompts to obtain an output that will be less detectable by the existing AI detection tools [9].

4.2 Survey Results

The survey included 50 (student) respondents from technical and non-technical study fields. 28 respondents indicated that they follow technical studies, while the rest indicated they follow non-technical studies (See Table 3).

Table 3. Breakdown of respondents' gender and study type

	Male	Female	Total
Technical Studies	24	4	28
Non-technical Studies	11	11	22
Total	35	15	50

4.3 To what extent does ChatGPT affect the environmental sustainability of university education?

This section presents the survey results of the Environmental Sustainability and University Guidelines questions. Among the results are ChatGPT's adoption rate, the effect of university guidelines on ChatGPT usage, and whether the energy consumption is actually considered by students. To explore the differences in usage among various groups, the results have been categorized into four groups: Technical, non-technical, adopters, and non-adopters. Based on these results, the research will further assess the effect of ChatGPT on the environmental sustainability of university education. Table 4 summarizes the results of this sub-research question and can be found in Appendix B.

To understand its environmental effect, it is crucial to first understand ChatGPT's state of adoption among students. As discussed in the methodology, adoption is considered only when a respondent has indicated using ChatGPT often or always. According to the survey results, 84% of respondents indicated they had ever used ChatGPT for their studies; however, the adoption rate was lower, about 54%. Therefore, according to Roger's diffusion of innovation theory, the overall state of adoption among students is already in its late majority phase and far beyond the 16% critical mass and Chasm mark. Further, when considering the state of adoption by type of studies, among students from non-technical backgrounds, the adoption rate is exactly 50%, while for students from technical studies, the rate stands at 57%. In turn, the state of adoption among the former group stands exactly between the early majority and late majority. In contrast, the latter group has already entered the late majority adoption state. A Chi-square test to determine whether adoption rates among technical and non-technical students are significantly different has resulted in a p-value of 0.828, suggesting an insignificant difference.

Interestingly, although the adoption rate among non-technical students is slightly lower than that of technical students, more respondents of the former group have indicated they have read their university's guidelines for AI usage, 41% and 29%, respectively.

Whereas 34% of the total respondents have indicated they have read their university guidelines for using AI tools, the effect appears to be limited. Circling back to the guidelines review, one of the questions raised was whether there is a correlation between guidelines and the usage of ChatGPT. The data shows that, despite reading the guidelines, about 71% indicated that the guidelines did not change their usage patterns. However, 18% have indicated they have started using ChatGPT more to make the AI output look more human-generated, with an additional 6% generally indicating they started using ChatGPT more after reading the guidelines. Overall,

almost a quarter (24%) of students who have read the guidelines have indicated they have increased their usage due to their university's guidelines. When analyzing the results for this question from the perspectives of adopters and non-adopters, a substantial difference of 44% compared to 0%, respectively, has been discovered. However, the results cannot be considered statistically significant (p=0.152), likely due to a small sample size resulting from the relatively low percentage of students who read the guidelines (34%).

While the guidelines might have a limited effect on usage, frequent use of ChatGPT instead of less energy-costly traditional search engines increases the university's education environmental footprint. When respondents were asked to indicate their degree of agreement with the following statement: "Since the launch of ChatGPT, I find myself using ChatGPT for my assignments more frequently than Google or other traditional search engines," about 48% of the respondents agreed or strongly agreed with hardly different results between technical and non-technical students, 50% compared to 45% respectively. When considering the results from the perspectives of adopters and non-adopters, these are respondents who indicated they use ChatGPT often or always and respondents who indicated they use ChatGPT rarely; The results are significantly different (p=0.02), with 63% of the former group agreeing or strongly agreeing, compared to 30% in the latter group.

With an adoption rate of 54% and 10 times more energy required, a question arises as to whether ChatGPT's energy consumption is considered by students. To answer this, respondents who have indicated to have used ChatGPT were asked whether they have ever considered the energy consumption of ChatGPT. Overall, 19% of the respondents indicated they had considered ChatGPT's energy consumption, conclusively demonstrating that it does not concern most students. When considering the responses of adopters and non-adopters to the same questions, with 19% and 20%, respectively, the responses of these groups almost coincide with the overall 19%. With relatively small differences, the same applies to technical and non-technical students. Further, to better grasp whether the energy consumption is a consideration, the survey went a step further by providing the respondents examples to comprehend the extent of energy consumption associated with ChatGPT. Respondents were then asked whether knowing this information, they would consider reducing their usage. In this case, when considering the responses of adopters compared to non-adopters, a Chi-square test reveals a significant difference (p=0.04). While 22% of the adopters responded they would consider reducing their usage, the rate of the latter group is almost 2.5 times higher and stands at 53%. As for technical and non-technical students, with more technical students willing to consider reducing their usage, the results differ but are not statistically significant, 40% compared to 24%, respectively. Overall, 33% of the respondents indicated they would consider reducing their usage. To provide respondents with flexible answers, respondents were given the option to enter an answer of their choice where one responded, "I will think about it.". This answer has been converted to "yes" in the data cleaning process.

Respondents were asked to enter the approximate number of education-related queries, including follow-up queries, they ask ChatGPT per month. While the overall average is 28 queries, technical students ask ChatGPT twice as many queries as non-technical students, 37 compared to 18. Moreover, adopters ask ChatGPT more almost seven times more queries than non-adopters, 46 monthly queries compared to 7. Overall, considering an adoption rate of 54%, and 10 times more energy required for each query (comparing to a Google query), it can be calculated that the cumulative energy required by students to complete their assignments using ChatGPT is approximately 5.4 times greater than in the pre-ChatGPT era.

4.4 To what extent does ChatGPT impact the educational sustainability of university education?

It is important to note that data in the following section has been obtained by collecting information solely from survey respondents who have indicated using ChatGPT rarely, often, or always. Therefore, all the analysis and statistical tests conducted have used a sample size of 42 (n=42). Tables 5 and 6 summarize the results and can be found in Appendix B.

As the previous section shows, with an adoption rate of 54%, ChatGPT is already strongly intertwined with university education, prompting the question of whether it alters students' learning. To answer this question, the survey's results were analyzed to assess whether ChatGPT impacts students' deeper learning and whether aspects of academic integrity and independent thinking are maintained.

With no statistically significant differences based on study type or adoption group, an overall score of 3.21 indicates that ChatGPT has a mild positive influence on deeper learning (Table 5). When considering the score of technical and non-technical groups, while the former group seems to have the highest positive influence on their deeper learning with a score of 3.34 (SD=0.6), the latter group scored the lowest from all groups specified in Table 5 - 3.02 (SD=0.44). In light of this score, it can be argued that ChatGPT has almost no effect when it comes to deeper learning for non-technical students. Moreover, while the gap between the aforementioned groups might be deemed substantial, an independent sample T-test demonstrated that the difference in scores is, in fact, not statistically significant (p=0.71). With regard to adopters and non-adopters, it is evident that while not statistically significant, adopters indicated a greater positive influence than non-adopters. Interestingly, further analysis of the results has revealed that adopters from technical studies have scored the highest score - 3.45 (SD=0.63).

With 69% of the respondents indicating that ChatGPT makes their assignments moderately or very much easier, ChatGPT has been found to have a considerable influence on assignment ease (Table 6). While the results of technical and non-technical almost perfectly align with the overall 69% rate, a Chi-square test discloses a significant difference between adopters and non-adopters (p=0.01). While 85% of the adopters indicated that ChatGPT makes their assignments moderately or much easier, for non-adopters, the rate is 40%. This suggests that adopters are more likely to find ChatGPT helpful compared to non-adopters. This aligns with the DOI theory, in which earlier adoption groups perceive more benefits from a new technology than late adoption groups.

While it is evident that ChatGPT can contribute to the ease of assignments, the data suggest that guidelines are not being followed

to the same degree. To explore the degree to which students follow institutional guidelines for the usage of Generative-AI tools, respondents were asked to indicate whether they agree or disagree with the following statement: "I sometimes knowingly use ChatGPT for assignments, even when it is forbidden, or when allowed, I do not fully follow the guidelines". The findings reveal that 64% of the respondents agreed with this statement (Table 6), with the rates among technical and non-technical students almost perfectly align the overall rate. Regarding adopters and non-adopters, while not significantly different (p=0.113), 56% of the adopters agreed with this statement, while the agreement rate among non-adopters is 80%.

The data shows that only 52% of the respondents are fully confident that their use of ChatGPT adheres to the rules and principles of academic integrity. As the main concern related to ChatGPT in higher education is academic integrity, an integral part of the research was to analyze students' perceptions of their adherence to academic integrity [26]. With about 48% compared to 59%, while not statistically significant (p=0.762), the responses demonstrate that students from technical backgrounds have less confidence in their academic integrity than their fellow non-technical students (Table 6). Concerning adopters and non-adopters, the former group has indicated 59% confidence, while the rate for the latter group is 40%. While not a statistically significant difference (p=0.197), this suggests that adopters have a higher confidence in academic integrity than non-adopters.

Further, 81% of the respondents have indicated that they can somewhat or completely relate to the statement, "I often use ChatGPT instead of thinking myself because it is easier and saves time". In that case, the results among the groups shown in Table 6 almost perfectly coincide with the general 81% relation rate. While the overall deeper learning score demonstrates a mild positive influence of ChatGPT on deeper learning, such results also suggest an over-reliance on ChatGPT, raising questions about developing crucial deeper learning skills, such as independent thinking and problem-solving.

5 DISCUSSION AND CONCLUSION

5.1 Discussion

This section will discuss and interpret the survey results that will be used to conclude ChatGPT's impact on the environmental and educational sustainability of higher education. The results reveal a general pattern of prioritization of convenience over learning and that most of the significant differences occur not based on the study type but based on one's frequency of ChatGPT usage, namely, based on one's affiliation to the adopters or non-adopters groups.

To understand ChatGPT's impact on the aforementioned sustainability aspects, it is crucial to discuss the differences between adopters and non-adopters as reflected in the results. Adopters, with a mild positive effect on deeper learning, seem to have learned how to leverage the capabilities of ChatGPT to make their university assignments easier. Likewise, their confidence in complying with academic integrity standards appears to be higher than that of their non-adopters counterparts. In addition, only 19% of the overall respondents have considered the energy consumption of ChatGPT, indicating that environmental sustainability is not a predominant factor influencing usage. Given the environmental implications of ChatGPT usage, 53% of the non-adopters have indicated they will consider reducing their usage while the rate among adopters was only 22%. As the deeper learning scores of both groups are not significantly different, the reluctance of adopters to reduce their usage, combined with the information above, might indicate they attribute a higher value to ChatGPT and have learned how to use it effectively. Furthermore, the reluctance to decrease the usage raises the question whether it stems from prioritizing ChatGPT's benefits over environmental values, or simply unawareness of the environmental implications associated with extensive energy consumption.

While ChatGPT has a mild positive influence on deeper learning, with no significant differences based on study type or affiliation to an adoption group, it considerably influences the ease of assignments among all groups. This lack of correlation between the extent to which ChatGPT simplifies assignments and the relatively low contribution to deeper learning might eventually result in students not truly achieving the required learning goals.

Although universities try to create guidelines that will ensure the achievement of educational goals in the ChatGPT era, only 34% of the respondents have read them. This might indicate that universities struggle to disseminate information related to usage of AI tools or in making students realize that the guidelines must be read, as the usage of such tools also entails various risks, such as potential violation of academic integrity.

However, with an overall 54% adoption rate and adopters executing almost seven times more queries than non-adopters, 46 monthly queries compared to 7, respectively, adoption is also environmentally costly. To put this into perspective, considering the overall average amount of monthly queries (28), an adoption rate of 54%, and that an academic year is 10 months long, the amount of energy required to answer the queries of students enrolled at the University of Twente in 2022, could charge an Apple iPhone 14 battery (3279 mAh, 3.87V) roughly 431,000 times [8, 30]. With almost half of the adopters, 44%, increasing their usage after reading the guidelines, it is evident that guidelines have, in fact, direct impact on the university's environmental footprint. Moreover, 63% of the adopters have agreed or strongly agreed that they nowadays use ChatGPT more frequently than Google or other search engines, further contributing to the increase in the education's environmental footprint.

Beyond the environmental footprint, it is evident that fundamental academic values are often overlooked by students. Overall, 64% of the respondents indicated they knowingly use ChatGPT when forbidden or, when allowed, do not follow the guidelines. This demonstrates that honesty and transparency, core values of the academy, are jeopardized. This is further emphasized by the responses of adopters, which indicate they use ChatGPT more often in order to make the text less detectable as being AI-generated. While academic integrity has always been dependent on the students to some extent, in the ChatGPT era, where advanced AI capabilities are available to any student, these concerning results suggest a lack of trustworthiness among students when it comes to their use of ChatGPT. Interestingly, when comparing the answers of adopters and non-adopters, it is observed that the latter group is more prone to use ChatGPT when forbidden, 56% compared to 80%, respectively.

These findings, combined with the higher confidence in academic integrity and a greater influence on the ease of assignments, suggest that adopters might have developed a better understanding than non-adopters as to when and how ChatGPT can be used effectively.

The survey results also demonstrate a shift in students' learning behaviors, where convenience and ease are prioritized over learning. With no significant difference among the groups shown in Table 6, overall, 81% of the respondents indicated they somewhat or completely relate with the statement, "I use ChatGPT instead of thinking myself because it is easier and saves time." This is a concerning pattern that might imply a formation of new learning culture, one that is dependent on ChatGPT and characterized by the lack of independent thinking. Regardless, such results can potentially undermine deeper learning that aims to teach students, among other things, to develop an academic mindset, think critically, and solve complex problems.

5.1.1 Limitations. In reflection on the research, several limitations should be acknowledged. First, this research has a relatively small sample size (n=50), implying limited statistical power and, consequently, limitations regarding the generalization of the results. Second, respondents were asked four questions about each deeper learning domain to measure the effect of ChatGPT on deeper learning; more questions about each domain would likely result in more accurate findings. Third, the research was bound to be completed within ten weeks. This limited the time for the literature review and the collection of survey responses. Finally, the research focused on the Dutch higher education system, limiting the generalization of the results to equivalent higher education systems outside the Netherlands.

The limitations regarding the assessment of the environmental impact should also be acknowledged. First, it is currently unknown how many traditional search engine queries are required to collect the same amount of information generated in one ChatGPT query. Therefore, the assessment is based on a 1-to-1 ratio, where each traditional search engine query was replaced by one ChatGPT query. Second, the environmental impact assessment has been done based on the adoption rate calculated in this research. This rate is subject to change, requiring frequent reassessment to map the impact. Finally, the advent of the Sustainable AI domain might result in reduced energy consumption per query, further suggesting a frequent reassessment is required [31].

5.2 Conclusion

This section combines the answers to the sub-research questions to provide a complete answer to the main research question – To what extent does the usage of ChatGPT by university students impact environmental and educational sustainability? The research included three sub-research questions encompassing topics such as the guidelines for Generative AI usage by students, the extent to which ChatGPT affects the environmental sustainability of university education, and the extent to which ChatGPT impacts the educational sustainability of university education, focusing on its impact on deeper learning.

With a 54% adoption rate, ChatGPT is already in its late majority stage and beyond the critical mass, indicating it is likely to be further adopted. In comparison, Von Garrel & Mayer's survey from May-June 2023 showed that only 35% of the respondents indicated they use AI tools occasionally, frequently, or very often [32]. This highlights a 19% increase that can potentially be explained by the spread of innovation through the early majority and continuous upgrades of ChatGPT, suggesting that it is expected to be further adopted. Considering that the main differences discovered in this research occur between adopters and non-adopters prompts the need for immediate action by universities.

Concerning ChatGPT's effect on environmental sustainability, the findings revealed a 5.4 increase in cumulative energy compared to the pre-ChatGPT era. With the option to completely ban the usage of ChatGPT not in sight, this entails a significant increase in universities' environmental footprint due to increased energy consumption. Therefore, the expectation for ChatGPT to be further adopted and the reluctance of adopters to reduce their usage requires universities to change or adapt their existing sustainability policies to ones that could potentially offset or decrease the energy consumed due to students' usage of ChatGPT.

Students ' guidelines for Generative AI usage have been reviewed to assess the boundaries in which students are expected to operate. The review of the University of Twente's guidelines has shown that teachers are given the option to select to what degree AI tools can be used based on the assignment's degree of susceptibility to being completed by AI. However, with the potential of being misused by students, the absence of reliable AI detection tools, and the rapid development of ChatGPT's capabilities, it is becoming increasingly difficult for teachers to prove whether a deviation from the instructions has occurred. This, combined with the fact that academic integrity is the main concern of ChatGPT, raises the "educator's dilemma": should tools like ChatGPT be banned for students or encouraged? However, due to the lack of reliable AI detection tools, the former option can be deemed unfeasible, shifting the discussion to how values of academic integrity could be cultivated to ensure an appropriate and instructive use of ChatGPT.

While ChatGPT has a mild positive influence on deeper learning, the research demonstrates a shift in students' behaviors towards a new learning culture, one that includes the prioritization of convenience over learning, even at the cost of violating university guidelines. Such a potential over-reliance on ChatGPT rather than independent thinking might potentially jeopardize fundamental academic values and undermine university education, prompting the need to understand why students use ChatGPT in the first place. Is it due to the convenience it offers (extrinsic motivation) or the desire to acquire more knowledge and improve their learning process (intrinsic motivation)? In an era in which assignments could be solved by ChatGPT, such research could further clarify how universities can alter their guidelines or educational methods to ensure students truly achieve the required learning outcomes.

5.3 Recommendations

ChatGPT has been already adopted by more than half of the students, requiring universities to take measures to account for its environmental and educational impacts. With a mild positive effect

on deeper learning but a considerable influence on the ease of assignment among adopters, it may be warranted for universities to adapt their guidelines, teaching, and assessment methods. In addition, as the current adoption rate of ChatGPT already entails a significant increase in the cumulative energy used by students to complete assignments and with a wider adoption expected in the future, concerns over the environmental implications are raised. Therefore, based on the research results, the following recommendations are given to universities and teachers to address these potential issues:

5.4 University Level

(1) **Further Research on Controlled Integration of ChatGPT in Education**
Although ChatGPT has already proven to have advantages in teaching, such as providing students with personalized tutoring, it also entails risks for academic integrity and, as this research shows, potentially negatively alternating learning patterns [1]. Therefore, further research is recommended to explore innovative ways in which ChatGPT can be incorporated into university education in a controlled manner that will ensure academic integrity and the achievement of learning outcomes.

(2) **Ethics Courses**
As this research shows, only about half of the students are confident about their adherence to the rules of academic integrity, prompting the need for mandatory ethics courses. As universities struggle with disseminating information related to the usage of AI-based tools, mandatory ethics courses, including an exam on institutional regulations and academic values, are a potential solution to establish an awareness of academic integrity. Moreover, as a similar adoption level of ChatGPT among secondary secondary school students can be assumed, it is vital to establish such an awareness as close as possible to students' first contact point with academia, preferably during the first year or semester.

(3) **University-Level Guidelines**
As no significant differences related to the adoption rate and usage patterns were detected based on the study type, it can be concluded that rather than design tailored faculty or program-level regulations, university-level regulations may be implemented.

(4) **Education for Sustainability**
Students' reluctance to reduce their usage of ChatGPT suggests that students prioritize its benefits over environmental values or are simply unaware of the environmental implications associated with extensive energy consumption. Consequently, this contributes to an increase in universities' environmental footprint resulting from students' substantial energy consumption. Therefore, there is room for enhancing students' environmental values by incorporating sustainability-related courses in curriculums, emphasizing the interplay of technology and environment. The embeddedness of such values can potentially minimize the environmental footprint.

(5) **ChatGPT Courses**
The infancy of prompt engineering can be argued to result in unnecessary energy waste, increasing the education's environmental footprint. Therefore, to avoid such energy waste, it is essential to teach students the way in which ChatGPT operates and, consequently, how to properly build a query that will achieve the optimal result. This can potentially result in a reduced number of queries required to achieve the students' goal, not only saving time for students but also contributing to the reduction of the university's environmental footprint.

(6) **Frequent Assessment**
ChatGPT is a rapidly developing innovation that requires frequent assessment of its impact on universities' environmental and educational sustainability. The constant development of ChatGPT can potentially impact the energy consumption required per query. This, combined with the indication that ChatGPT's adoption rate is expected to rise, together with the potential development of the prompt engineering discipline and the raise of the Sustainable AI domain, requires a frequent assessment to monitor its dynamic effect on the environmental and educational sustainability aspects.

5.5 Teachers Level

(1) **Assessment Through Oral Exams and Presentations**
As assignments such as writing or literature review are susceptible to being completed by ChatGPT, grading criteria based on oral exams and presentations can be used as an additional or alternative measure to validate learning outcomes. As previously recommended by the National Academic Integrity Network, beyond writing and reading assignments, oral components could be used to ask students questions about and around the topic and the way the assignment has been approached [19]. Alternatively, presentation is an additional form of possible assessment, not only validating students' understanding but also contributing to their public speaking skills.

(2) **Highlighting ChatGPT's Limitations**
While not disregarding its advanced capabilities, exposing students to ChatGPT's weaknesses and disadvantages might stimulate critical thinking toward its output. Given that ChatGPT has already proven to be inherently biased and sometimes incorrect, it is essential that students learn to think critically about its output. Letting students engage in activities or tasks in which they personally witness mistakes of ChatGPT could contribute to developing such critical thinking.

In light of any technological innovation, it is vital to ensure that technologies designed to improve processes do not undermine university education. Circling back to the definition of Hewlett Foundation, deeper learning includes competencies necessary for students to master to succeed in the job market, essentially supporting their employability [10]. Therefore, in an era where it might be tempting for students to misuse ChatGPT to complete their assignments quickly, universities must make the required adjustments to ensure that students' ability to acquire skills necessary for their employability remains intact. Lastly, the academic community must ensure that ChatGPT does not transform into a tool that, intentionally

or unintentionally, causes a suppression of independent thinking among students.

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A APPENDIX A - DISCLOSURE

During the preparation of this work the author(s) used Grammarly in order to improve sentence structure. After using this tool/service, the author(s) reviewed and edited the content as needed and take(s) full responsibility for the content of the work.

B APPENDIX B - SURVEY RESULTS

Table 4. To what extent does ChatGPT affect the environmental sustainability of university education?

% of students that…	Technical	Non-technical	Adopters	Non-adopters	Overall
adopted ChatGPT	57%	50%	-	-	54%
read their university guidelines for using generative AI tools	29%	40%	33%	34%	34%
have read the guidelines, increased their usage of ChatGPT after reading their university guidelines	38%	11%	44%	0%	24%
agree or strongly agree they use ChatGPT for assignments more frequently than Google or other traditional search engines	50%	45%	63%	30%	48%
have used ChatGPT, considered its energy consumption	16%	24%	19%	20%	19%
knowing the consumption, will consider reducing their use of ChatGPT	40%	24%	22%	53%	33%
Average amount ChatGPT queries per month	37	18	46	7	28

Table 5. To what extent does ChatGPT impact the educational sustainability of university education? Deeper learning score.

	Technical	Non-technical	Adopters	Non-adopters	Overall
Cognitive domain	3.19	3.03	3.31	3.15	3.36
Interpersonal domain	3.26	3.01	3.23	3.13	3.2
Intrapersonal domain	3.34	3.03	3.19	3.13	3.17
Overall Effect on Deeper Learning	3.34 (+)	3.02 (+)	3.25 (+)	3.14 (+)	3.21 (+)

Table 6. To what extent does ChatGPT impact the educational sustainability of university education?

% of students...	Technical	Non-technical	Adopters	Non-adopters	Overall
perceiving that ChatGPT makes their university assignments moderately or very much easier	68%	71%	85%	40%	69%
that knowingly use ChatGPT when forbidden or when allowed, do not fully follow the guidelines	64%	65%	56%	80%	64%
confident that their use of ChatGPT adheres to the rules of academic integrity	48%	59%	59%	40%	52%
that used ChatGPT can somewhat relate or completely relate to the statement, "I use ChatGPT instead of thinking myself because it is easier and saves time"	80%	82%	82%	80%	81%