The Role of Generative AI Chatbots in Asynchronous Learning: Enhancing Student Engagement and Learning Effectiveness

Author: L.H.F. Moons

SNR: 2127678

ANR: 553622

Supervisor: K.J.M.G. Meesters

[a]*Master Information Management, TiSEM – Tilburg School of Economics and Management, University of Tilburg, Warandelaan 2, 5037 AB, Tilburg, Netherlands. February 2025*

KEYWORDS

Generative AI
Asynchronous
Learning

ABSTRACT

This study investigates whether the integration of Generative AI (GAI) chatbots can enhance asynchronous learning by improving student engagement, reducing perceived isolation, and contributing to overall learning effectiveness. Drawing on a mixed-methods research design, the study combined quantitative survey data with qualitative insights from a case study and a semi-structured interview. A total of 31 students from higher education participated in the survey, while detailed chatbot usage logs were collected during an eight-week course in "Online Data Collection & Management." Results indicate that GAI chatbots can address several limitations of asynchronous learning. By offering continuous, on-demand feedback, chatbots help students overcome time lags inherent in teacher-student interactions and mitigate feelings of isolation. Survey data suggest that learners perceive chatbots as enhancing productivity, clarifying complex concepts, and supporting more flexible study schedules. However, participants also voice concerns regarding the reliability of chatbot-generated responses, as well as potential overreliance on automated solutions at the expense of critical thinking and independent problem-solving skills. These findings underscore the importance of balanced implementation strategies. Institutions should provide clear guidelines on responsible chatbot use and incorporate accuracy checks to ensure high-quality support. Ultimately, this research contributes to the evolving body of literature on technology-enabled pedagogy, illustrating the promise and pitfalls of using GAI chatbots to enrich asynchronous learning environments.

Lennart Moons
Email address: l.h.f.moons@tilburguniversity.edu

Contents

1 Introduction

Over the past decade, businesses have faced increasing pressure to operate more flexibly and efficiently. Rapid globalization, technological advancements, and shifting workforce expectations have pushed organizations to adopt new ways of working, often moving toward remote and asynchronous collaboration. The COVID-19 pandemic accelerated this transformation, forcing companies to implement digital solutions that enabled employees to work and communicate without being in the same physical space or even working at the same time. What initially began as a necessity, quickly became a preferred mode of operation for many organizations. (Kadaruddin, 2023).

Alongside the shift to remote and asynchronous work, businesses have also embraced automation and artificial intelligence (AI) to enhance efficiency and manage capacity challenges. One of the most prominent developments in this area is the rise of generative AI, particularly in customer service. Companies are increasingly leveraging AI-powered chatbots to provide 24/7 support, handle routine queries, and reduce reliance on human customer service representatives. For instance, Intercom, a leading customer relationship management company, recently launched "Fin," an AI customer service agent that has already handled millions of customer inquiries. By automating common interactions, they can provide faster service while reallocating human employees to more complex and strategic tasks (Intercom, 2023). Similarly, major corporations such as Meta, Amazon, and Google have integrated AI-driven chat solutions to streamline customer interactions and reduce operational costs (The Times, 2023).

These trends are not just limited to customer service. AI is also being implemented in internal business operations to optimize workflows, automate repetitive tasks, and support employees in decision-making. AI-powered virtual assistants help teams manage projects asynchronously, enabling workers across different time zones to collaborate effectively. In industries facing labor shortages, such as healthcare, retail, and finance, AI-driven automation has become a critical tool for maintaining operations without increasing staff numbers (Wang et al., 2023). Research has shown that AI systems not only improve efficiency but also enhance user experiences by providing faster, more personalized responses (Kadaruddin, 2023).

Given the widespread adoption of generative AI in business, a compelling question arises: could similar AI-driven solutions be applied to education? Educational institutions face many of the same challenges as businesses capacity constraints, the need for flexible service delivery, and an increasing demand for asynchronous interaction. Just as companies deploy AI chatbots to assist customers and employees, universities struggle to provide real-time support for students, particularly outside of classroom hours. With students engaging in more self-directed learning, asynchronous, AI-powered tools could play a role in offering better education to students (Chukwuere, 2024).

1.1 Problem Statement

The increasing need to adopt asynchronous learning and generative AI in education reflects the growing demand for flexible and personalized learning experiences. Asynchronous learning and generative AI could be of help in supporting this new development. Both technologies have their advantages, but they also introduce new challenges that must be taken into consideration to ensure their effective use.

Asynchronous education offers several benefits to students and educators. It provides greater flexibility, allowing students to engage with materials and discussions at their own convenience, which can be especially helpful for working professionals and students with different learning paces (Bozkurt & Sharma, 2021). Moreover, research has shown that asynchronous learning can enhance student participation, as students have more time to reflect before contributing to discussions (Martin et al., 2020). Despite these advantages, asynchronous learning also presents challenges. One of the primary concerns is the lack of immediate interaction, which may lead to reduced engagement and motivation among students (Gikandi, 2019). Without real-time feedback from instructors or peers, students might struggle with complex concepts and experience a sense of isolation (Singh & Thurman, 2019).

Generative AI, such as AI-driven tutoring systems and chatbots, has the potential to support students by providing instant responses to their questions, generating personalized learning paths, and automating administrative tasks (Zawacki-Richter et al., 2019). Studies indicate that AI-powered tools can improve student learning outcomes by offering adaptive support and customized learning materials (Holmes et al., 2022). These technologies can also assist educators by reducing their workload and allowing them to focus on more complex instructional tasks (Luckin et al., 2018). However, integrating generative AI in education also raises concerns. One major issue is the accuracy and reliability of AI-generated responses. If the AI system provides incorrect or misleading information, students may develop misunderstandings (Wang et al., 2023). Furthermore, there are ethical concerns related to data privacy, as AI tools often require access to personal information to deliver personalized learning experiences (Selwyn, 2020). Additionally, AI may not fully replicate human interaction, which is essential for critical thinking development and deep learning (Schmid et al., 2021).

For asynchronous learning and generative AI to be effective, students must have sufficient digital literacy to navigate online platforms and AI-based tools (van Deursen & Helsper, 2018). They need to be self-motivated and capable of managing their time efficiently, as these learning models require independent engagement (Garrison, 2016). Since younger students often need more direct supervision, these technologies are likely to be most beneficial for students in higher education, where self-directed learning is more common (Means et al., 2021).

Looking at the individual developments and the sources, both asynchronous learning and generative AI offer benefits for education, yet they also present challenges that may hinder their effectiveness in certain implementations. Despite their individual impacts, little is known about their combined effect on students and educational outcomes. Does one compliment the other, enhance the effects of asynchronous learning? Or does it result in the opposite, asynchronous learning becomes less effective in combination with generative AI? Or do they not influence each other at all? Or might it be a combination of the three? This is where the gap lies, in understanding how the characteristics of asynchronous learning and generative AI interact and influence effective learning. To assess their true impact, it is essential to examine their properties together, identifying how and when they can complement or challenge each other.

1.2 Research objectives & questions

As technology advances, both asynchronous learning and the use of generative AI chatbots are becoming more common in higher education. However, it remains unclear how these two elements work together and whether they help or hinder students' learning. The main goal of this study is to explore how generative AI chatbots can support or affect asynchronous learning, focusing on both the benefits and possible challenges. This study sets out the following objectives:

1. Examine how generative AI chatbots influence student engagement in asynchronous learning, particularly focusing on reducing feelings of isolation.
2. Evaluate the impact of generative AI chatbots on perceived learning effectiveness, including clarity of understanding, motivation, and time management.
3. Identify potential challenges and ethical concerns associated with over-reliance on chatbots, such as the risk of reduced critical thinking or academic integrity issues.

1.3 Research question

Following the problem statement and the objectives, the main question is:

"Can generative AI chatbots complement asynchronous learning, and how do students perceive its effectiveness for learning?"

To address this main question, the study investigates several sub-questions:

1. How do generative AI chatbots and asynchronous course structures together shape students' overall learning experience, especially regarding engagement and support?
2. In what ways does the availability of generative AI-driven tool intersect with the flexibility of asynchronous learning, influencing students' motivation and perceived effectiveness?
3. How might the interaction between asynchronous learning and generative AI tools affect students' study habits, particularly their sense of independence and development of critical thinking skills?

By exploring these research objectives and questions, the study aims to provide insights into the combined effect of asynchronous learning and generative AI chatbots, ultimately contributing to a better understanding of effective learning strategies in modern higher education.

1.4 Structure

Chapter 1: Introduction: This chapter provides the foundation for the research by introducing the context of asynchronous learning and the rise of generative AI chatbots in education. It discusses the problem statement, research objectives, and research questions, laying the groundwork for the study's significance and purpose.

Chapter 2: Literature Review: This chapter explores existing literature on effective learning, asynchronous learning, and generative AI in education. It defines key concepts, analyzes prior research on learning effectiveness, and identifies advantages and challenges associated with both asynchronous learning and generative AI chatbots. Additionally, it synthesizes how these two elements interact and introduces a conceptual model that guides the study.

Chapter 3: Propositions Based on the literature review and conceptual model, this chapter presents research propositions that hypothesize how generative AI chatbots influence asynchronous learning. These propositions address topics such as engagement, perceived learning effectiveness, and the potential risks of over-reliance on AI tools.

Chapter 4: Methodology This chapter outlines the research design and methodology used to investigate the study's research questions. It details the case study conducted at Tilburg University, the data collection methods (chatbot logs, surveys, and interviews), and the analytical techniques applied. The chapter also discusses the reliability and validity of the research approach.

Chapter 5: Results: This chapter presents the findings of the study, analyzing data collected from chatbot interactions, survey responses, and interviews. It examines chatbot usage patterns over time, categorizes the types of questions students ask, and assesses their perceptions of chatbot effectiveness.

Chapter 6: Discussion: This chapter interprets the results in the context of the research propositions and literature review. It evaluates whether the findings align with or contradict existing theories and discusses their implications for asynchronous learning and AI implementation in education. Additionally, it outlines the study's limitations and areas for future research.

Chapter 7: Conclusion: The final chapter summarizes the study's key findings and their contributions to the field of education. It reflects on the role of generative AI chatbots in asynchronous learning, highlights practical applications, and provides recommendations for educators and institutions.

2 Literature Review

This chapter examines literate on effective learning, asynchronous learning, and generative AI in education. It begins by defining effective learning and exploring key factors that influence learning outcomes. Next, it discusses asynchronous learning, outlining its characteristics and conditions for success. The chapter then explores the role of generative AI chatbots in education and their potential impact on asynchronous learning and learning effectiveness. Finally, the literature is synthesized to establish a foundation for the conceptual model and research propositions in the following chapters.

2.1 Literature on effective learing

Effective learning is a fundamental goal in education, ensuring that students not only acquire knowledge but also apply it in meaningful ways. This chapter explores the concept of effective learning, how it is measured, and the various factors that contribute to it.

2.1.1 Defining effective learning

Effective learning refers to the process in which students acquire, retain, and apply knowledge in a meaningful and adaptable way. It is not only about memorizing facts but about developing a deep understanding of concepts and the ability to apply them in real-life and problem-solving situations (Biggs & Tang, 2011). Learning effectiveness is influenced by multiple factors, including cognitive abilities, prior knowledge, learning environment, and teaching methodologies (Brown et al., 2014). Motivation also plays a crucial role in learning success, as students who are intrinsically motivated tend to engage more deeply with the material and develop stronger retention skills (Deci & Ryan, 1985). Additionally, cognitive strategies, such as self-regulated learning and reflection, significantly impact the ability of students to manage their learning process effectively (Zimmerman, 2002).

Over time, different educational theories have shaped our understanding of effective learning. Early theories, such as behaviorism, emphasized repetition and reinforcement (Skinner, 1954). Later, cognitive and constructivist theories highlighted the importance of active learning and problem-solving (Piaget, 1952; Vygotsky, 1978). In recent years, digital learning tools have introduced new ways to measure and improve learning effectiveness (Siemens, 2014). While traditional learning often focused on standardized assessments and direct instruction, modern approaches emphasize student-centered learning, collaboration, and technology integration. Research shows that modern methods, such as project-based learning and interactive discussions, lead to deeper understanding and better retention (Mayer, 2008; Prince, 2004).

2.1.2 Factors Contributing to Effective Learning

Students adopt different learning strategies, which influence their ability to learn effectively. Some common learning styles include visual, auditory, and kinesthetic learning (Fleming & Baume, 2006). Additionally, self-regulated learning, where students take control of their learning process, has been shown to improve academic success (Zimmerman, 2002).

Cognitive load theory suggests that learning is most effective when information is presented in a way that does not overwhelm the working memory (Sweller, 1988). Techniques such as

chunking information, using visuals, and applying active recall strategies enhance retention and comprehension (Mayer & Moreno, 2003).

Social learning theories emphasize the importance of interaction and discussion in the learning process (Bandura, 1977). Studies indicate that collaborative learning environments promote deeper understanding and critical thinking compared to passive learning methods (Johnson & Johnson, 2009). Peer interactions and group discussions enable students to refine their knowledge and develop problem-solving skills (Slavin, 1995).

Digital tools and online resources have transformed the way students learn. E-learning platforms provide access to a wealth of knowledge, enabling self-paced and interactive learning experiences (Means et al., 2013). Research by Graham (2006) shows that blended learning, which combines traditional and digital methods, can improve learning outcomes.

2.1.3 Measuring Effective Learning

Effective learning can be measured through various indicators, including knowledge retention, critical thinking skills, and the ability to apply knowledge in different contexts (Bloom, 1956). Additionally, student motivation and engagement are considered important factors in determining the success of a learning process (Ryan & Deci, 2000).

Learning effectiveness is often evaluated using standardized tests, project-based assessments, and peer reviews. Traditional exams measure factual recall, while formative assessments, such as reflections and portfolios, provide deeper insight into student learning (Black & Wiliam, 1998). Digital tools, such as learning analytics, are increasingly used to track student progress and adapt teaching methods accordingly (Siemens & Long, 2011). One challenge in assessing learning effectiveness is the diversity of learning styles and needs among students. While standardized testing provides measurable results, it may not fully capture deep learning and critical thinking (Gibbs, 1992). Another important measuring factor is the perceived effectiveness by students. When students perceive a method as effective it is often positively related with student performance (Eva & Regehr, 2005).

2.1.4 The Role of Flexibility in Learning

Flexibility in learning allows students to engage with educational content at their own pace and according to their individual needs. Research indicates that self-paced learning improves comprehension and long-term retention compared to rigid instructional methods (Traxler, 2018).

In structured learning, students follow a predefined curriculum with set deadlines and instructions, whereas self-paced learning allows them to move through content based on their own progress (Moore, 2013). Structured learning provides guidance, while self-paced learning can increase autonomy and motivation (Deci & Ryan, 1985). Studies show that students who have control over their learning schedules tend to be more motivated and engaged (Dabbagh & Kitsantas, 2012). However, too much flexibility can lead to procrastination and decreased performance, highlighting the need for a balanced approach (Steel, 2007). This might indicate that the best method might be a combination of the two. Where the student follows a predefined curriculum with aspects of self-paced learning, trying to bring out the best of both sides.

To summarize, understanding effective learning involves examining its definitions, measurement methods, and contributing factors. Effective learning is influenced by cognitive processes, student engagement, and the learning environment. Measuring learning effectiveness requires a combination of traditional assessments and modern digital tools. Additionally, student learning patterns, cognitive load management, social interactions, and technology integration all play crucial roles. Finally, flexibility in learning environments can enhance student satisfaction and performance but must be structured appropriately to prevent disengagement. These insights form the foundation for exploring how asynchronous learning and generative AI can impact student learning outcomes.

2.1.5 Course Structure and Pedagogical Approaches

In order to better understand effective learning and the influence of asynchronous learning and generative AI (GAI), we must create a theoretical foundation of course structures and methods used to teach students, as this forms the basis of how students learn.

Higher education courses are typically designed around a structured framework that integrates lectures, assignments, and exams to achieve learning objectives. Lectures are the cornerstone of most courses, providing students with theoretical knowledge, foundational concepts, and opportunities for engaging with subject-matter experts. Research suggests that lectures are effective for disseminating large volumes of information to a broad audience, although their passive nature can limit deep learning unless supplemented by active learning strategies (Bligh, 2000).

Assignments play a complementary role by allowing students to apply theoretical knowledge in practical contexts. These activities encourage critical thinking, problem solving, and creativity, often using individual or collaborative formats. According to Biggs and Tang (2011), well-designed assignments aligned with course objectives are essential for constructive alignment, ensuring that students develop the intended competencies.

Exams, often summative in nature, serve as a primary assessment method, measuring student They are commonly divided into mid-term and final assessments to gauge progress and final outcomes. While traditional exams focus on recall and comprehension, there is a growing push for more authentic assessments that emphasize application, analysis, and synthesis (Boud & Falchikov, 2007).

Additional components like tutorials, group projects, and discussions are increasingly integrated to foster active engagement and collaborative skills. These components enhance the core structure, making courses more dynamic and student-centered. However, studies highlight the need for ongoing adaptation of course structures to accommodate diverse student needs and evolving educational technologies (Laurillard, 2012).

2.1.6 Student Learning Patterns

In order to understand effective learning and the influence of asynchronous learning and generative AI (GAI) chatbots, we must understand the learning behavior and patters of students. This will give a better understanding of when students engage in learning and why.

Student learning patterns refer to the behaviors, habits, and schedules students adopt to engage with their academic responsibilities. These patterns vary significantly across

individuals, influenced by factors such as personal preferences, academic demands, cultural norms, and external obligations like part-time work or family responsibilities. However, common trends have emerged from research into when and how students' study, particularly in higher education.

One recurring pattern is the tendency for students to engage in intensive study sessions closer to assessment deadlines or exams, often referred to as "cramming." This behavior is frequently driven by procrastination, perceived workload, or a preference for short bursts of concentrated effort rather than consistent, distributed practice (Steel, 2007). While cramming can yield short-term gains, it often compromises long-term retention and deep understanding of material, highlighting a critical area for intervention in educational practice (Hartwig & Dunlosky, 2012).

Timing also plays a critical role in student learning behavior. Research shows that many students prefer studying during evening or late-night hours, especially in higher education, where flexibility in scheduling is greater. Gomes et al. (2011) observed that this aligns with natural circadian rhythms for many young adults, who often experience peak cognitive performance in the late afternoon and evening. This preference is compounded by the quiet and distraction-free environment often available during these hours, enabling better focus and productivity.

Studies on distributed learning patterns suggest that students tend to study more intensively as deadlines approach, with significant increases in study time during the two weeks leading up to major exams or project submissions (Ceo. 2012). This behavior underscores the importance of promoting effective time management and study planning strategies, as students who consistently distribute their study efforts achieve better long-term academic outcomes than those who rely on last-minute preparation (Cepeda et al., 2006).

2.2 Asynchronous learning

This chapter explores asynchronous learning, focusing on its definition, key characteristics, and role in education. It examines how asynchronous learning differs from traditional and synchronous learning models and discusses the factors that influence its effectiveness. Additionally, it provides an overview of the conditions necessary for successful implementation, setting the stage for its relationship with generative AI in learning environments.

2.2.1 Defining Asynchronous Learning

Asynchronous learning refers to a learning format where students can engage with educational content at different times rather than following a fixed schedule. Unlike synchronous learning, which requires real-time interaction, asynchronous learning allows students to access materials, participate in discussions, and complete tasks at their own pace (Hrastinski, 2008). This learning model is commonly utilized in online courses, distance education, and blended learning environments (Means et al., 2013). Asynchronous learning methods include pre-recorded lectures, discussion forums, self-paced assignments, and digital reading materials, providing learners with flexibility in time management and location. Furthermore, technological advancements, such as tutoring systems and online learning

platforms, have enhanced the personalization and accessibility of asynchronous education (Siemens, 2014).

The concept of asynchronous learning has evolved significantly over time. Traditional correspondence courses, which relied on postal mail, were an early form of asynchronous education (Moore, 2013). With advancements in technology, digital platforms such as Learning Management Systems (LMS) and Massive Open Online Courses (MOOCs) have expanded the reach and effectiveness of asynchronous learning (Anderson, 2008). Today, the integration of multimedia content, discussion forums, and AI-driven tools has further enhanced the accessibility and interactivity of asynchronous education (Siemens, 2014).

2.2.2 Asynchronous Learning: Advantages and Challenges

One of the primary benefits of asynchronous learning is flexibility. Students can access learning materials at any time, making education more inclusive for individuals with different schedules or commitments. Additionally, it allows learners to process information at their own pace, which can enhance comprehension and retention (Garrison, 2017; Bernard et al., 2014). Asynchronous learning also fosters personalized learning experiences, as students can revisit materials multiple times to reinforce their understanding. Furthermore, it promotes accessibility for diverse learners, including those with disabilities, by allowing the use of assistive technologies such as screen readers and captioned videos (Burgstahler, 2015).

Another advantage of asynchronous learning is its ability to support different learning styles. Students who prefer reading-based learning can access written content, while visual and auditory learners can engage with video lectures and / or podcasts (Mayer, 2009). This multimodal approach enhances student engagement and knowledge retention.

Research also suggests that asynchronous discussions lead to more thoughtful and reflective contributions compared to real-time conversations, as students have more time to critically engage with the content before responding (Dennen, 2008). Furthermore, asynchronous learning fosters independent problem-solving and self-discipline, which are crucial skills for professional and academic success (Gikandi et al., 2011). Additionally, asynchronous learning enables a global classroom, allowing students from different time zones and cultural backgrounds to interact and share perspectives, thereby enriching the educational experience (Hrastinski, 2019).

Despite its advantages, asynchronous learning also presents challenges. A major concern is the lack of real-time interaction, which can lead to feelings of isolation and disengagement among students (Bolliger & Inan, 2012). Without direct communication with peers and instructors, students may struggle to clarify doubts or engage in meaningful discussions, which can impact their motivation and learning outcomes (Richardson et al., 2017).

Self-discipline and time management are crucial for success in asynchronous settings, as students must take responsibility for completing coursework without immediate supervision (Broadbent & Poon, 2015). Research suggests that students who lack these skills are more likely to procrastinate, leading to lower academic performance and increased stress levels (Steel, 2007). Institutions can mitigate this challenge by providing structured learning plans, progress tracking tools, and targeted academic support (Dabbagh & Kitsantas, 2012).

While asynchronous learning promotes flexibility and self-paced study, its effectiveness depends on multiple factors. Students must develop self-regulation skills and maintain intrinsic motivation to stay engaged. The lack of real-time interaction can lead to isolation, making structured support systems essential. Furthermore, technological accessibility and digital literacy play a key role in ensuring that all students can fully participate. Without these elements in place, students may struggle with engagement and retention, limiting the potential benefits of asynchronous learning for effective learning.

2.2.3 Conditions for Effective Asynchronous Learning

For asynchronous learning to be effective, students must develop self-regulation skills. Self-regulated learners set goals, monitor their progress, and adjust their learning strategies as needed (Zimmerman, 2002). Time management is another essential skill, as students need to allocate sufficient time for studying without the structure of scheduled classes (Ellis, 2013).

The design of asynchronous courses plays a significant role in their success. Research suggests that well-structured courses with clear objectives, engaging multimedia content, and interactive elements such as discussion boards and quizzes enhance learning outcomes. Providing regular feedback through automated systems or instructor intervention can also help keep students engaged and on track (Bonk & Zhang, 2008; Means et al., 2013).

Although asynchronous learning allows for independence, instructors and institutions still play a crucial role. Effective instructor presence, even in an asynchronous format, can be achieved through timely feedback, personalized messages, and periodic live sessions to address student concerns (Richardson et al., 2017). Institutional support, such as access to learning resources, technology assistance, and academic advising, also contributes to student success (Tinto, 2012). For asynchronous learning to be effective, students must develop self-discipline and strong learning habits. Well-structured courses with interactive elements and adequate teacher support significantly enhance learning efficiency.

To conclude Asynchronous learning offers significant opportunities for making education more flexible and accessible. However, its success depends on students' self-discipline, well-designed courses, and institutional support. While asynchronous learning promotes independence, it must be balanced with interactive and structured elements to maintain student engagement. Understanding these factors is crucial for optimizing asynchronous learning as an effective educational model.

2.3 Generative AI in Education

This chapter explores generative AI in education, focusing on its definition, applications, and role in learning environments. It examines how generative AI, particularly AI-powered chatbots, is being integrated into education and its potential to influence learning processes. Additionally, it considers key factors related to its use, setting the stage for analyzing its interaction with asynchronous learning and learning effectiveness.

2.3.1 Definition of Generative AI

Generative artificial intelligence (generative AI) is a branch of artificial intelligence focused on creating new content, such as text, images, audio, and even code. Unlike traditional AI models, which analyze data to classify, predict, or retrieve information, generative AI produces original

outputs by learning patterns from vast datasets. This is achieved through advanced machine learning models, particularly deep learning techniques that mimic human cognitive functions (Goodfellow et al., 2014).

One of the primary frameworks used in generative AI is the Generative Adversarial Network (GAN). A GAN consists of two competing neural networks: a generator, which creates new data, and a discriminator, which evaluates its authenticity. Through repeated interactions, the generator improves its ability to produce realistic outputs (Goodfellow et al. 2014). Another key development in generative AI is transformer-based models, particularly the Generative Pre-trained Transformer (GPT), which processes and generates human-like text using vast amounts of training data (Vaswani et al., 2017; Radford et al., 2019). Transformer models rely on an attention mechanism that allows them to analyze the relationships between words in a sentence, leading to highly coherent and context-aware text generation.

Generative AI operates in several ways, including Natural Language Processing (NLP), where it powers chatbots, virtual assistants, and automated content creation. In image generation, models such as DALL·E and Stable Diffusion create realistic images from textual descriptions. These AI systems are trained using extensive datasets and refined through reinforcement learning, ensuring that the generated outputs align with user prompts and expectations (Jurafsky & Martin, 2021; Ramesh et al., 2021).

At a fundamental level, generative AI works by recognizing complex patterns in input data and generating new instances that resemble the original dataset. The training process involves unsupervised learning, where the AI system detects hidden structures in the data, and supervised fine-tuning, where human feedback helps refine the outputs (Brown et al., 2020). This ability to generate meaningful and coherent responses has led to widespread applications in various fields, including creative industries, business automation, and education.

While generative AI continues to evolve, its core function remains the same: leveraging machine learning algorithms to produce new and contextually relevant content.

2.3.2 Generative AI: Advantages and Challenges

In education, GAI is primarily used in intelligent tutoring systems and adaptive learning platforms. One of the most widely adopted applications is generative AI-powered chatbots, which provide students with personalized learning support. These chatbots offer benefits such as accessibility, efficiency, and enhanced engagement but also present challenges related to accuracy, over-reliance, and ethical concerns. This section discusses the role of GAI chatbots in education, outlining their key advantages and potential challenges, and their impact on asynchronous learning and learning effectiveness.

24/7 Availability and Immediate Feedback

One of the benefits of generative AI chatbots is their ability to provide instant feedback at any time. Unlike human instructors who have limited availability, chatbots can answer students' questions immediately, reducing delays in learning. This feature is particularly useful in asynchronous learning environments, where students work at different times and require support outside regular class hours. Immediate responses help students stay engaged and progress in their studies without waiting for instructor feedback. For example, a student studying late at night can clarify a concept without having to wait until the next day. This

ensures that learning remains continuous and uninterrupted, which could improve asynchronous learning (Wang et al., 2023).

Personalized Learning Support

Generative AI chatbots can adapt to individual students' needs, providing customized explanations and resources. They analyze user queries and learning patterns to offer tailored responses, ensuring that students receive relevant support. For example, a chatbot can detect when a student struggles with a specific concept and provide additional examples or alternative explanations. Additionally, chatbots can adjust difficulty levels based on prior interactions, helping students build their knowledge progressively. In an asynchronous learning setting, this personalized approach allows students to study at their own pace without feeling pressured to keep up with a fixed curriculum (Holmes et al., 2019). By ensuring that each student receives information suited to their learning style and level, chatbots could improve the overall effectiveness of learning by making education more accessible and adaptive.

Increased Engagement and Motivation

Interacting with AI chatbots can make learning more engaging. Many students feel more comfortable asking questions in a private, nonjudgmental setting compared to traditional classrooms. Chatbots encourage active participation by allowing students to clarify doubts without fear of embarrassment. Additionally, AI-driven interactions often include gamification elements, such as quizzes and interactive challenges, which help maintain student interest. For instance, a chatbot might reward students with virtual badges for completing certain learning milestones (Luckin et al., 2016). In asynchronous learning, where students may lack immediate human interaction, chatbots provide a sense of engagement that keeps them motivated. The ability to interact dynamically with AI fosters a more active learning process, which could lead to better retention and understanding of the material.

Improved Study Efficiency and Productivity

Generative AI chatbots help students streamline their study routines by summarizing complex materials, generating practice questions, and organizing study plans. These tools reduce the time spent searching for information and enhance productivity by providing structured learning assistance. For example, a chatbot can generate a summary of a long research article, allowing students to grasp key points quickly. Additionally, chatbots can assist in scheduling study sessions by reminding students of upcoming deadlines and suggesting study topics based on their progress (Bannister et al., 2023). In asynchronous learning, where students must manage their own time effectively, these productivity-enhancing features help them stay on track. By reducing cognitive load and making information more accessible, chatbots could contribute to more effective learning experiences.

Potential for Over-Reliance

Despite their benefits, excessive reliance on generative AI chatbots may hinder students' ability to develop critical thinking and independent problem-solving skills. If students become too dependent on AI-generated responses, they may struggle to analyze and evaluate information on their own. Overuse of chatbots could lead to superficial learning, where students focus on quick answers rather than deep understanding. For example, if a student

relies on a chatbot to provide solutions for every problem rather than working through challenges independently, they may not develop essential analytical skills (Luckin et al., 2016). In asynchronous learning, where self-directed learning is crucial, this over-reliance can reduce students' ability to engage deeply with content, possibly affecting the long-term retention of knowledge and learning effectiveness.

Accuracy and Reliability Concerns

One major drawback of generative AI chatbots is the potential for inaccurate or misleading information. AI-generated responses are based on pre-existing datasets and algorithms, which may not always provide correct or contextually appropriate answers. If students rely on incorrect information, it can lead to misunderstandings and negatively impact their learning outcomes. For example, if a chatbot misinterprets a complex question and provides an incorrect response, a student might unknowingly integrate false information into their studies (Creely & Blannin, 2023). In asynchronous learning, where students may lack immediate instructor validation, inaccurate chatbot responses can create confusion and hinder learning effectiveness. To mitigate this risk, institutions must implement quality control measures and ensure that chatbots are continuously updated with accurate educational content.

Ethical Issues

ethical concerns arise when students use generative AI chatbots to complete assignments or generate work without properly engaging with the learning process. The temptation to use chatbots for academic dishonesty, such as generating essays or solving problems without personal effort poses a significant challenge. This undermines academic integrity and reduces the educational value of assignments (Currie, 2023). In an asynchronous learning setting, where direct supervision is minimal, students must be encouraged to use chatbots as learning aids rather than as shortcuts to bypass critical thinking. Institutions should implement clear guidelines on ethical AI use to ensure students develop essential skills rather than relying on automation for academic success.

Conclusion

GAI chatbots have the potential to transform education by offering continuous support, personalized learning experiences, and improved study efficiency. Their ability to provide instant feedback and adapt to student needs makes them valuable tools in asynchronous and self-directed learning environments. However, challenges such as accuracy, over-reliance, and ethical considerations must be carefully managed to maximize their effectiveness. By addressing these concerns, educational institutions can integrate AI chatbots responsibly, ensuring they enhance rather than replace traditional teaching methods. Ultimately, when implemented thoughtfully, GAI chatbots could enhance the effectiveness of asynchronous learning by providing accessible, personalized, and structured educational support.

2.3.3 Student Generative AI Chatbot Perceptions

The adoption of generative AI chatbots in educational settings has raised a range of opinions from students, largely shaped by their experiences and expectations. For many, GAI chatbots represent a transformative tool that significantly enhances their learning process. Students often highlight the convenience of chatbots, particularly their 24/7 availability, as a key benefit. Unlike traditional resources that may require fixed schedules or instructor availability,

chatbots provide instant support, enabling students to access help whenever they need it, including during late-night study sessions (Holmes et al., 2019, Wang et al. 2023).

In terms of utility, students frequently describe GAI chatbots as effective for specific academic tasks, such as explaining difficult concepts, summarizing complex materials, and assisting with technical questions. For example, students working on assignments often use chatbots to clarify doubts about course material or to gather ideas for structuring their work. Chatbots also provide step-by-step problem-solving assistance, which is especially beneficial in technical subjects such as mathematics or programming (Luckin et al., 2016). Many students find that these tools help them better understand topics they might have otherwise struggled with, enhancing their confidence and fostering a more active role in their learning.

GAI chatbots are also praised for their ability to personalize learning. By analyzing individual queries, chatbots can adapt their responses to match a student's knowledge level, offering tailored feedback or supplementary resources. This adaptability aligns with students' diverse needs, making learning more inclusive and accommodating (Woolf, 2009). Furthermore, students who are hesitant to ask questions in traditional classroom environments often feel more comfortable interacting with chatbots, as these interactions are private and nonjudgmental. This encourages engagement and supports students who may otherwise remain silent.

Students frequently highlight the role of GAI chatbots in improving their productivity by offering immediate solutions and streamlining academic tasks. For instance, chatbots are often used to simplify complex readings, generate concise summaries, and automate repetitive tasks, such as formatting references or solving practice problems. These functionalities allow students to focus more on higher-order learning objectives, such as analysis and application, rather than getting bogged down in routine activities (Bannister et al., 2023). Furthermore, chatbots help students stay organized by providing timely reminders for deadlines and study plans tailored to their schedules. This personalized support ensures that students can allocate their time efficiently, balancing academic demands with other responsibilities. By reducing the cognitive load associated with managing multiple academic tasks, GAI chatbots enhance perceived productivity, enabling students to achieve their goals more effectively (Wang et al., 2023).

However, student perceptions are not without criticism. A common concern is the accuracy and depth of chatbot responses. While chatbots excel at providing concise answers, they sometimes struggle with complex or highly nuanced questions, leading students to question their reliability. This is particularly problematic in disciplines requiring detailed analysis or critical thinking, where students expect comprehensive and context-aware responses (Creely & Blannin, 2023). Another concern is the risk of over-reliance on chatbots. Some students worry that extensive use of these tools might undermine their ability to develop independent problem-solving and critical thinking skills, which are essential for long-term academic and professional success.

Ethical concerns also shape student perceptions. Issues such as data privacy and the potential misuse of chatbots for academic dishonesty are frequently cited as challenges. For instance, students worry about the confidentiality of their interactions and whether sensitive information might be shared or misused. Additionally, the temptation to use chatbots for

generating assignment content rather than as a learning aid raises questions about maintaining academic integrity (Currie, 2023).

The adoption of Generative AI (GAI) chatbots in educational settings has brought out a range of student perceptions, with many highlighting the convenience and 24/7 availability as significant benefits, particularly for late-night study sessions. Students appreciate chatbots for explaining difficult concepts, summarizing complex materials, and providing step-by-step problem-solving assistance, which enhances understanding and fosters a more active learning role. This functionality can significantly influence asynchronous learning by offering immediate, personalized support, thus allowing students to engage with materials at their own pace and improving learning effectiveness through timely feedback. Chatbots also personalize learning by adapting responses to individual queries, supporting diverse needs, and offering a private, nonjudgmental environment that encourages engagement, which is particularly beneficial in asynchronous settings where real-time peer or instructor support may be limited. Additionally, chatbots improve productivity by streamlining academic tasks, simplifying readings, and offering timely reminders, allowing students to focus on higher-order learning objectives.

However, concerns about the accuracy and depth of chatbot responses persist, especially in disciplines requiring nuanced analysis and critical thinking, potentially affecting the reliability of asynchronous learning. Some students fear over-reliance on chatbots might undermine independent problem-solving and critical thinking skills, which are crucial for effective learning outcomes. Ethical issues such as data privacy and the potential misuse of chatbots for academic dishonesty also shape student perceptions, raising questions about confidentiality and academic integrity, which could further impact the trust and effectiveness of asynchronous learning environments.

2.4 synthesis of literature

This chapter synthesizes the insights from the literature on asynchronous learning and generative AI (GAI) chatbots. It examines how these two interact, identifying their complementary aspects as well as potential conflicts. The synthesis is structured around the key characteristics of asynchronous learning and GAI chatbots, followed by a matrix summarizing their interaction points.

2.4.1 Characteristics of Asynchronous Learning

Asynchronous learning is characterized by its flexibility and self-paced nature, allowing students to engage with educational content at their own convenience. Key benefits and challenges include:

1. **Flexibility:** Students can access materials at any time, accommodating different schedules and time zones.
2. **Self-Paced Learning:** Learners can revisit content as needed, promoting deeper understanding and retention.
3. **Reflective Learning:** The absence of immediate responses encourages students to reflect before contributing to discussions.
4. **Isolation**: Lack of real-time interaction can lead to feelings of disconnection and decreased motivation.

5. **Self-Discipline Requirements**: Students must manage their time effectively without external structure.

2.4.2 Characteristics of Generative AI (Chatbots)

GAI chatbots are AI-driven tools that simulate human-like conversations to support learning. Their characteristics and challenges include:

1. **24/7 Availability:** Chatbots provide instant feedback at any time, reducing delays in learning.
2. **Personalization:** They tailor responses based on individual learning needs, supporting adaptive learning.
3. **Efficiency:** Chatbots summarize content and generate study materials, improving productivity.
4. **Enhanced Engagement**: Chatbots lower psychological barriers, encouraging students to ask questions without fear of judgment.
5. **Accuracy Concerns**: AI-generated responses may be incorrect or lack depth, leading to potential misunderstandings.
6. **Over-Reliance**: Excessive use might hinder the development of critical thinking and independent learning skills.
7. **Ethical Issues**: The use of generative AI tools for learning brings fort an ethical issue of Academic integrity.

2.4.3 Matrix of Interaction Points

Aspect	Asynchronous learning	Gai Chatbots	Complement or conflict
Flexibility	Access materials anytime, Delayed interaction with instructors	24/7 availability for instant support and responses to queries reducing frustration	**Complement**: Both offer flexible learning options + enhances interaction timeliness
Self-Paced Learning	Students control their learning speed + it encourages independent study	Personalized responses tailored to learning pace	**Complement**: Supports individualized learning
Engagement	Potential for isolation without real-time interaction	Interactive, judgment-free environment encourages questions	**Complement**: Chatbots mitigate isolation
Critical Thinking	Requires self-reflection and independent problem-solving	Risk of over-reliance, reducing critical engagement	**Conflict**: May hinder deep learning if overused
Content Accuracy	Content from verified educational sources	Potential for incorrect or biased AI-generated information	**Conflict**: Reliability concerns in AI responses

Table 1: Interaction matrix

The synthesis indicates that GAI chatbots largely complement asynchronous learning by addressing its inherent challenges, such as lack of immediate feedback and student isolation. Their ability to provide personalized, real-time responses enhances the flexibility and self-paced nature of asynchronous education. However, challenges remain in areas such as content accuracy and potential over-reliance, which could impact students' critical thinking and independent learning skills. Understanding these dynamics is crucial for optimizing the integration of GAI chatbots in asynchronous learning environments to maximize their effectiveness while mitigating risks.

2.5 Conceptual Model

This conceptual model illustrates the relationship between Generative AI (GAI) chatbots and asynchronous learning (AL) and how their interaction influences effective learning (EL). The model provides a framework for evaluating their combined impact on student learning effectiveness.

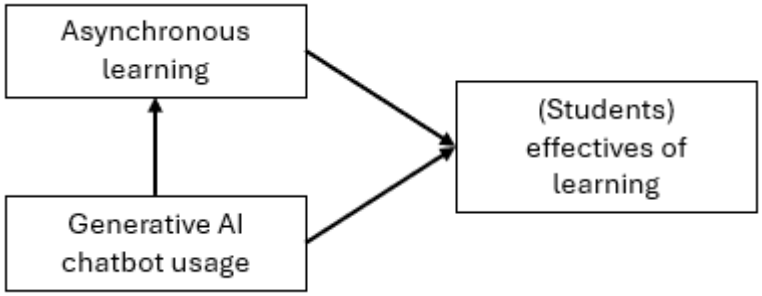

Figure 1: Conceptual model

This conceptual model illustrates the interplay between asynchronous learning and the use of Generative AI (GAI) chatbots, highlighting how these factors collectively influence the effectiveness of student learning. The model is built around the following three components:

1. **Asynchronous Learning (AL):** contributes positively to learning by offering flexibility, self-paced study, and reflective learning opportunities. However, it also presents challenges such as reduced engagement and the need for self-discipline.
2. **Generative AI Chatbots:** Enhance the learning experience through Provide personalized, real-time support, reduce learning barriers, and improve efficiency, yet may introduce risks such as over-reliance and inaccurate responses.
3. **Effective Learning (EL):** is the outcome variable, influenced by both AL and GAI. The interaction between AL and GAI can enhance learning when the chatbot mitigates AL's challenges, but it may also hinder learning if it encourages passive consumption or reduces critical thinking.

The model visually represents these relationships, with arrows indicating the direction of influence. The model suggests that GAI chatbots can moderate the relationship between asynchronous learning and effective learning, either amplifying positive outcomes or mitigating negative ones.

2.5.1 Relationships

Direct Relationships

- *AL → EL*: Asynchronous learning could enhance effective learning by offering flexibility and autonomy, but its effectiveness depends on student engagement, motivation, and self-regulation
- *GAI → EL*: Generative AI chatbots support effective learning by providing real-time feedback and adaptive learning experiences. However, they also introduce challenges, such as accuracy concerns and the potential for over-reliance.

Moderating effects

- *Generative AI Moderating AL → EL*: Generative AI chatbots serve as a moderating factor in the relationship between asynchronous learning and effective learning. Their ability to provide instant clarification and support can address the shortcomings of asynchronous learning, such as student isolation and delayed feedback. However, the extent of this benefit depends on the chatbot's accuracy and the way students use it—whether as a supplementary learning aid or a crutch for quick answers.

For instance, students who struggle with motivation in self-directed learning environments may benefit from chatbot-driven engagement, but excessive dependence on AI-generated responses could lead to shallow learning and diminished critical thinking.

3 Propositions

This chapter builds on the conceptual model by outlining five propositions that link asynchronous learning and Generative AI (GAI) chatbots to effective learning. Each proposition addresses a specific aspect of how GAI chatbots can either strengthen or weaken learning in an asynchronous environment. After each proposition a description is given.

Proposition 1: *Generative AI reduces the sense of isolation in asynchronous learning by providing continuous, easily accessible support.*

Generative AI chatbots could lower feelings of isolation in asynchronous learning by offering accessible support at any time. When students study alone and cannot immediately ask an instructor for help, a chatbot's continuous presence can quickly help or give explanations, making them feel more connected. This real-time availability gives students a sense of comfort, knowing they can get quick answers whenever they need them. As a result, they are less likely to feel detached or alone while studying independently.

Proposition 2: *Generative AI increases perceived learning effectiveness in asynchronous settings by offering fast, personalized feedback.*

When GAI chatbots deliver fast, personalized feedback, students in asynchronous courses could perceive their learning as more effective. Students often need immediate answers to clarify doubts, and chatbots can deliver those answers without long waits. By giving clear explanations or examples, chatbots prevent students from getting stuck on difficult topics and give them a better understanding. This direct feedback loop can motivate them to keep working on tasks without waiting for long periods. As a result, the better understanding and faster help can improve how students perceive their own learning progress and effectiveness.

Proposition 3: *Over-reliance on Generative AI weakens students' critical thinking and independent problem-solving skills in asynchronous courses.*

An overreliance on GAI chatbots in asynchronous settings can weaken students' critical thinking and problem-solving skills. If they constantly depend on automated solutions, they may fail to develop the deeper reasoning needed to handle complex challenges. Relying mostly on chatbot answers can also reduce curiosity, as students might not explore multiple sources or reflect on their own learning paths. As a consequence, their long-term ability to analyze and evaluate information may suffer.

Proposition 4: *The value of Generative AI (GAI) chatbots in asynchronous learning depends on the accuracy and reliability of their responses.*

The success of GAI chatbots in asynchronous learning relies heavily on the accuracy and reliability of their responses. If the chatbot frequently provides correct and meaningful information, students are more likely to trust and use it regularly. However, repeated mistakes or incomplete answers can quickly undermine confidence, causing students to abandon the tool. This link between reliability and trust is key to ensuring chatbots truly support effective learning.

Proposition 5: *Generative AI enables more efficient time management in asynchronous courses, especially near deadlines or exams.*

GAI chatbots enable students to manage their time more efficiently in asynchronous courses, particularly when facing important deadlines or exams. By giving clear explanations and quick clarifications, these tools help students complete tasks without lengthy searches for additional resources. With the chatbot's support, they can use their study sessions more productively, focusing on deeper analysis and comprehension. This can reduce stress and help them stay organized throughout the course.

4 Methodology

This chapter describes the research methodology used to answer both the main, the sub-questions and the propositions of this study. The chosen approach is based on collecting and analyzing data from multiple sources to gain a deeper understanding of the relation between generative AI and asynchronous learning and its effects on learning. First, the research design will be explained. followed by a description of a case study used for this research. Then, for each of the data sources, there will be explained how they were analyzed and what data collection steps were taken.

4.1 Case Study

For this research, a collaboration was established with Tilburg AI, an initiative launched by Tilburg University to responsibly integrate AI into education. This initiative is supported by various schools within Tilburg University, including TSHD, TSB, TLS, and TiSEM. One of its key projects is the development of a course-specific interactive chatbot.

During the fall semester of 2024, Tilburg AI conducted a case study with this chatbot on the course "Online Data Collection & Management". This is a course with both on campus and online lectures on the extraction of data from the internet. For eight weeks of the 10-week long course, students had access to a chatbot integrated with all the study materials available in the online course environment, such as lecture slides, the course manual, and assignments. Throughout this period, Tilburg AI monitored the chatbot's usage for 8 weeks by collecting data on the date's questions were asked, the content of those questions, and the chatbot's responses.

For the purposes of this study, Tilburg AI provided access to the dataset of the case study. This data serves as a foundation for analyzing generative AI chatbot usage, including identifying usage patterns and understanding its applications in an educational and asynchronous learning context.

4.2 Research Design

For the research a combination of both quantitative and qualitative methods was chosen. This was done because neither quantitative nor qualitative approaches alone would provide a complete picture of the relation between generative AI, asynchronous learning and its effect on learning. Nor could it else sufficiently explain students' perceptions on its effectiveness. The quantitative part of the study, primarily in the form of surveys, provides numerical data on the student's perspective of effectiveness. This data can show, for instance, if students generally find generative AI effective for asynchronous learning.

To gain deeper insights, the study also includes several qualitative data sources. First, chat logs generated by the chatbot provide valuable information about the nature of questions asked by students', the types of problems they encounter, and how they phrase their queries. Analyzing these logs allows for a better understanding of the use cases of a chatbot in an asynchronous environment. Second, a semi-structured interview was held. This offers personal narratives and possible explanations for the patterns observed in the chat logs and survey results. By discussing motivations, challenges, and experiences in detail via an

interview, students could explain factors that else may be missed by purely quantitative measures.

By merging these qualitative and quantitative elements, the study aims to gain a more complete view of both what students do with a generative AI chatbot and why they do it, thus strengthening the overall analysis on the effects of generative AI on asynchronous learning and its effectiveness.

4.3 Data Analysis Methods

The data analysis in this study is designed to comprehensively evaluate the patterns of chatbot usage, categorize the types of questions students ask, and assess the validity and reliability of the findings. By employing both quantitative and qualitative methods, this section outlines the processes used to analyze data from the case study, the survey and the interview, providing a structured approach to uncovering meaningful insights.

4.3.1 Case study

To analyze the data from the case study several analysis methods were use. First an analysis was performed on the course itself. The purpose of this analysis was to create insights into the structure of the course. This includes lecture, assignment and exam dates, as this data might give and indication on why students use the generative AI chatbot at certain times. The analysis was performed by analyzing the course website.

keyword-based categorization

secondly, a **keyword-based categorization** method was applied on the chatbot data. This was done to identify patterns in how students interacted with the system. Specifically, the type of questions asked by the students. Within this method there was a specific focus on messages from the Message Content column in the dataset where the Sender was "User," as these represent student-initiated questions.

In order to use the keyword categorization, first a sampling was performed on the data. This was done to create an initial insight in the type of questions asked and used terminology. Each 10th prompt was analyzed to find common question categories. Then, for each category, keywords were defined so that with the help of a python script, each question asked by a student would be automatically classified. For example, the **Technical Support** category included terms such as "error," "debug," "code," and "software," while **Course Material** included words like "assignment," "concept," "lecture," and "theory". The full python code can be found in the appendix. Each message was scanned for the presence of these keywords, and the system assigned a category based on matches.

Keyword-based categorization is particularly suitable because it offers a relatively simple way to gain an initial impression of the types of questions being asked. This approach aligns well with the goal of creating a quick overview of student queries. While more advanced techniques (e.g., training a specialized model) could be used, they risk overshooting the aim of creating initial insight in major themes. Instead, by defining clear search terms (e.g., “assignment,” “lecture,” “concept,” “error,” “debug”), the system automatically classifies messages into the categories. This allowed for efficiently spotting of common question types,

reveal usage trends, and handle large datasets without manual sorting, making it an effective method.

Although the keyword-based method is straightforward and efficient, it has limitations, such as potential misclassification of ambiguous messages or those covering multiple themes. To address this, the results were cross validated with the qualitative methods, to ensure the findings accurately reflected student behavior and perceptions.

Usage over time

In addition to the categorizing of questions asked, there was also performed an analysis on chatbot usage over time. This analysis is performed to examine when students use the chatbot. Understanding when students interact with the chatbot can provide valuable insights into their learning habits, study schedules, and the contexts in which they seek assistance.

The analysis on usage over time focuses on identifying usage patterns at three levels: Weekly, daily and hourly usage. The analysis was performed by using python code to structure the data on each level and create visualizations. This data was then combined with the course information such as lecture dates and deadlines. This together gives a comprehensive picture of when and why students use a chatbot at certain times.

4.3.2 Survey

To study the impact and effectiveness of generative AI chatbots in asynchronous learning, a survey was conducted among students at Tilburg University. The main goal of this survey is to understand how students experience the role of AI chatbots in their learning process, focusing on aspects such as ease of use, effectiveness, motivation, and possible limitations.

Through structured questions to which participants could respond on a 5-point Likert scale (ranging from “strongly disagree” to “strongly agree”), this survey collects quantitative data on students' attitudes toward AI chatbots and their impact on learning. The collected data is analyzed to identify patterns in how students interact with AI and to assess whether chatbots support or hinder the asynchronous learning process.

To analyze the survey data effectively, several statistical methods were applied to ensure reliable and meaningful insights. The first step involved a quantitative assessment using descriptive statistics, such as mean. This helped in identifying overall trends in students' perceptions of chatbot effectiveness, ease of use, and impact on learning. This method allowed for a straightforward interpretation of the data and highlighted key areas where the chatbot either excelled or fell short.

To ensure the reliability of the survey, an internal consistency test using Cronbach’s alpha was conducted. This statistical test measures how well different survey questions that address the same topic are related to each other. A Cronbach’s alpha value of 0.7 or higher is generally considered acceptable, indicating that the survey questions consistently measure the same underlying concept. This was particularly important for evaluating areas such as learning support and productivity, ensuring that the responses provided a coherent picture of students’ perceptions.

Additionally, the survey responses were analysed using python scripts to create visualizations. This analysis included the making of bar charts per question to be able to visually seethe data and check if there are any special results which might not be visible otherwise. This structured approach of the different analysis ensures the validity of the findings and also enables the drawing of draw meaningful conclusions about how generative AI supports asynchronous learning.

4.3.3 Semi-Structured Interview

Based on the results from the case study and survey, a semi-structured interview was designed to gain deeper insights into student experiences with the AI chatbot. While the data from the case study and survey provided valuable information on when and how students used the chatbot, they did not necessarily explain why students engaged with the chatbot at specific moments or why they held certain perceptions reflected in the survey responses. The interview aimed to provide possible explanations for these findings by exploring students' motivations, reasoning, and personal experiences in more detail.

The interview questions were carefully developed based on the propositions outlined in the study and the uncertainties that emerged from the results of the case study and survey. By aligning the questions with these key areas, the interview sought to clarify the underlying factors influencing chatbot usage patterns and student perceptions. This approach ensured that the interview complemented the existing data sources by providing qualitative depth to support or either contradict the other findings.

4.4 Data Collection Steps

In this section for each of the 3 data sets it collection steps will be mentioned. Followed by the data cleaning and preparation steps taken to make the data ready for analysis.

4.4.1 Case Study

The first step in the data collection of the case study was the analyzing of the course page. This was done on Canvas. The digital environment from Tilburg University. Within the course all section were analysed for relevant information such as the dates of lectures and exams. This data was then written down in a word document.

For the data of the chatbot logs, no real collection steps had to be taken. The data got provided by Tilburg AI in the form of a CSV file containing all the chat logs from the eight weeklong case study.

However, for the data cleaning and preparation several steps had to be taken. When looking at the data in the CSV file it became clear that the prompts were not correctly sorted according to their timestamps. To make the data more easily analyzable all the prompts were put into order according to their timestamps, from oldest to newest date. This was done in excel where the prompts per row could automatically be sorted according to the timestamps. Secondly the dataset contained duplicates. ChatGPT, a generative AI chatbot was used to find and mark all the duplicates in the data. Then by hand all the duplicates were checked and removed. Since the chatlogs were already anonymized when received. No steps for data anonymization had to be taken.

4.4.2 Survey

Following the case study, several data collection steps were taken for the survey. Initially, the survey was sent out via email to the 46 students involved in the case study. However, after 1 week there were only five responses. Because of this the survey was sent out again to the same students. After one more week no new responses were registered.

To ensure a larger data set, and a better represented population, it was decided to distribute the same questionnaire to around 200 students at Tilburg University in the faculty of Economics and Management, aiming for a total of 50 responses. This would result in a response rate of 25% which should be reachable. Achieving this target provides a broader view of the chatbot's perceived effectiveness across a more diverse group of respondents ensuring better external validity. One week after the survey had been send out to the 200 students via WhatsApp groups and email. After the first round a total of 25 students had responded. A week later after the second mailing and WhatsApp reminder texts the total number of responses became 31.

After this the survey was closed and the gathered data was extracted from Microsoft forms in the form of an CSV file. Looking at the CSV file the data checked on duplicate entries by students. These were not found. The data was also checked on outliers. However no significant outliers could be found in the survey data.

4.4.3 Semi-Structured Interview

After the case study and the survey, the question for the interview were determined and prepared for an interview. For the interview three students were invited. From the three students one was, given a very short timeframe, available for an interview.

Prior to the interview the interviewee was sent the list of questions which would be asked during the interview. Including information on the setup of the interview and its purpose. This gave the interviewee time to prepare. The interview was conducted via Microsoft Teams. During the interview each question would be introduced and answered one by one. The collection of the interview was done in several ways. The first way was by recording of the interview with the help of OBS. OBS is a screen capture application. Secondly the interview got transcribed with the help of the transcribe function in Microsoft word.

After the interview was completed, the data had to be cleaned and prepared for the analysis. firstly, the transcription of the interview had to be summarized into the main points discussed by the interviewee so that any irrelevant information for the research would be left out. After this the results were sent to the interviewee via email to validate their answers.

5 Results

This chapter presents the findings of the study, offering a detailed analysis of data collected

5.1 Case study results

5.1.1 Course analysis results

From the analysis of the course page and its documents different interesting information for this research was found. This course featured several important contact moments and deadlines. Weekly, students attended tutorials and team coaching sessions every Tuesday or Wednesday, depending on tutorial groups. These tutorials and coaching sessions were held between 9 am till 2 pm. However, during the first two weeks of the course, only an introductory lecture and tutorials were conducted, with no team coaching sessions. During the coaching sessions, students were able to work on a group project and ask their instructors questions about the group project if needed.

One major part of the course was a group project. The kickoff of the project took place in week three of the course. At the same time the course specific chatbot got formally introduced to the students. This group project focused on conducting a small research on a topic of their own choosing. In which the students had to use data which they themselves had to acquire by the use of web scraping. The kickoff for the group project took place on Tuesday, September 10 (calendar week 37), and the project deadline was set for Sunday, October 13.

As a final test the students had a final exam. This exam focused on the theory of the course which were discussed during the lectures, as well as small programming tasks related to online data collection. The final exam for the course was held on October 16.

5.1.2 Chatbot time Analysis

This section of the results focuses on the data collected through students' use of the chatbot. By analyzing the interactions between students and the chatbot, we aim to gain insights into how and when this tool is utilized within an academic context. Specifically, this analysis examines the types of questions asked, usage patterns over time, and the relationship between chatbot usage and academic milestones such as deadlines and exams.

Chatbot Usage Per Week

Analyzing the data revealed several key patterns in chatbot usage throughout the course. See diagram 1 for the visualization. In the first two weeks, chatbot usage was notably low. A significant spike occurred during week 37, with nearly 621 total prompts submitted. This aligns with the kickoff of the group project. However, in the following week, chatbot usage dropped substantially to just under 300 prompts. This declining trend continued until week 42 (October 14–20), where a minor uptick in usage was observed compared to the preceding two weeks. This is in line with the date of the final exam in the same week.

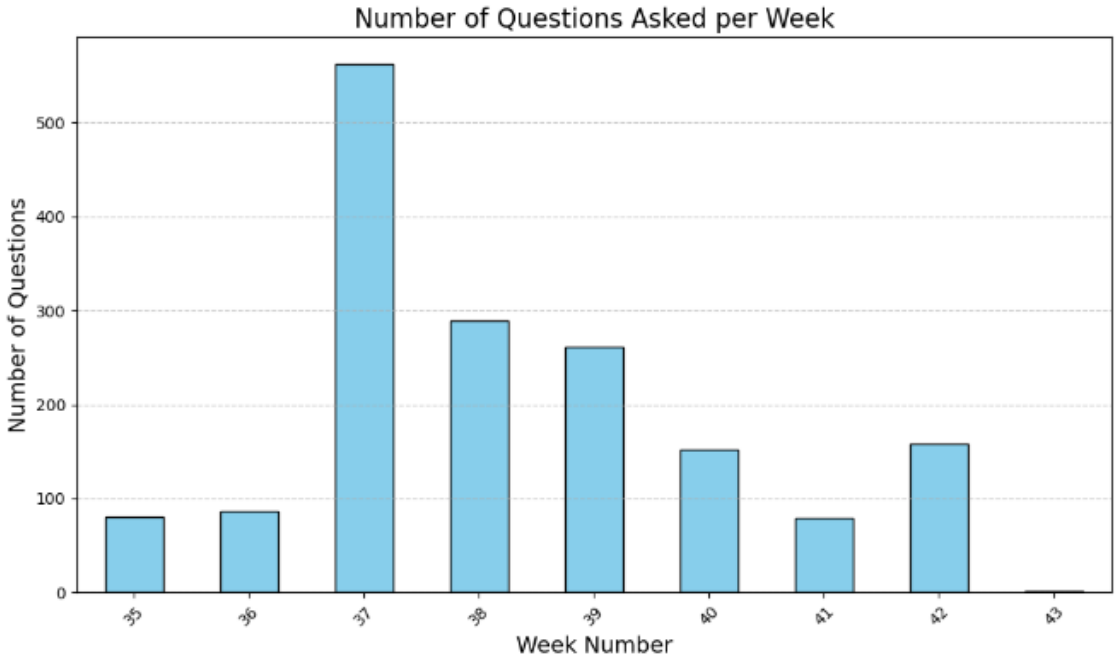

Figure 2: nr of questions asked per week

Chatbot Usage by Day of the Week

Examining the weekly timeline of chatbot usage shows that the chatbot was predominantly used on Tuesdays and Wednesdays. These two days accounted for 58% of the total 1,671 questions posed by students. Usage during the weekend was the lowest across the week. Monday, Wednesday, and Thursday demonstrated similar levels of activity, collectively accounting for 33% of the total prompts. The remaining percentage of chatbot usage occurred over the weekend.

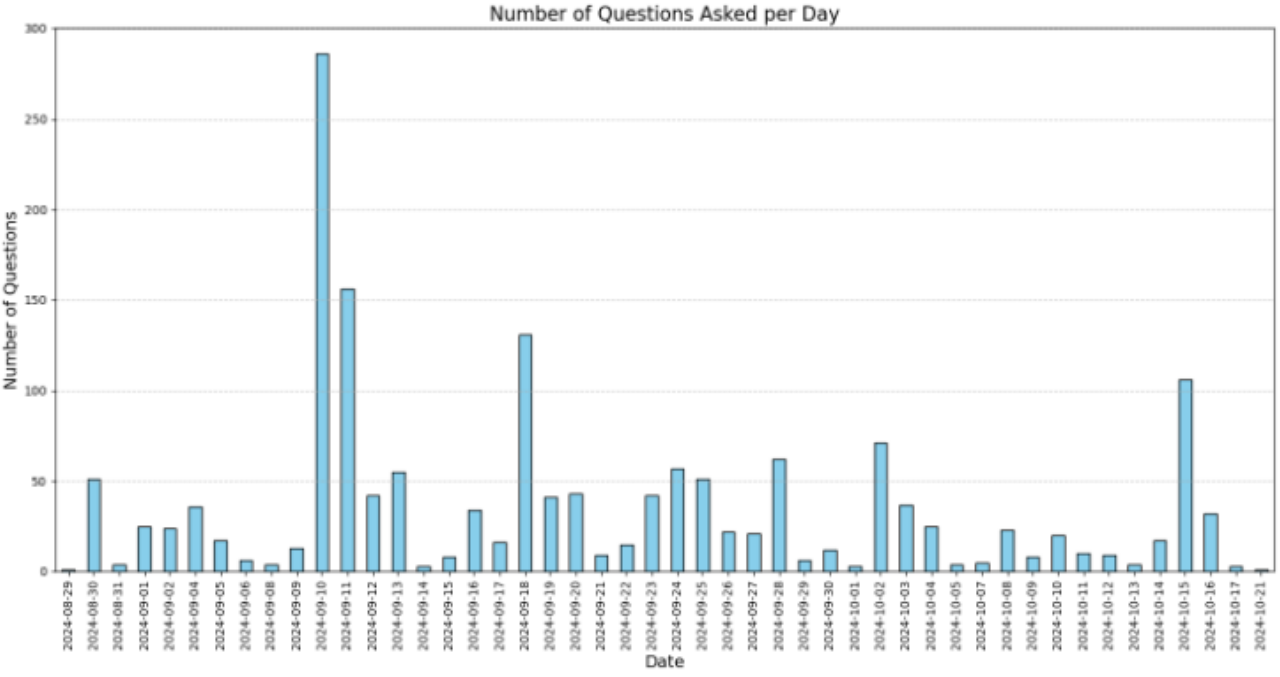

Figure 3: nr of questions asked per day

Looking at the figure above you can see a clear pattern of high chatbot usage on certain days. For example, the day before the exam on 15-10-2024 there is a spike in usage. And on 10-9-2024 there is a massive spike on the day of the group project kickoff. The figure 4 billow also gives a good representation of the nr of questions asked per day of the week. Showing that the majority of questions asked is on Tuesday and Wednesday. The days of the tutorials.

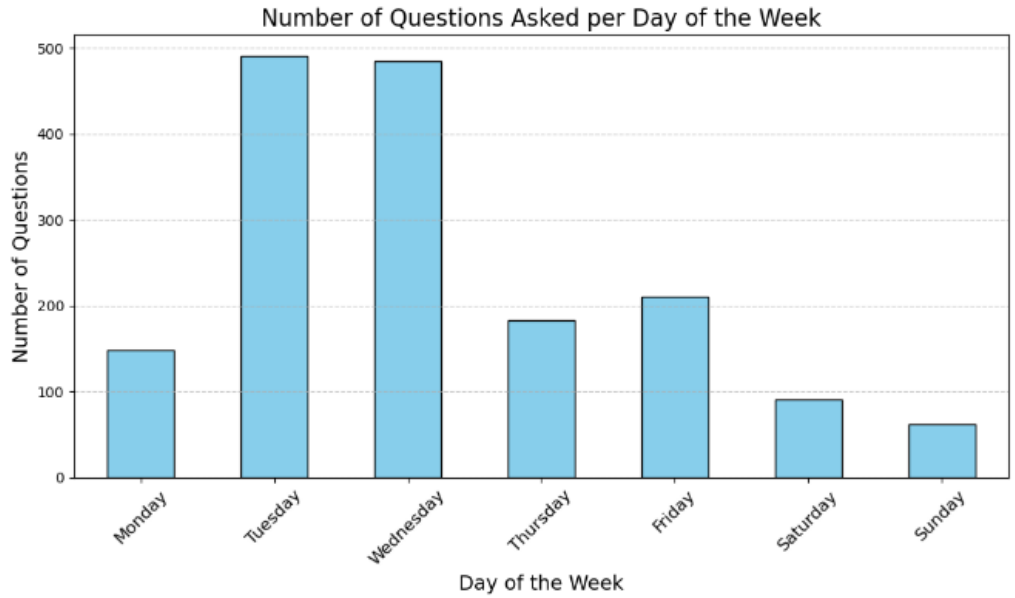

Figure 4: Number of questions asked per day of the week.

Chatbot Usage per hour of day

As seen in figure 2 below there is a clear pattern on the usage of the chatbot per hour of the day. The data shows that the chatbot is primarily used between 9 a.m. and 2 p.m., with a significant peak occurring between 11 a.m. and 12 a.m. Additionally, there is a slight increase in usage observed later in the evening, from 6 till 10 pm.

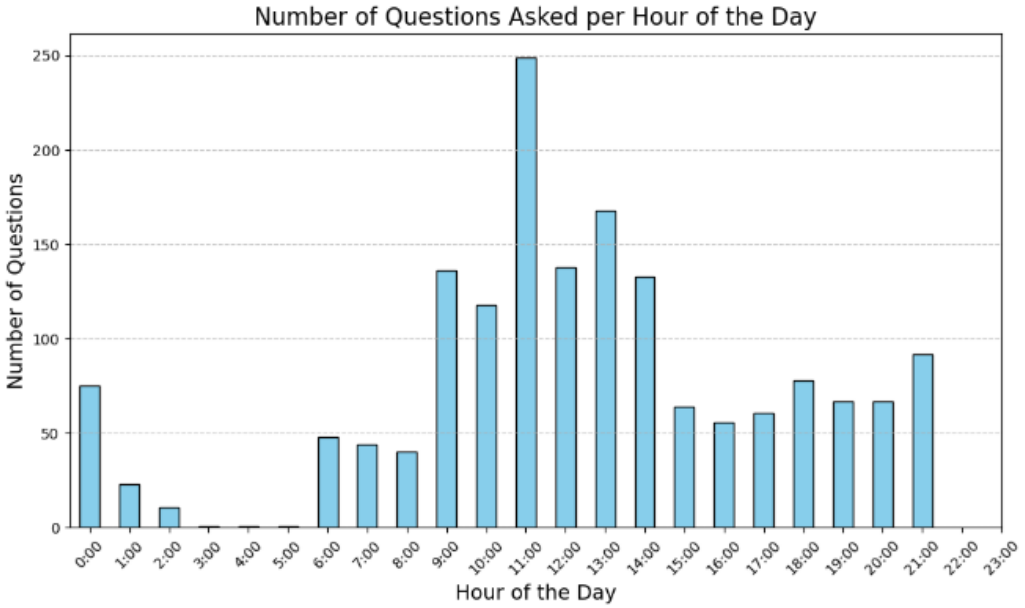

Figure 5: number of questions asked per hour of the day.

5.1.3 Type of questions asked

Analyzing the chat history of the students there was a clear pattern in the type of questions they asked. A total of 4 clearly distinguishable categories were determined. They are ass followed: General clarification, Technical Support, Course Material and Administrative questions. In the appendix in section 9.1.1 the code used for the categorization and the keywords used can be found. The table below shows an overview of the number of questions asked per category.

Category	Nr of questions
General Clarifications	1009
Technical Support	449
Course Material	177
Administrative Questions	46

Table 2: Nr of questions per category

In the table you can see that the majority of the questions asked by students focus on general clarification. When further looking into this data it became clear that sometimes, mostly follow up questions on technical support got categorized in this category. This means that even more questions were asked on technical support than initially categorized with the python code.

5.2 Survey results

The survey provided valuable insights into students' experiences and perceptions regarding the use of chatbots for academic purposes. Overall, the findings highlight a range of perspectives on how these tools influence productivity, learning, and engagement.

Students generally reported positive impacts on their productivity, with an average score of 3.97 out of 5. Many highlighted that chatbots significantly enable faster completion of academic tasks, which was reflected in a high average score of 4.50. This efficiency was complemented by the tools' ability to aid in understanding complex topics. With an average score of 3.80, students found chatbots helpful in clarifying challenging material, while their ability to assist with grasping difficult concepts also scored positively at 3.87.

The engagement aspect of chatbots presented a more varied response. While some students appreciated how these tools made studying more engaging, as reflected in a moderate score of 3.03. But when looking further into the data the response by students was divided. Where 8 students gave it a score of 2 and 12 students gave it a score of 4. Indicating that there is a difference between two groups of students. Figure 6 gives the visual representation of the phenomenon. Showing the clear differences between the two groups of answers by students.

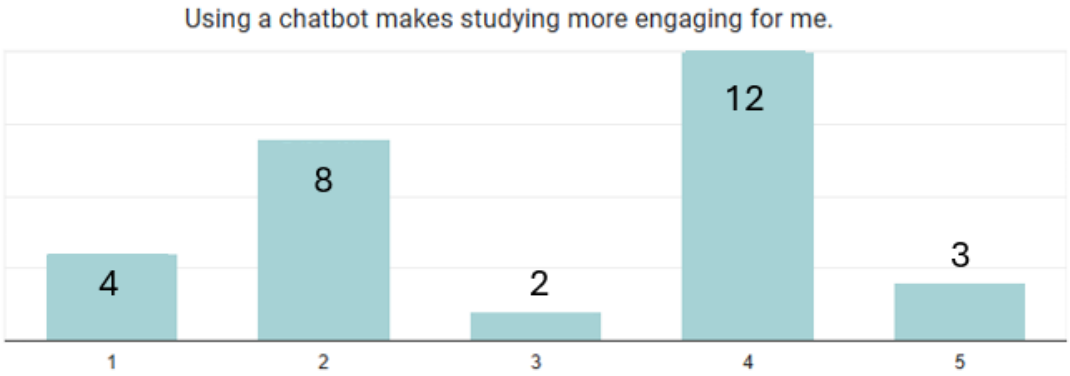

Figure 6: using a chatbot makes studying mor engaging

others emphasized the benefit of feeling encouraged to ask questions that they might hesitate to voice in a classroom setting. Again, there were some students who did not agree at all and some who totally agreed. This was highlighted by an encouraging average score of 3.83. However, trust in chatbots as reliable academic resources was notably low, with an average score of 2.07. This indicates a significant skepticism among students about the accuracy and dependability of chatbot responses.

Ethical concerns also surfaced as a prominent theme. The survey revealed an average score of 2.97, indicating that students are mindful of potential ethical implications, such as fairness and the risk of academic misconduct associated with chatbot use. Despite these concerns, many students appreciated the ease of use of chatbots, with an average score of 4.03, and recognized their effectiveness in planning and executing academic tasks, scoring an average of 3.93.

5.2.1 Cronbach's alpha

To check the internal consistency of the survey a Cronbach's alpha test was performed. For this test three questions of the survey were taken which should represent the same concept of productivity or faster learning and working

It consisted of the following three statements:

1. Using a chatbot improves my productivity when studying.
2. A chatbot enables me to complete study tasks faster.
3. A chatbot enable me to grasp difficult concepts faster.

The analysis yielded a Cronbach's alpha value of 0.63, indicating a moderate level of reliability among these items. Further analysis revealed that dropping any one of these questions did not significantly improve the Cronbach's alpha. Dropping the first question resulted in a lower alpha of 0.60. dropping the second gave an alpha of 0.62. Dropping the last question gave a small increase to 0.65. This suggests that the inclusion of all three items almost contributes similarly to the overall consistency of the scale. While this value suggests some coherence in how respondents perceived these aspects of chatbot use, it also highlights the potential for further refinement of the questions to achieve a higher level of consistency.

5.3 Interview results

During the interview several questions were asked concerning the use of generative AI. First each question will be stated followed by the answer the student gave on the question.

Do you think that having an AI chatbot available at any time make you feel more connected or supported during your studies? And why so?

One participant highlighted that having a 24/7 AI chatbot greatly increased their sense of academic support. They noted that this instant accessibility allowed them to resolve questions as soon as they arose, rather than waiting for an instructor's or peer's reply. In an asynchronous course, where live interactions are not as frequent, the chatbot helped prevent feelings of being on your own by offering ongoing help at any hour, including late evenings and in the weekends. The participant explained that this immediate feedback boosted their confidence and kept them motivated to tackle more difficult topics. Overall, the student's experience suggests that around-the-clock availability of the chatbot can reduce downtime in the learning process and enhance the sense of continuous support.

In what ways, if any, do the chatbot's continuous availability influence your motivation or feelings of isolation in an asynchronous setting?

The respondent emphasized how the continuous availability of the chatbot alleviated some of the isolation often experienced in asynchronous courses. They described the chatbot as a "study partner," highlighting that knowing help was always accessible helped with motivation. Instead of feeling disconnected due to fewer live interactions, the student found reassurance in being able to ask questions whenever they arose, thereby reducing the likelihood of getting stuck or discouraged. This immediate support seemed to reinforce their engagement.

Do you feel rapid feedback helped clarify a concept more effectively than waiting for a tutor or professor's response? And why so?

The participant reported that receiving rapid feedback from the chatbot significantly improved concept clarity compared to waiting for a tutor or professor. They noted that when delays occur like waiting a day or two for an emailed response some of the context and urgency surrounding the question can be lost. Conversely, the chatbot's immediate assistance helped them address misunderstandings right away, keeping the learning process more continuous and focused. The student indicated that this prompt clarification increased their reduced frustration, allowing them immediately better understand concepts without prolonged confusion.

In your experience, how does receiving quick, tailored feedback from a chatbot compare to traditional methods in terms of improving your understanding of the material?

The student emphasized the benefits of immediate, tailored feedback from the chatbot, particularly noting that it provided quick, targeted answers to specific questions. When compared to traditional methods such as waiting for scheduled office hours or emails. the rapid, personalized nature of the chatbot responses was seen as a major advantage for clarifying doubts. Although the participant acknowledged that a human instructor might offer more in-depth explanations, they felt the chatbot's fast feedback loop effectively filled knowledge gaps, thereby enhancing their understanding of the material. This immediacy appeared to support the student in maintaining a smooth and continuous study flow.

Have you ever felt you depended too heavily on the chatbot's responses rather than working through problems on your own? What effect do you feel it has on learning?

The participant admitted occasionally relying on the chatbot more than intended, particularly when short on time. While it provided quick answers, the student worried that this might reduce deeper learning and independent problem-solving. They acknowledged it was convenient to use the chatbot as a shortcut but recognized a potential trade-off in terms of building their own mastery and critical thinking. This suggests that while the chatbot is useful for efficiency, it also requires balance to ensure skill development.

Do you feel that the convenience of chatbot help with developing your own critical thinking and problem-solving skills? Why so?

The respondent noted that the chatbot could both promote and impede the development of critical thinking and problem-solving abilities. On one hand, it often offered different perspectives that spurred the student to think more broadly about a problem. On the other hand, overusing the chatbot risked bypassing the mental processes involved in working through a challenge independently. Therefore, the participant considered the chatbot a useful springboard for further thought but cautioned that relying on it too heavily could hamper the honing of essential cognitive skills.

Do you trust the information, which is given by a generative AI chatbot, specifically in an educational context? Explain yourself.

The student expressed a cautious stance regarding the chatbot's information, noting that they do not fully trust it without verifying against other sources. While it serves as a helpful discussion partner, they stressed the importance of cross-referencing answers with textbooks or lecture notes, especially when the question is complex or highly specific. This highlights the need for users to remain critical and not treat the chatbot as an absolute authority.

What level of accuracy do you expect from an AI chatbot before considering it a useful and trustworthy tool for your coursework?

Regarding expectations of accuracy, the participant indicated a need for the chatbot to be correct a majority of the time around 80 to 90 percent to maintain trust. Occasional minor mistakes were deemed acceptable, but persistent inaccuracies would quickly undermine its perceived usefulness. This response underscores a threshold concept in user trust: once errors become frequent enough to erode confidence, students may abandon the tool

How has having access to an AI chatbot changed the way you plan your study sessions or approach deadlines?

Having 24/7 access to the chatbot prompted the student to adopt a more flexible study schedule. With support available at all hours, they felt more comfortable studying during evenings or weekends, no longer constrained by the need to align complex questions with traditional office hours. This flexibility also reduced stress around deadlines by letting them seek immediate clarification whenever needed, thus allowing more efficient time management and planning.

Can you describe a scenario where the chatbot specifically helped you optimize your time when preparing for an exam or submitting an assignment?

The student highlighted a specific instance where the chatbot's availability late at night proved particularly valuable. They were able to troubleshoot a programming bug outside of regular support hours, preventing a delay in completing their assignment. This real-time assistance allowed them to maintain momentum and meet the submission deadline without relying on an instructor. Their account suggests that the chatbot not only saves time but also helps mitigate stress by providing immediate, round-the-clock problem-solving support.

How do you think using generative AI chatbots influences the development and practice of critical thinking skills among students?

According to the participant, generative AI chatbots can foster critical thinking by prompting users to examine the logic behind the AI's responses. Seeing how the chatbot reasons or makes connections can lead to new insights, as students compare the chatbot's suggestions to their own thinking process. However, the student also warned that heavy dependence on the chatbot might reduce opportunities for independent exploration and self-guided problem-solving. Therefore, the effect on critical thinking seems to vary based on how responsibly students choose to integrate the tool into their study routines

Would you say generative AI chatbots make your study experience more engaging or less engaging, and what factors contribute to that perception?

The respondent described their study experience as more engaging due to the chatbot's interactive nature. They likened it to having a study partner for real-time questions and follow-up discussions. However, the student also noted that the quality and accuracy of the chatbot's answers play a significant role in sustaining that engagement: repeated inaccuracies or inability to handle complex queries can turn the tool from an asset into a source of frustration.

6 Discussion

The results of this study provide a multifaceted understanding of how university students utilize generative AI chatbots in academic settings. The discussion evaluates these findings in the context of the study's hypotheses, the literature review, and the research questions. Key insights are drawn to assess the practical implications and theoretical contributions of the research.

6.1 Interpretation of Findings

For the interpretation of the finding, we will look back at the propositions of the study answering them one by one. First the proposition will be repeated followed by its answer.

Proposition 1: *"Generative AI reduces the sense of isolation in asynchronous learning by providing continuous, easily accessible support."*

Based on the theory in the document, asynchronous learning often makes students feel isolated because there is less real-time interaction with classmates or instructors. Researchers like Bolliger and Inan (2012) explain that this isolation can harm motivation and engagement. However, the document's interview results show that having an AI chatbot available 24/7 helps students feel more supported, even if no teacher is around. One student described the chatbot as a "study partner," highlighting that quick answers at any hour make them feel less alone. This matches the theory suggesting that timely feedback and interaction can reduce isolation in self-paced learning settings.

In other words, the chatbot's constant availability directly addresses the lack of real-time instructor support in asynchronous courses. Because students can ask questions any time and receive an immediate response, they feel more connected and less worried about studying on their own. Therefore, the results from both the interview and the broader data analysis support Proposition 1: a generative AI chatbot can indeed reduce the sense of isolation by offering continuous and easy-to-reach assistance, in line with what the theories predict.

Proposition 2:*"Generative AI increases perceived learning effectiveness in asynchronous settings by offering fast, personalized feedback."*

A key finding in the survey is that most students believe chatbots help them complete study tasks more quickly. This was reflected in a relatively high average score of 4.50 (out of 5) for the statement "A chatbot enables me to complete study tasks faster." Students also gave an average score of around 3.80 for the statement "A chatbot helps clarify complex topics," implying that receiving immediate feedback helps them avoid the frustration of waiting on an instructor's or peer's reply. When students can instantly ask questions about difficult concepts and receive custom explanations, they perceive their study process as more effective and less stressful.

From the interview, the student explained that the chatbot's around-the-clock availability was crucial for resolving confusion quickly. In asynchronous courses where direct teacher interaction is limited, a long wait for email responses or office hours can interrupt a student's study flow. By contrast, a chatbot's immediate feedback often tailored to the exact nature of the question keeps learners motivated and focused on their tasks. This "fast help" also helps them transition smoothly between different course topics without extensive downtime. The

student emphasized that once they understood a concept more fully in real time, they felt more confident moving on to more advanced course material, thus reinforcing the perceived effectiveness of this learning approach.

Additionally, the time-based analysis of usage patterns—particularly the spike in chatbot interactions on days leading up to project deadlines or exams—shows that students tend to seek help right when they need it most. This further demonstrates that real-time, targeted feedback can reduce bottlenecks in the learning process. Instead of being stuck on a particular question or concept, they can quickly clarify it and proceed, which they interpret as more effective for their overall learning.

The combination of survey data, interview insights, and usage patterns support proposition 2. Students find the chatbot's instant and personalized feedback to be a major advantage in asynchronous learning, helping them work faster, understand complex topics more confidently, and ultimately perceive their learning as more efficient and effective

Proposition 3: *"Over-reliance on Generative AI weakens students' critical thinking and independent problem-solving skills in asynchronous courses."*

The study's survey results revealed a nuanced view of how students feel about chatbots. While many reported timesaving and convenience benefits, they also showed relatively low trust in the chatbot's accuracy (only 2.07 out of 5 on average). This skepticism can be seen as a positive sign because it indicates students do not automatically accept chatbot answers without a second thought. Yet, there is a subset of students who, in moments of time pressure, may rely on the chatbot to provide quick solutions—potentially at the expense of deeper learning.

During the interview, the participant openly admitted using the chatbot as a shortcut when they were under deadline pressure. Although they recognized its value for quick explanations or clarifications, they also worried that relying too heavily on it could diminish their own problem-solving skills. Instead of wrestling with a difficult topic, analyzing multiple sources, or practicing reasoning steps independently, they might accept the bot's answer too quickly. This can hamper the development of critical thinking, which usually requires comparing different viewpoints, making mistakes, and then learning from those mistakes in the process.

Moreover, the data analysis of chatbot usage before exams or project deadlines shows students often flood the chatbot with technical or conceptual questions in the final stretch. While this last-minute help can improve short-term performance, it may also incentivize surface-level learning—prioritizing fast answers over understanding *why* or *how* certain solutions work. Over the long run, such behavior could reduce the self-reliance that asynchronous learning is supposed to foster.

Hence, the evidence points toward a mixed picture: the chatbot is undeniably helpful for quick, targeted assistance, but too much dependence on it can discourage the persistent, exploratory mindset that fuels critical thinking. Taken together, these data-based observations and personal perspective support Proposition 3 by warning that overuse of generative AI chatbots in an asynchronous environment could erode deeper cognitive skills if not balanced with independent study habits and critical analysis.

Proposition 4: *"The value of Generative AI (GAI) chatbots in asynchronous learning depends on the accuracy and reliability of their responses."*

This idea centers on whether students trust the chatbot's responses and whether those answers are correct enough to be genuinely useful. From the survey data, the average trust score was around 2.07 out of 5, which indicates a notable level of caution among students regarding chatbot reliability. In other words, although many students benefit from quick and convenient help, they do not fully rely on it as a single, foolproof source of truth.

During the interview, the participant acknowledged the chatbot's usefulness for instant clarifications but also expressed hesitation about automatically accepting its answers. They mentioned that, especially for complex or nuanced questions, they usually double-check the chatbot's response against their lecture notes, textbooks, or verified online sources. This underscores the concern that the chatbot can sometimes produce incorrect or incomplete information.

Furthermore, the chatbot usage data (time-based analysis) shows a high frequency of questions around deadlines or exams, moments when students are eager for fast answers. While a rapid response in these periods can be extremely valuable, any inaccurate information could quickly mislead students and jeopardize their exam preparation. For this reason, if the bot is perceived as often giving incorrect or shallow answers, its overall value for learning drops significantly.

Thus, Proposition 4 is supported by the findings: students find a generative AI chatbot helpful only if it reliably provides correct or at least directionally accurate information. When reliability is questioned, the chatbot transitions from being a "valuable learning aid" to a "use-with-caution" tool in asynchronous settings.

Proposition 5: *"Generative AI enables more efficient time management in asynchronous courses, especially near deadlines or exams."*

Efficiency and time management emerged as major themes in the study. From the survey, students gave the statement "A chatbot enables me to complete study tasks faster" an average rating of 4.50 out of 5, indicating a strong perception that chatbots help them make better use of their study hours. Additionally, the statement "Using a chatbot improves my productivity when studying" scored nearly 4.0, reinforcing the conclusion that students generally feel more efficient when they can access real-time support.

The time-based analysis showed significant spikes in chatbot use right before project deadlines and exams. For instance, usage sharply rose in the lead-up to the group project deadline and again just prior to the final exam. This pattern suggests that students heavily rely on the chatbot during high-stakes moments, presumably to clarify last-minute questions, tackle problematic areas, and confirm understanding of key concepts. Because asynchronous courses require learners to manage their own schedules—often juggling multiple assignments—immediate, on-demand assistance from a chatbot helps them stay focused and use limited study hours more effectively.

In the interview, the participant shared that the chatbot was most helpful when they were stuck on a technical issue or needed a quick refresher on course material. Instead of spending extra time searching through documents or waiting for an instructor's email reply, they could

quickly move forward. This immediate resolution of questions allowed them to maintain momentum rather than lose valuable time.

Therefore, Proposition 5 is supported by survey data, usage patterns, and student testimony: generative AI chatbots can indeed streamline the learning process in asynchronous courses, particularly when students are under pressure to meet important deadlines or prepare for exams.

6.2 Answer to research questions

In this section the research questions as stated at the beginning of this research will get answered. First the question will be repeated followed by its answer.

Main Research Question: *"Can generative AI chatbots complement asynchronous learning, and how do students perceive its effectiveness for learning?"*

Yes, the findings strongly suggest that generative AI chatbots do complement asynchronous learning by providing on-demand support and rapid feedback, which students find particularly helpful when studying independently. The chatbot's continuous availability (24/7) fits well with the flexibility of asynchronous learning, allowing students to clarify questions or solve technical issues without waiting for an instructor's next office hour or email reply.

From the survey, most students felt that the chatbot saved time (average score of 4.50 out of 5 for enabling faster task completion) and helped in clarifying difficult topics (around 3.80). The interview also showed that instant feedback fostered a smoother study flow and reduced feelings of isolation, a known challenge in self-paced courses. Overall, students perceived the chatbot as an effective tool but were cautious about blindly trusting its answers (low trust score of 2.07). Thus, they see it as a valuable supplement—especially for handling simpler questions—yet still rely on verified course materials or instructors for more complex or nuanced explanations.

Sub-Question 1: "*How do generative AI chatbots and asynchronous course structures together shape students' overall learning experience, especially regarding engagement and support?"*

The combination of 24/7 chatbot availability and the flexibility inherent in asynchronous courses shapes a more supportive learning experience. Students can engage with course materials whenever it suits their schedules, then immediately consult the chatbot if confusion arises—rather than waiting days for help. This reduced waiting time lessens frustration and helps maintain momentum.

Regarding engagement, the chatbot's instant responses counteract the sense of isolation typical in asynchronous environments. Usage data showed spikes on weekdays (particularly Tuesdays and Wednesdays), aligning with course activities and suggesting that students actively incorporate the chatbot into their routine. They do not have to depend solely on instructor interactions or peer discussions, which are more limited in asynchronous settings. Consequently, students remain more consistently engaged with the material.

Sub-Question 2: *"In what ways does the availability of a generative AI-driven tool intersect with the flexibility of asynchronous learning, influencing students' motivation and perceived effectiveness?"*

Flexibility in asynchronous learning means students organize their own study times. The chatbot's round-the-clock availability perfectly aligns with this structure: whenever a question or technical issue emerges, students can get rapid assistance. This direct alignment drives motivation because they are less likely to get stuck or frustrated by delayed instructor feedback.

Students' perceived learning effectiveness also rises when they quickly resolve doubts and continue studying without interruption. Survey responses showed strong agreement that the chatbot speeds up task completion and aids concept understanding. The interviewee noted how motivating it was not to worry about "losing time" if a problem popped up outside normal class hours. As a result, students tend to view their asynchronous course work as more productive and successful.

Sub-Question 3: *"How might the interaction between asynchronous learning and generative AI tools affect students' study habits, particularly their sense of independence and development of critical thinking skills?"*

On one hand, the chatbot encourages independent study by giving students fast, self-guided help. Students can tackle challenging problems on their own schedule, building confidence in learning without constant instructor oversight. The immediate feedback loop also prompts some to delve deeper into topics—especially when the chatbot's answer sparks further questions or needs cross-checking with official materials.

On the other hand, over-reliance can undermine development of critical thinking and problem-solving skills if students routinely accept the chatbot's answers at face value. The interviewee admitted to sometimes using the bot as a shortcut under time pressure, which may bypass important learning steps like exploring multiple perspectives or learning from mistakes. This tension suggests students should use generative AI as a springboard for deeper inquiry rather than a sole solution engine, preserving the independent, reflective mindset that asynchronous education aims to cultivate.

6.2.1 Overall statements

Looking at these answers a few key points can be noted on the influence of generative AI of asynchronous learning and its effects on effective learning. They are as follows:

- Generative AI chatbots offer timely, flexible support that addresses key pain points in asynchronous learning, such as student isolation and delayed feedback.
- Survey results highlight improved efficiency and understanding, while interview data reveals the chatbot's positive impact on motivation and consistency.
- Challenges include students' distrust of AI-generated answers and the risk that overuse could diminish critical thinking.
- Used responsibly, however, the chatbot can complement asynchronous learning to enhance student engagement, time management, and perceived effectiveness.

6.3 Limitations

While this research provides valuable insights into how GAI-powered chatbots can be used in academic settings, several limitations must be acknowledged :

1. **Single-Institution Sample**: Because the survey data came solely from students at Tilburg University, the findings may not capture broader trends across different universities or cultural settings. Each institution may exhibit unique traits in terms of technology adoption, academic structure, and student engagement. Consequently, it remains uncertain whether these results can be generalized to a wider population.
2. **Narrow Course Context**: The case study centered on one particular course: "Online Data Collection & Management." While this provided useful insights into chatbot usage, the focus on a single academic context limits the applicability of the findings to other courses or disciplines. Different subjects, teaching methods, and student populations could lead to distinct patterns of chatbot interaction, preventing definitive claims about all learning environments.
3. **Incomplete Behavior Tracking**: The analysis only tracked the questions submitted through the official chatbot interface. Any student activities involving external platforms or additional AI tools were not captured, leading to a potentially incomplete view of their overall chatbot-related behaviors. This limitation may influence internal validity by overlooking alternative interactions.
4. **Small Participant Pool**: Both the case study and the survey involved a modest number of students. In the case study, just 46 students' chatbot interactions were recorded, and the survey also drew from a relatively limited group. Small sample sizes can reduce the reliability and statistical power of the results, making it harder to detect subtle usage patterns or general trends.

Taken together, these constraints highlight the need for caution when applying the study's conclusions to different settings and underscore the importance of expanding both the sample size and scope of future investigations.

6.4 Future research

Although this study highlights how generative AI chatbots and asynchronous learning can interact to influence educational outcomes, several opportunities exist for further exploration.

First, future investigations could use larger and more diverse populations. While this research primarily focused on a single course at one institution, replicating the study across different universities and student demographics could provide a more comprehensive picture of how cultural and contextual differences shape chatbot use. Such expanded efforts could refine our understanding of the ways asynchronous learning and AI-based tools converge in various learning environments.

Second, additional studies might delve more deeply into discipline-specific variations. Different academic fields—such as the humanities, sciences, or professional programs—can involve distinct learning methods and assessment strategies, potentially affecting how students use chatbots. A multi-course or multi-disciplinary analysis would help clarify whether the patterns observed in this study hold true for a wider array of subjects.

Third, a promising area for future research involves longitudinal methods. Monitoring changes in student behaviors, attitudes, and performance over several semesters can reveal whether reliance on chatbots grows or diminishes over time, and how repeated or continuous use influences the development of independent problem-solving skills. A longitudinal perspective might also uncover subtle shifts in how learners balance quick AI support with deeper, critical thinking activities.

Finally, further studies could focus on ethical frameworks and trust mechanisms. Survey results and interview feedback indicated that students are concerned about data privacy and the reliability of chatbot-generated answers. Examining how to establish transparent AI oversight, align ethical guidelines, and promote responsible usage would be valuable for educational institutions seeking to expand chatbot implementation. By addressing these challenges, researchers and practitioners can enhance the trustworthiness and pedagogical value of generative AI in asynchronous learning.

7 Conclusion

This study set out to explore whether generative AI (GAI) chatbots can complement asynchronous learning, and how students perceive their effectiveness in supporting learning. Drawing on a combination of case study data, survey responses, and a semi-structured interview, the research highlights both the potential benefits and the key concerns surrounding the incorporation of GAI chatbots into higher education.

One of the central findings is that GAI chatbots can indeed address several of the shortcomings inherent to asynchronous learning. Because students are not bound by strict schedules or real-time interaction, they often face delays in getting feedback and can experience a sense of isolation. Chatbot usage patterns observed in the case study show that students intensively utilize the tool when approaching deadlines or in the evenings when human support is often unavailable. The availability of immediate, on-demand answers can alleviate feelings of being "left on one's own," bolstering learners' motivation and maintaining study continuity. Survey results similarly indicate that many students perceive chatbots as beneficial for staying productive, clarifying complex concepts, and offering quick guidance on assignments.

At the same time, the study points to areas where reliance on GAI chatbots could undermine essential elements of the learning process. While personalization and instant feedback appear to enhance perceived effectiveness—especially by reducing wait times for clarifications—there remains a risk that students may lean too heavily on AI-generated solutions. Overusing the chatbot could curtail the development of independent problem-solving and critical thinking skills, which are vital for long-term academic growth. Additionally, concerns about academic integrity emerged from both the survey and the interview, reflecting the tension between leveraging AI as a supportive resource versus employing it as a shortcut around intellectual engagement.

A further challenge pertains to the reliability and depth of chatbot responses. Although GAI systems can provide coherent and rapid answers, they occasionally generate inaccuracies or oversimplifications. Students who do not cross-check chatbot-generated information with other sources may inadvertently adopt erroneous interpretations of course material. This skepticism surfaced in the survey findings, where trust in chatbot accuracy was notably lower

than overall satisfaction with its convenience. The interviewee likewise emphasized the importance of verifying the chatbot's outputs, especially for complex or context-specific tasks.

Despite these reservations, the data suggests that GAI chatbots can play a beneficial moderating role in asynchronous education, particularly by mitigating feelings of isolation and by expediting routine academic tasks (such as summarizing resources or clarifying straightforward questions). When used judiciously, chatbots may free up instructors' time for more intricate discussions and personalized follow-up—reinforcing, rather than replacing, human interaction.

For educational institutions integrating GAI chatbots, balance is crucial. Clear guidelines on appropriate chatbot usage can help students benefit from the tool without overly compromising the cultivation of higher-order thinking. Institutions may also consider instituting accuracy checks or limiting chatbot functionality for certain graded assignments. Encouraging students to cross-verify AI-generated information with course readings or human feedback can promote a healthier interplay between automation and human-led learning. Although the findings shed light on how students use chatbots in an asynchronous environment, the sample size—particularly in the survey—could be expanded to strengthen generalizability. Future studies might explore how GAI chatbots perform in different academic disciplines, levels of study (e.g., undergraduate vs. postgraduate), and more diverse cultural contexts. Furthermore, controlled experiments comparing student performance and engagement in courses that use GAI chatbots to those that do not could offer deeper insights into the direct impact of AI tools on learning outcomes.

In conclusion, the study demonstrates that GAI chatbots hold promise as a complementary support mechanism in asynchronous learning settings by providing immediate assistance, enhancing motivation, and improving study efficiency. Yet, the technology also raises important considerations about critical thinking, academic integrity, and the accuracy of AI-generated responses. By striking an informed balance, educators and students alike can harness chatbots' benefits while safeguarding the deeper, more reflective elements of the learning process.

8 References

Anderson, T. (2008). *The theory and practice of online learning*. Athabasca University Press.

Bandura, A. (1977). *Social learning theory*. Prentice Hall.

Bannister, P., Santamaría-Urbieta, A., & Alcalde-Peñalver, E. (2023). *A Systematic Review of Generative AI and* (English Medium Instruction) Higher Education. *Aula Abierta*.

Bernard, R. M., et al. (2014). *How does distance education compare with classroom instruction? Review of Educational Research, 74*(3), 379-439.

Biggs, J., Tang, C., & Kennedy, G. (2022). *Teaching for quality learning at university 5e.* McGraw-Hill Education (UK).

Black, P., & Wiliam, D. (1998*). Assessment and classroom learning. Assessment in Education*, 5(1), 7-74.

Bligh, D. A. (2000). *What's the use of lectures?: First U.S. edition of the classic work on lecturing.* ISBN: 978-0-787-95162-7.

Bloom, B. S. (1956). *Taxonomy of educational objectives: The classification of educational goals*. Longmans.

Bozkurt, A., & Sharma, R. C. (2021). *Education in normal, new normal, and next normal: Observations from the past, insights from the present and projections for the future*. Asian Journal of Distance Education, 16(1), 1-10.

Boud, D., & Falchikov, N. (Eds.). (2007). *Rethinking assessment in higher education: Learning for the longer term.* Routledge/Taylor & Francis Group.

Bolliger, D. U., & Inan, F. A. (2012). *Development and validation of the online student connectedness survey*. The International Review of Research in Open and Distributed Learning, 13(3), 41-65.

Broadbent, J., & Poon, W. L. (2015). *Self-regulated learning strategies & academic achievement in online higher education learning environments: A systematic review*. The Internet and Higher Education, 27, 1-13.

Brown, P. C., Roediger, H. L., & McDaniel, M. A. (2014). *Make it stick: The science of successful learning*. Harvard University Press.

Brown, Tom & Mann, Benjamin & Ryder, Nick & Subbiah, Melanie & Kaplan, Jared & Dhariwal, Prafulla & Neelakantan, Arvind & Shyam, Pranav & Sastry, Girish & Askell, Amanda & Agarwal, Sandhini & Herbert-Voss, Ariel & Krueger, Gretchen & Henighan, Tom & Child, Rewon & Ramesh, Aditya & Ziegler, Daniel & Wu, Jeffrey & Winter, Clemens & Amodei, Dario. (2020). *Language Models are Few-Shot Learners*. 10.48550/arXiv.2005.14165.

Burgstahler, S. (2015). *Universal design in higher education: From principles to practice*. Harvard Education Press.

Candy, P. C. (2004). *Self-direction for lifelong learning: A comprehensive guide to theory and practice*. Jossey-Bass.

Cepeda, N. J., Pashler, H., Vul, E., Wixted, J. T., & Rohrer, D. (2006). *Distributed practice in verbal recall tasks: A review and quantitative synthesis.* Psychological Bulletin*, 132*(3), 354–370. https://doi.org/10.1037/0033-2909.132.3.354.

Chen, C. M., Huang, S. H., & Chang, W. C. (2020). *Personalized e-learning system with self-regulated learning assisted mechanisms for promoting learning performance*. Expert Systems with Applications, 120, 37-48.

Chukwuere, J. E. (2024). *The future of generative AI chatbots in higher education*. arXiv preprint arXiv:2403.13487. https://arxiv.org/abs/2403.13487

Creely, E., & Blannin, J. (2023). *Exploring Teacher and Student Perceptions of Artificial Intelligence in Education: A Case Study*. Journal of Educational Technology.

Currie, G. M. (2023). *Academic integrity and artificial intelligence: Is ChatGPT hype, hero or heresy?* Seminars in Nuclear Medicine, 53*(5),* 719–730. https://doi.org/10.1053/j.semnuclmed.2023.04.008.

Dabbagh, N., & Kitsantas, A. (2012*). Personal learning environments, social media, and self-regulated learning: A natural formula for connecting formal and informal learning.* The Internet and Higher Education, 15(1), 3-8.

Davenport, T. H., & Prusak, L. (1998). *Working Knowledge: How Organizations Manage What They Know.* Harvard Business School Press.

Deci, E. L., & Ryan, R. M. (1985). *Intrinsic motivation and self-determination in human behavior.* Springer.

Dennen, V. P. (2008). *Cognitive apprenticeship in educational practice: Research on scaffolding, modeling, mentoring, and coaching as instructional strategies.* Handbook of research on educational communications and technology, 3, 813-828.

Van Deursen, A. J. A. M., & Van Dijk, J. A. G. M. (2014). *The digital divide shifts to differences in usage.* New Media & Society, 16(3), 507-526.

van Deursen, A. J. A. M., & Helsper, E. J. (2018). *The digital divide: Evaluating differences in digital skills among diverse populations*. New Media & Society, 20(9), 3289-3309.

Ellis, R. A. (2013). *Quality experiences in blended learning: Domains of quality and pedagogical design.* Computers & Education, 66, 1-3.

Farrelly, T., & Baker, N. (2023). *Generative Artificial Intelligence: Implications and Considerations for Higher Education Practice.* Education Sciences.

Fleming, N. D., & Baume, D. (2006). *Learning styles again: VARKing up the right tree!* Educational Developments, 7(4), 4-7.

Garrison, D. R. (2017). *E-learning in the 21st century: A framework for research and practice.* Routledge.

Garrison, D. R., Anderson, T., & Archer, W. (2000). *Critical inquiry in a text-based environment: Computer conferencing in higher education.* The Internet and Higher Education, 2(2-3), 87-105.

Gibbs, G. (1992). *Improving the quality of student learning*. Technical and Educational Services.

Gikandi, J. W. (2019). *Promoting effective e-learning practices through digital formative assessment.* International Journal of Educational Technology in Higher Education, 16(1), 1-19.

Gikandi, J. W., Morrow, D., & Davis, N. E. (2011). *Online formative assessment in higher education: A review of the literature.* Computers & Education, 57(4), 2333-2351.

Gomes, A. A., Tavares, J., & de Azevedo, M. H. P. (2011). *Sleep and academic performance in undergraduates: A multi-measure, multi-predictor approach.* Chronobiology International, *28*(9), 786–801.

Goodfellow, I., Pouget-Abadie, J., Mirza, M., Xu, B., Warde-Farley, D., Ozair, S., ... & Bengio, Y. (2014). *Generative adversarial networks.* Communications of the ACM, 63*(*11), 139–144.

Graham, C. R. (2006). *Blended learning systems: Definition, current trends, and future directions.* The handbook of blended learning: Global perspectives, local designs, 3-21.

Hartwig, M. K., & Dunlosky, J. (2012). Study strategies of college students: Are self-testing and scheduling related to achievement? *Psychonomic Bulletin & Review, 19*(1), 126–134. https://doi.org/10.3758/s13423-011-0181-y.

Hill, R. (2023). AI as Fad or AI as Lasting? Priorities for College Faculty Instructional Development for Generative Artificial Intelligence. *Irish Journal of Technology Enhanced Learning.*

Holmes, W., Bialik, M., & Fadel, C. (2022). *Artificial intelligence in education: Promises and implications for teaching and learning*. Routledge.

Hrastinski, S. (2008). *Asynchronous and synchronous e-learning.* Educause Quarterly, 31(4), 51-55.

Hrastinski, S. (2019). *What do we mean by blended learning?* TechTrends, 63(5), 564-569.

Intercom. (2023). *AI-powered customer service: The rise of Fin.* The Times UK. Retrieved from https://www.thetimes.co.uk/article/intercom-supremos-are-right-in-the-eye-of-the-ai-storm-hhzwc8jgf

Jiayu, Y. (2023). *Challenges and Opportunities of Generative Artificial Intelligence in Higher Education Student Educational Management.* Advances in Educational Technology and Psychology.

Jurafsky, Daniel & Martin, James. (2008). *Speech and Language Processing: An Introduction to Natural Language Processing, Computational Linguistics, and Speech Recognition.*

Kadaruddin, K. (2023). *Empowering Education through Generative AI: Innovative Instructional Strategies for Tomorrow's Learners.* International Journal of Business, Law, and Education.

Laurillard, D. (2012). *Teaching as a Design Science: Building Pedagogical Patterns for Learning and Technology.* Routledge. https://doi.org/10.4324/9780203125083.

LeCun, Y., Bengio, Y., & Hinton, G. (2015). *Deep learning.* Nature, 521(7553), 436-444.

Luckin, R., Holmes, W., Griffiths, M., & Forcier, L. B. (2016). *Intelligence unleashed: An argument for AI in education.* Pearson.

Luckin, R., Holmes, W., Griffiths, M., & Forcier, L. B. (2018). *Artificial intelligence and human learning: Reimagining education for the future.* UCL Press.

Martin, F., Sun, T., & Westine, C. D. (2020). *A systematic review of research on online teaching and learning from 2009 to 2018.* Computers & Education, 159, 104009.

Mayer, R. E. (2009). *Multimedia learning (2nd ed.)*. Cambridge University Press.

Means, B., Bakia, M., & Murphy, R. (2021). *Learning online: What research tells us about whether, when and how.* Routledge.

Means, B., Toyama, Y., Murphy, R., Bakia, M., & Jones, K. (2013). *The effectiveness of online and blended learning: A meta-analysis of the empirical literature.* Teachers College Record, 115(3), 1-47.

Michel-Villarreal, R., Vilalta-Perdomo, E., Salinas-Navarro, D. E., Thierry-Aguilera, R., & Gerardou, F. S. (2023). *Challenges and Opportunities of Generative AI for Higher Education as Explained by ChatGPT.* Education Sciences, 13(9), 856. https://doi.org/10.3390/educsci13090856.

Moore, M. G. (2013). *Handbook of distance education (3rd ed.)*. Routledge.

Nicol, D. J., & Macfarlane-Dick, D. (2006). *Formative assessment and self-regulated learning: A model and seven principles of good feedback practice.* Studies in Higher Education, 31(2), 199-218.

Radford, A., Wu, J., Child, R., Luan, D., Amodei, D., Sutskever, I., & et al. (2019). *Language models are unsupervised multitask learners*. OpenAI. https://cdn.openai.com/better-language-models/language_models_are_unsupervised_multitask_learners.pdf

Ramesh, Aditya & Pavlov, Mikhail & Goh, Gabriel & Gray, Scott & Voss, Chelsea & Radford, Alec & Chen, Mark & Sutskever, Ilya. (2021). *Zero-Shot Text-to-Image Generation*. 10.48550/arXiv.2102.12092.

Richardson, J. C., Maeda, Y., & Swan, K. (2017). *Social presence in online learning: A meta-analysis of research.* Educational Research Review, 22, 22-39.

Schmid, L., Gläser-Zikuda, M., & Randler, C. (2021). *The role of teachers in fostering student engagement in online learning environments.* Learning and Instruction, 71, 101351.

Selwyn, N. (2016). *Digital division or digital decision? A study of non-users and low-users of computers.* Educational Studies, 42(1), 1-20.

Selwyn, N. (2020). *Should robots replace teachers? AI and the future of education*. Polity Press.

Seo, E. H. (2012). *Cramming, active procrastination, and academic achievement.* Social Behavior and Personality: An International Journal, 40*(8), 1333–1340.*

Shanto, S. S., Ahmed, Z., & Jony, A. I. (2023). *PAIGE: A generative AI-based framework for promoting assignment integrity in higher education.* STEM Education.

Shum, H.-Y., He, X., & Li, D. (2018). *From Eliza to XiaoIce: Challenges and opportunities with social chatbots.* Frontiers of Information Technology & Electronic Engineering, 19(1), 10–26. https://doi.org/10.1631/FITEE.1700826.

Siemens, G. (2014). Connectivism: *A learning theory for the digital age.* International Journal of Instructional Technology and Distance Learning, 2(1), 3-10.

Singh, V., & Thurman, A. (2019). *How asynchronous learning supports students in higher education*. Educational Technology Research and Development, 67(3), 587-611.

Steel, P. (2007). *The nature of procrastination: A meta-analytic and theoretical review of quintessential self-regulatory failure.* Psychological Bulletin, 133(1), 65–94.

Swan, K., Garrison, D. R., & Richardson, J. C. (2009). *A constructivist approach to online learning: The Community of Inquiry framework.* The Internet and Higher Education, 12(3-4), 99-105.

Sweller, J. (1988). *Cognitive Load During Problem Solving: Effects on Learning.* Cogn. Sci., 12, 257-285.

Tavakol, M., & Dennick, R. (2011). *Making sense of Cronbach's alpha.* International Journal of Medical Education, 2*,* 53–55. https://doi.org/10.5116/ijme.4dfb.8dfd.

The Times. (2023). *The AI revolution in customer service: How chatbots are transforming business interactions.* The Times UK.

Tinto, V. (2012). *Completing college: Rethinking institutional action*. University of Chicago Press.

Topol, E. J. (2019). *High-performance medicine: The convergence of human and artificial intelligence.* Nature Medicine, 25(1), 44–56. https://doi.org/10.1038/s41591-018-0300-7.

Vaswani, Ashish & Shazeer, Noam & Parmar, Niki & Uszkoreit, Jakob & Jones, Llion & Gomez, Aidan & Kaiser, Lukasz & Polosukhin, Illia. (2017). *Attention Is All You Need*. 10.48550/arXiv.1706.03762.

Walczak, K., & Cellary, W. (2023). *Challenges for higher education in the era of widespread access to Generative AI.* Economics and Business Review.

Wang, Q., Decker, A., & Zhang, X. (2023). *Evaluating the reliability of AI-generated educational content.* AI & Society, 38(1), 15-30.

Wang, T., Lund, B. D., Marengo, A., Pagano, A., Mannuru, N. R., Teel, Z. A., & Pange, J. (2023). *Exploring the potential impact of artificial intelligence (AI) on international students in higher education: Generative AI, chatbots, analytics, and international student success.* Applied Sciences, 13(11), 6716. https://doi.org/10.3390/app13116716.

Woolf, B. P. (2009). *Building intelligent interactive tutors: Student-centered strategies for revolutionizing e-learning.* Morgan Kaufmann. https://doi.org/10.1016/B978-0-12-373594-2.X0001-9.

Zawacki-Richter, O., Marín, V. I., Bond, M., & Gouverneur, F. (2019). *Systematic review of research on artificial intelligence applications in higher,education.* International Journal of Educational Technology in Higher Education, 16(1), 39.

Zimmerman, B. J. (1990). *Self-Regulated Learning and Academic Achievement: An Overview.* Educational Psychologist, 25(1), 3–17. https://doi.org/10.1207/s15326985ep2501_2.

Zimmerman, B. J. (2002). *Becoming a self-regulated learner: An overview.* Theory into Practice, 41(2), 64-70.

9 Appendix

9.1 Data Analysis Python Code

9.1.1 categorizing user prompts

```python
import pandas as pd

# Load the dataset
# Replace 'your_file_path.csv' with the path to your CSV file
data = pd.read_csv("C:/Users/Beheer/OneDrive/Tilburg uni/Thesis/Main Data/sorted_messages.csv")

# Filter for user messages
user_messages = data[data['Sender'] == 'User']

# Define a function to categorize messages
def categorize_message(message):
    message = str(message).lower()  # Ensure message is a string and lowercase
    if any(keyword in message for keyword in ['code', 'python', 'sql', 'error', 'scrape', 'selenium', 'debug', 'terminal']):
        return 'Technical Support'
    elif any(keyword in message for keyword in ['grade', 'pass', 'course', 'assignment', 'project']):
        return 'Course Material'
    elif any(keyword in message for keyword in ['deadline', 'teacher', 'admin', 'submit']):
        return 'Administrative Questions'
    else:
        return 'General Clarifications'

# Apply categorization to the user messages
user_messages['Category'] = user_messages['MessageContent'].apply(categorize_message)

# Summarize the categorization results
category_summary = user_messages['Category'].value_counts()

# Display categorized data
print("Category Summary:\n", category_summary)
print("\nSample Categorized Messages:\n", user_messages.head())

# save the categorized messages to a new CSV file
output_path = 'categorized_user_messages.csv'
user_messages.to_csv(output_path, index=False)
print(f"\nCategorized messages saved to {output_path}")
```

9.1.2 prompts per week

```
import pandas as pd
import matplotlib.pyplot as plt

# Load your dataset
data = pd.read_csv("C:/Users/Beheer/OneDrive/Tilburg uni/Thesis/Data/sorted_messages.csv")

# Ensure the Timestamp column is in datetime format
data['Timestamp'] = pd.to_datetime(data['Timestamp'])

# Extract the week of the year
data['Week'] = data['Timestamp'].dt.isocalendar().week

# Group messages by week
weekly_trends = data.groupby('Week').size()

# Plot the weekly trends
plt.figure(figsize=(12, 6))
weekly_trends.plot(kind='line', marker='o', color='blue', linewidth=2)
plt.title('Messages by Week of the Year')
plt.xlabel('Week Number')
plt.ylabel('Number of Messages')
plt.xticks(rotation=0)
plt.grid(axis='y', linestyle='--', alpha=0.7)
plt.tight_layout()
plt.show()
```

9.1.3 Prompts per hour of day

```
import pandas as pd
import matplotlib.pyplot as plt

# Load your dataset
data = pd.read_csv("C:/Users/Beheer/OneDrive/Tilburg uni/Thesis/Data/sorted_messages.csv")

# Ensure the Timestamp column is in datetime format
data['Timestamp'] = pd.to_datetime(data['Timestamp'])

# Extract hour of the day
data['Hour'] = data['Timestamp'].dt.hour

# Group messages by hour of the day
hourly_trends = data.groupby('Hour').size()

# Plot the hourly trends
plt.figure(figsize=(10, 6))
hourly_trends.plot(kind='bar', color='skyblue', edgecolor='black')
plt.title('Messages by Hour of the Day')
plt.xlabel('Hour of the Day')
plt.ylabel('Number of Messages')
plt.xticks(rotation=0)
plt.tight_layout()
plt.show()
```

9.1.4 Prompts per day & heatmap

```python
import pandas as pd
import matplotlib.pyplot as plt


# Laad de data in
messages_data = pd.read_csv("C:/Users/Beheer/OneDrive/Tilburg uni/Thesis/Data/sorted_messages.csv")

# Controleer of de nodige kolommen aanwezig zijn
required_columns = ['Sender', 'MessageContent', 'Timestamp']
if not all(col in messages_data.columns for col in required_columns):
    raise ValueError(f"De dataset moet de volgende kolommen bevatten: {', '.join(required_columns)}")

# Filter de data: alleen berichten van 'User'
user_messages = messages_data[messages_data['Sender'] == 'User']

# Zorg dat de Timestamp kolom in datetime formaat staat
user_messages['Timestamp'] = pd.to_datetime(user_messages['Timestamp'])

# Voeg een kolom toe voor de dag van de week
user_messages['DayOfWeek'] = user_messages['Timestamp'].dt.day_name()

# Tel het aantal berichten per dag van de week
day_counts = user_messages['DayOfWeek'].value_counts().reindex(
    ['Monday', 'Tuesday', 'Wednesday', 'Thursday', 'Friday', 'Saturday', 'Sunday']
)

# Plot een staafdiagram
plt.figure(figsize=(10, 6))
day_counts.plot(kind='bar', color='skyblue', edgecolor='black')
plt.title('Number of Questions Asked per Day of the Week', fontsize=16)
plt.xlabel('Day of the Week', fontsize=14)
plt.ylabel('Number of Questions', fontsize=14)
plt.xticks(rotation=45, fontsize=12)
plt.grid(axis='y', linestyle='--', alpha=0.7)
plt.tight_layout()
plt.show()

# Tel het aantal vragen per specifieke dag
user_messages['Date'] = user_messages['Timestamp'].dt.date
daily_counts = user_messages.groupby(['DayOfWeek', 'Date']).size().unstack(fill_value=0)

# Plot een heatmap per dag van de week
plt.figure(figsize=(15, 8))
plt.imshow(daily_counts, aspect='auto', cmap='Blues', interpolation='nearest')
plt.colorbar(label='Number of Questions')
plt.title('Daily Questions Grouped by Day of the Week', fontsize=16)
plt.xlabel('Dates', fontsize=14)
plt.ylabel('Day of the Week', fontsize=14)
plt.xticks(range(len(daily_counts.columns)), daily_counts.columns, rotation=90, fontsize=10)
plt.yticks(range(len(daily_counts.index)), daily_counts.index, fontsize=12)
plt.tight_layout()
plt.show()
```

9.1.5 Number of questions asked per week

```
import pandas as pd
import matplotlib.pyplot as plt
import os

# Definieer het correcte pad naar het bestand
messages_data = pd.read_csv("C:/Users/Beheer/OneDrive/Tilburg uni/Thesis/Final/Chatbot_logs.csv")

# Controleer of het bestand bestaat
if not os.path.exists(file_path):
    raise FileNotFoundError(f"Bestand niet gevonden: {file_path}")

# Laad de data in
messages_data = pd.read_csv(file_path)

# Controleer of de nodige kolommen aanwezig zijn
required_columns = ['Sender', 'MessageContent', 'Timestamp']
if not all(col in messages_data.columns for col in required_columns):
    raise ValueError(f"De dataset moet de volgende kolommen bevatten: {', '.join(required_columns)}")

# Filter de data: alleen berichten van 'User'
user_messages = messages_data[messages_data['Sender'] == 'User']

# Zorg dat de Timestamp kolom in datetime formaat staat
user_messages['Timestamp'] = pd.to_datetime(user_messages['Timestamp'], errors='coerce')

# Verwijder rijen met niet-converteerbare tijdstempels
user_messages = user_messages.dropna(subset=['Timestamp'])

# Voeg een kolom toe voor de week
user_messages['Week'] = user_messages['Timestamp'].dt.isocalendar().week

# Tel het aantal berichten per week
weekly_counts = user_messages['Week'].value_counts().sort_index()

# Plot een staafdiagram
plt.figure(figsize=(10, 6))
weekly_counts.plot(kind='bar', color='skyblue', edgecolor='black')
plt.title('Number of Questions Asked per Week', fontsize=16)
plt.xlabel('Week Number', fontsize=14)
plt.ylabel('Number of Questions', fontsize=14)
plt.xticks(rotation=45, fontsize=10)
plt.grid(axis='y', linestyle='--', alpha=0.7)
plt.tight_layout()
plt.show()
```

9.2 List of interview questions

Do you think that having an AI chatbot available at any time make you feel more connected or supported during your studies? And why so?

In what ways, if any, do the chatbot's continuous availability influence your motivation or feelings of isolation in an asynchronous setting?

Do you feel rapid feedback helped clarify a concept more effectively than waiting for a tutor or professor's response? And why so?

In your experience, how does receiving quick, tailored feedback from a chatbot compare to traditional methods in terms of improving your understanding of the material?

Have you ever felt you depended too heavily on the chatbot's responses rather than working through problems on your own? What effect do you feel it has on learning?

Do you feel that the convenience of chatbot help with developing your own critical thinking and problem-solving skills? Why so?

Do you trust the information, which is given by a generative AI chatbot, specifically in an educational context? Explain yourself.

What level of accuracy do you expect from an AI chatbot before considering it a useful and trustworthy tool for your coursework?

How has having access to an AI chatbot changed the way you plan your study sessions or approach deadlines?

Can you describe a scenario where the chatbot specifically helped you optimize your time when preparing for an exam or submitting an assignment?

How do you think using generative AI chatbots influences the development and practice of critical thinking skills among students?

Would you say generative AI chatbots make your study experience more engaging or less engaging, and what factors contribute to that perception?