How Students (Really) Use ChatGPT: Uncovering Experiences Among Undergraduate Students

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The widespread adoption of chatbots and large language models has significantly impacted various aspects of daily life. This study employs mixed methods to analyze ChatGPT logs from 36 undergraduate students, providing a comprehensive examination of how this technology is integrated into academic contexts. ChatGPT had diverse applications with the most prevalent uses centering on essay writing assistance. We identify more dynamic scenarios, such as students utilizing ChatGPT to generate and learn computer code across multiple programming languages. The study explores the evolving parasocial relationship between students and ChatGPT, particularly focusing on conversational repair processes and how these interactions change over time. Building upon previous research in human-chatbot interactions, we offer insights into the nuanced ways students engage with AI-powered language models. These findings inform a set of design recommendations aimed at enhancing future chatbot interactions and contributing to the ongoing discourse on the role of AI in education and beyond.

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1 Introduction

The rapid proliferation of large language models (LLMs) and chatbots, exemplified by ChatGPT, has fundamentally altered the landscape of information access and task assistance across various domains, including education. As these AI-powered tools become increasingly integrated into academic environments, there is a pressing need to understand how students interact with and utilize these technologies in their daily academic pursuits, prompting discussions on whether we should and how we may integrate LLM-driven chatbots more deeply into educational settings [98]. OpenAI's announcement of ChatGPT Edu on May 30, 2024, a version of ChatGPT claimed to be built for universities to responsibly deploy AI following initial partnerships with several US universities [74], has sparked more cautious optimism and worries on this issue [13].

Despite the growing body of research on AI in education, there remains a significant gap in our understanding of the nuanced, real-world applications of ChatGPT by students for learning, particularly in higher education settings. This lack of comprehensive insight poses several challenges for educators, policymakers, and technologists alike []. While potential benefits of AI-assisted learning are evident [], concerns about academic integrity, the development of critical thinking skills, and the long-term impacts on learning outcomes persist. Moreover, the dynamic nature of student-AI interactions, which can range from simple query-response exchanges to complex, multi-turn conversations, adds layers of complexity to this issue.

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Traditional approaches to studying technology use in education often focused on self-reported data or controlled experiments, or qualitative interviews, which may not capture the full spectrum of spontaneous, authentic interactions that occur between students and AI tools like ChatGPT. Additionally, previous research in this area has primarily focused on isolated aspects of AI use in education, such as its impact on specific subjects or its role in cheating prevention. However, these studies often fail to provide a holistic view of how students integrate AI tools into their broader academic strategies and workflows. Additionally, the rapid evolution of LLMs means that findings from even a few years ago may not fully reflect the current capabilities and uses of these systems.

Self-Directed Learning (SDL) offers a useful lens for exploring these interactions [49]. SDL emphasizes learners' ability to take initiative, set goals, and independently manage their learning processes [91][49]. In this age of increasingly online, informal, open, and distance forms of learning and expanded notions of learning, environments, SDL has become a critical competency for learner success [68]. ChatGPT, with its capacity to provide instant information and adapt to diverse queries, has the potential to become a significant enabler of SDL in higher education.

Our study addresses these gaps by employing a mixed-methods approach to analyze complete ChatGPT usage logs from 36 undergraduate students. By examining authentic, unfiltered interactions, we offer a comprehensive view of how students engage with ChatGPT for learning, from brief queries to extended dialogues. This study frames ChatGPT as an emerging online context for SDL, investigating how students integrate it into their learning practices in real-world, non-classroom settings. It contributes to the broader discourse on the transformation of SDL in the age of generative AI, examining the sociotechnical factors shaping these interactions and offering design recommendations for effectively integrating ChatGPT into self-directed learning beyond traditional boundaries.

2 Related Work

Building on the foundation of Self-Directed Learning (SDL) theory, we review how students are integrating ChatGPT into their daily learning in higher education. Lastly, we explore insights from existing research on human-chatbot interaction to deepen our understanding of how undergraduate students incorporate ChatGPT into their daily learning practices.

2.1 Self-Directed Learning in the Evolving Technological Landscape

Self-directed learning (SDL) is a process in which individuals take the initiative and responsibility for their own learning, including identifying their learning needs, formulating goals, finding resources, selecting appropriate learning strategies, and evaluating outcomes [44]. SDL occurs across various environments, including formal settings such as classrooms [56], and informal contexts such as at home [95], workplaces [47, 48], or through digital platforms like YouTube [97], Facebook [78], Duolingo [52], and MOOCs [72]. Advances in information and communication technologies (ICT) have expanded opportunities for SDL, enabling learners to move beyond formal curricula to pursue self-driven, flexible exploration [68]. The growing prevalence of online and informal learning has made SDL a critical competency for learner success [49]. Recent studies emphasize the effectiveness of SDL on platforms like YouTube, where learners access diverse resources and learn at their own pace [66, 97]. These studies also highlight how emerging technologies are reshaping SDL, transforming it from a solitary, linear process into an interactive and dynamic one [16].

2.1.1 Understanding Self-Directed Learning in the Age of Generative AI. The rise of large language models (LLMs) like ChatGPT is transforming learning by enabling personalized experiences that adapt to individual needs and styles

[51, 54]. This adaptability fosters dynamic, interactive engagement, marking a shift toward generative AI-enhanced SDL, where tools like ChatGPT become central to the learning process.

ChatGPT accelerates SDL by providing accessible, personalized learning experiences that transcend traditional educational boundaries. While rooted in established SDL principles, its integration introduces new opportunities and challenges, such as the risks of over-reliance and ethical concerns like privacy and data security [49].

2.1.2 The Conceptual Model for Understanding Self-Directed Learning in Emerging Online Environment . To better understand the mutual shaping of self-directed learning and emerging online context, Song and Hill [91]have proposed a comprehensive framework. Rather than isolating technology as a discrete dimension of online learning, their framework considers technology as an integral context that shapes the SDL process. Based on the models of Candy[11], Hiemstra[37], and Garrison[28], Song and Hill's model contains the following three components: 1)*personal attributes*; 2) *process*; 3) *learning context*. First, *personal attributes* refer to the moral, emotional, and intellectual management of a person. In online environment, the model highlights the personal attributes as *resource use*, *strategy use*, and *motivation*. Second, the *process* construct indicates learner autonomy over the learning process, which involves *planning*, *monitoring*, and *evaluating*. Third, the *learning context* refers to the environment where learning takes place. Under this components, Song and Hill emphasizes the *design elements*, which concern resources, structure, and nature of tasks, and *support elements*, which concern instructor feedback and peer collaboration. This third component, the learning context, was added as a new dimension to reflect the impact of environmental factors on SDL. At the same time, this model highlights the the complex and dynamic interaction between the various components and call for future studies to examine the envolving online learning context.

Li *et al.* [49] build on this evolving perspective of SDL generative AI context by expanding Song and Hill's [91] model of SDL. Their new framework introduces new indicators and subcategories, such as personal attributes (e.g., technology readiness, content area knowledge, prior learning experience, self-efficacy beliefs, attitudes, emotions, and perspectives), autonomous-adaptive processes (highlighting learners' adaptations throughout the process), and enriched learning contexts (incorporating social dimensions like ethical considerations, intellectual property, privacy, security, transparency, and socio-political-cultural influences). In their study of ChatGPT as a new online context for self-directed language learning, they employ YouTube video content analysis and interviews. However, as their research focuses solely on language learning, th authors call for future studies to include other learning areas and diverse types of data.

2.2 ChatGPT's Integration into Students' Learning in Higher Education

2.2.1 ChatGPT's integration into higher education for targeted applications. The application of LLMs in educational settings is a growing area of research, with several studies exploring their potential benefits and challenges [46, 57, 60]. ChatGPT, in particular, has emerged as a significant academic tool for students in higher education, raising important questions about the integration of AI in learning environments [98]. While existing research often prioritizes educators' perspectives in evaluating the potential and pitfalls of ChatGPT, there is a critical need to foreground students' experiences and viewpoints to gain a more comprehensive understanding [89, 92]

Recent studies have begun to explore the various ways students engage with ChatGPT. For instance, researchers have investigated how students use ChatGPT to develop specific academic skills, such as improving their English writing abilities [24, 35]and learning programming [43, 70, 103], highlighting these as common use cases among students. Broader investigations have also been conducted to understand the overall patterns of ChatGPT usage in academic

contexts. Von Garrel and Mayer [98] conducted a national survey of students in Germany, identifying twelve distinct academic uses of ChatGPT, including writing assistance, creative thinking, and debugging coursework-related issues.

Similarly, Jishnu et al. [41] surveyed students in higher education and found that content creation and information seeking are primary motivations for using ChatGPT. Their study also revealed discipline-specific variations, suggesting that students' preferences for using ChatGPT differ significantly across academic fields. Interestingly, Jishnu et al. [41] also noted that, beyond academic purposes, students utilize ChatGPT for personal development tasks such as planning and decision-making in daily life, pointing to new avenues for research on non-academic applications of ChatGPT among students.

ChatGPT has integrated into various aspects of education, with existing studies focusing on its applications in diverse academic disciplines. For instance, research highlights its use in domains such as coding, language acquisition, and academic writing, showing its ability to tailor learning experiences to specific subject areas [references needed]. However, the scope of its influence extends far beyond these individual domains and even beyond the purely academic domain, requiring a broader examination of its impact on the learning process as a whole.

Based on the above literature, research on how students in higher education use ChatGPT is still emerging, with most studies narrowly focusing on specific educational settings and academic applications. There is a pressing need to expand this understanding to include how students utilize ChatGPT in their daily lives, beyond academic tasks, to encompass personal development and other non-academic uses.

Methodologically, most existing studies on students' use of ChatGPT rely on self-reported surveys [1, 89, 92, 98], which are useful for gathering large-scale data but have inherent limitations in accurately capturing true user behavior. While some studies have analyzed actual interactions between students and ChatGPT, these are often limited to specific contexts or short time frames, such as a single course duration [35, 43]. The absence of detailed, longitudinal data on students' interactions with ChatGPT has restricted a deeper understanding of how these tools function within educational settings.

Furthermore, theoretical engagement within this research area has been limited. While Jishnu et al. [41] employed the Uses and Gratification Theory and Strzelecki [92] drew upon and developed aspects of the Technology Acceptance Theory, much of the existing work focuses on observable behaviors without delving into or extending theoretical frameworks that could inform broader implications, as highlighted by Følstad et al [26]. This gap suggests a need for more nuanced methodological approaches and theoretical explorations that can enrich our understanding of students' interactions with ChatGPT, addressing the broader implications of LLMs in educational and personal contexts.

2.2.2 Ethical and Responsible Use of AI for SDL in Higher Education. The reception of ChatGPT in educational contexts has been both enthusiastic and cautious, reflecting a mix of opportunities and challenges. Proponents argue that ChatGPT can support skill development, enhance personalized learning, and provide accessible educational resources, making it a valuable tool for both teaching and learning processes [87, 89]. Advocates highlight its potential to offer real-time feedback, assist with language learning, and enable learners to explore concepts in an interactive and adaptive manner, thereby promoting engagement and innovation in education [2].

However, critics have raised concerns regarding its integration into education, particularly around issues of academic integrity, bias, fairness, and students' over-reliance on AI tools [17]. For instance, the use of ChatGPT to generate assignments or solve problems without genuine student input poses risks to the development of critical thinking and problem-solving skills. Additionally, AI-generated content may inadvertently perpetuate biases present in training data, leading to potentially unfair or misleading outputs [6]. These challenges are further compounded in informal learning

environments where students' use of ChatGPT may lack adequate guidance and oversight, leaving them vulnerable to negative outcomes such as misinformation or misuse.

Questions surrounding data privacy, malicious use, and the potential for over-reliance on AI further highlight the need for cautious and ethical implementation. For example, students might rely on ChatGPT not only for academic work but also for decision-making without verifying the credibility of the information provided. Similarly, malicious use of ChatGPT could involve generating harmful or deceptive content, raising concerns about its impact on both individual learners and broader educational integrity [64]. These risks are particularly pronounced in informal settings where the absence of institutional safeguards can exacerbate misuse.

Given these concerns, the exploration of ChatGPT's role in self-directed learning outside the classroom is both urgent and necessary. Research into how students navigate and utilize ChatGPT autonomously can help identify strategies to maximize its potential while mitigating associated risks. This includes developing frameworks for responsible use, fostering digital literacy, and ensuring that AI tools are leveraged to complement, rather than replace, critical thinking and active learning processes [49, 85].

2.3 Understanding Human-Chatbot Interaction: Implications for Students' Self-Directed Learning with ChatGPT

Research in Human-Computer Interaction (HCI) has significantly contributed to our understanding of how users perceive, interact with, and respond to chatbots and AI-driven interfaces. As chatbots become more integrated into everyday life, these studies offer valuable insights into the dynamics of human-chatbot interaction, highlighting both opportunities and challenges associated with AI use.

Overview of human-chatbot interaction. Chatbots are at the forefront of this shift, transforming how humans engage with computers [9]. Defined as computer programs that communicate with users through natural language [88], chatbots have evolved considerably with the advent of advanced AI models like ChatGPT. ChatGPT, a large language model powered by the GPT (Generative Pre-trained Transformer) architecture, is specifically designed to generate coherent and contextually relevant text-based responses, simulating human-like interactions in a conversational setting [73].

The rise of ChatGPT has redefined the role of AI-driven chatbots, greatly enhancing the quality and frequency of interactions between users and AI. Examining how humans interact with chatbots provides insights into the dynamic influence between technology and its users, reflecting the broader mutual shaping between technology and society [8]. Moreover, chatbots pose significant ethical challenges, including concerns about privacy, data security, and the biases that may be embedded within AI algorithms [81]. By investigating human experiences and interactions with LLM-based chatbots, researchers can better identify ethical risks and contribute to the development of guidelines and regulations that ensure chatbots are integrated into daily life in a secure and beneficial manner.

Previous studies have explored human-chatbot interactions from multiple angles, often focusing on aspects such as user acceptance, trust, and user experience, which involve examining users' internal states and expectations. However, these areas of study are not fully accessible through the interaction data we have collected. Consequently, our focus shifts towards identifying the observable themes and patterns within human-chatbot conversations that have been highlighted in prior research, with a specific emphasis on student-chatbot interactions. This approach allows us to draw directly from the conversational data, offering a grounded understanding of how students engage with AI chatbots in educational and personal contexts.

User-Chatbot Interaction. Chatbots often fail to meet user expectations, resulting in dissatisfaction and skepticism [9, 40, 58, 104]. Failures can occur when chatbots provide incorrect answers, misunderstand user intent, or respond in ways that seem unnatural or irrelevant. These shortcomings can disrupt the user experience and diminish trust in the technology [58, 104]. From the user's perspective, Li et al. [50] found that users employ various coping strategies when faced with conversational issues, such as rephrasing their input, repeating keywords, or shifting to related topics. However, Zaroukian et al. [105] highlighted an automation bias, where users often accept incorrect chatbot responses due to the overall perceived accuracy of chatbots, which can undermine successful interactions. Users may also contribute to conversational breakdowns by using ambiguous language, making spelling or grammar errors, or engaging in non-sensical or offensive speech, all of which can impair chatbot performance [38, 75].

From the chatbot's perspective, Chaves and Gerosa [12] propose the concept of conversational and social intelligence to address these challenges. By enhancing these aspects, chatbots can better manage conversational issues and improve interactions with users, fostering more effective communication and reducing misunderstandings.

Emotions generated during human-chatbot interaction. Researchers emphasize the importance of examining the various emotions generated during human-chatbot interactions, as these emotions play a critical role in shaping the overall user experience. Negative emotions, such as frustration or confusion, are often the primary reasons users discontinue conversations, while positive emotions can help prevent communication breakdowns and enhance the effectiveness of chatbot interventions [94, 100]. Moreover, chatbots that display emotional cues, such as expressing empathy or adjusting their responses based on perceived user mood, can significantly increase users' willingness to continue interactions, making the chatbot appear more supportive and engaging [25, 55, 77] Additionally, some studies focus on chatbots' ability to regulate user emotions. Chatbots can influence users' emotional states over time by asking about their mood, offering behavioral and cognitive interventions, and recognizing stressful situations to suggest appropriate emotional regulation strategies [19, 32, 62, 63]. These capabilities not only enhance the user experience but also position chatbots as potential tools for emotional support, extending their utility beyond simple informational exchanges.

Parasocial relationships in human-chatbot interaction. Chatbots, through their use of natural language and conversational formats, simulate human-like interactions, often creating a parasocial dynamic where users develop one-sided emotional connections despite knowing the chatbot is not human [59, 99]. This phenomenon reflects how chatbots can mimic interpersonal communication, allowing users to engage with them as they would with another person.

Research has explored the anthropomorphism of chatbots, examining how their perceived humanness influences interactions. Factors contributing to this perception include linguistic attributes like grammar, plausibility, and language style [18, 102], as well as psychological and interactional qualities such as humor, interactivity, and perceived consciousness [7, 101]. Emotional characteristics like empathy and self-disclosure further enhance chatbots' human-like qualities, impacting user engagement and satisfaction. However, Crolic et al. [15] found that anthropomorphism can have mixed effects: it negatively impacts users who are angry, possibly due to unmet expectations of chatbot efficacy, while having neutral effects on users in a calmer state. Additionally, Monteayor, Halpern, and Fairweather discussed the current fundamental limits of simulated empathy from AI in the field of clinical medicine and care, questioning the application of AI in health care and mental support [67].

The absence of genuine empathy and emotional intelligence in chatbots can lead to user frustration, especially in contexts where emotional support is critical, such as during discussions of personal or academic stress (Fryer et al., 2019).

This highlights the limitations of chatbots in fully replicating the nuanced emotional dynamics of human-to-human interactions.

Chatbot use by students. AI-based chatbots to become increasingly prominent in educational environments, reshaping traditional learning paradigms [5, 39, 69, 79, 107]. By simulating human-like interactions, AI chatbots engage students in interactive learning experiences, providing dynamic and immediate responses that can significantly enhance the educational process [23, 36]. These chatbots offer real-time assistance, addressing student queries [20, 21, 45], supporting assignment completion and research efforts [27, 43, 103, 103, 107], and even extending mental health support to students in need [19].

While the advantages of integrating chatbots into educational settings are clear, these benefits come with inherent risks. Security concerns, such as data privacy and unauthorized access to sensitive information, pose significant challenges [39, 79]. Additionally, the potential for chatbots to disseminate misinformation due to their reliance on large-scale, unverified data sources raises questions about the reliability and accuracy of the information provided [93]. Furthermore, the lack of scientific rigor in some chatbot applications can undermine their educational value, necessitating a careful balance between leveraging AI for student support and maintaining standards of academic integrity.

Overall, our study diverges from prior research by focusing specifically on the detailed, long-term interactions between students and ChatGPT, analyzing both academic and personal use cases. Unlike many existing studies that rely on self-reported surveys or short-term observations, we employ a mixed-methods approach that includes direct analysis of interaction logs, providing a richer, more nuanced understanding of how students engage with chatbots over time. This approach allows us to explore the unique dynamics of student-chatbot relationships, including the emergence of parasocial interactions and the practical challenges students face, offering new insights into the role of chatbots in educational and personal contexts.

In our study, ChatGPT serves as the context of students' self-learning. This perspective allows us to examine the interactive relationships between students' and ChatGPT in the their daily use of ChatGPT for multiple purposes of learning. This examination involves investigating how ChatGPT's functionalities, such as conversational interaction, personalized feedback, and content generation, (not) support and (not) enhance their learning experience and how the interaction between students and ChatGPT together shape this process.

3 Dataset

Our dataset comprises chat histories from undergraduate students at a research university in the northeastern United States. We recruited participants through on-campus flyers and offered a $10 compensation for their participation. The data collection process occurred in two waves: an initial group of 12 users in October 2023, followed by an additional 24 users in January 2024, resulting in a total sample of 36 undergraduate students. Participants were instructed to export their complete chat history from chat.openai.com and upload the resulting zip file to our secure website. The donated data encompassed all historical conversations between the participants and ChatGPT. To ensure participant privacy and data security, we implemented a rigorous anonymization process. The final dataset is structured as follows: (1) User ID: (it's more like the documentation name, not identifiable online, non-related to students' real ID); (2) Title (like the conversation themes, automatically generated by ChatGPT); (3) Conversation ID (one conversation can have one to multiple user entries and ChatGPT's responses); (4) Create Time; (5) User Text; and (6) ChatGPT Text.

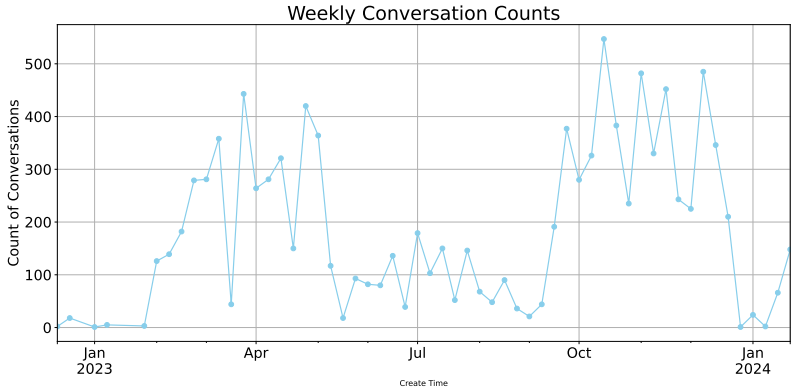

Fig. 1. Timeseries of the conversations in our dataset

Though the chat logs themselves do not explicitly contain links to personal information such as email addresses, the content of the conversations could potentially reveal aspects of a participant's identity. To mitigate this risk, we removed all identifiable user information during the data cleaning process. Furthermore, we did not collect any demographic information, and there is no way to connect a specific chat log to the individual who donated it, as all identifying links were removed or anonymized.

Some details of the data are shown in Table 1. Our dataset spans over a year of activity, with an average of 45 sessions per user (standard deviation 66). The average session duration was 13 minutes. Figure 1 shows the timeseries of conversations in our dataset. The dataset follows school patterns closely, with reduced activity during Spring break (March), summer and during holidays in December.

Table 1. Dataset details.

# Users	# Unique Chats	# Messages	Mean Session Duration	Period of coverage
36	1,631	10,536	13.2 minutes	Dec 2022 - Jan 2024

4 Methods

Our methods relied on topic modeling (using BERTopic) used for inductive analysis [96] of the topics identifying in all log data. The results of the twelve BERTopic analyses and the qualitative analysis of the BERTopic results revealed three primary categories: (1) different subjects or topics, such as social sciences and humanities, natural sciences, and formal sciences (e.g., computer science and mathematics); (2) varying scenarios and the nature of tasks, such as email generation and writing improvement; and (3) the interactive relationship between students and ChatGPT, including polite and collaborative interactions. BERTopic results mainly discover the learning areas, with limited discovery of the subcategories under nature of tasks and student-ChatGPT. Therefore, we did another round of inductive manual open-coding using Nvivo to identify more subcategories under the varying scenarios and nature of tasks, and student ChatGPT. Based on the codes drawn from qualitative coding together, we used classifier to further applied the codes to all data and also get verification from the classifier. Combing the three methods, we conducted a comprehensive and detailed analysis of the data.

4.1 Qualitative Analysis for BERTopic

Our final line of analysis applies BERTopic [33] to the user prompts to try to obtain the categories from the data automatically. This step serves both as a validation for our qualitative coding as well as provide automated analysis tools which can help extend our analysis beyond our dataset. We used the Bidirectional Encoder Representations from Transformers (BERT) for contextualized topic modeling. BERT embeddings model the semantic context [65] of words by mapping corpus terms in semantic space "in which distance represents semantic association." [3] We used the BERTopic package [33] to cluster BERT embeddings [82] using Hierarchical Density-Based Spatial Clustering of Applications with Noise (HDBSCAN) [10]. Similar documents in the corpus will be closer to each other. Each document will also be closer to words semantically closer to it.

To find the optimum number of topics for the BERTopic model, we trained 25 different models by changing minimum cluster size (an HDBSCAN hyperparameter) by increments of 10 at a time.[1] The first model's minimum cluster size was set to 15, and the last model was set to 255. The higher the minimum cluster size, the lower the number of clusters - and the lower the number of identified topics. To identify the top model, we calculated the coherence score of each model using the Gensim *CoherenceModel* feature.[2] Coherence values have been found to be good at approximating human ratings of a topic model "understandability" [83]. We selected the model with the top coherence score (0.39), with a minimum cluster size of 50, that produces a topic model with 88 topics.

After the topics were identified using BERTopic package, we qualitatively analyzed each of the topics. We randomly sampled 10 user text and 10 ChatGPT text under each topic for qualitative analysis. Two of our researchers read through all the samples under each topic, summarized the topic of the samples and wrote a description for each topic. Our two researchers made detailed notes, providing reasons for each topic name and highlighting topics that may not be substantive for our analysis. They met and compared their understanding of the samples under each BERTopic to determine if there were any major differences and disagreement. This process allowed us to organize the topics into twelve themes. Using the BERTopic library, we merged all topics within each theme.[3]

The twelve themes identified were: (1) Science, Technology and Management: engagements focused on questions about science, technology, and management. Most of these discussions are about schoolwork; (2) Coding: students are either asking for code generation or engaging in rewriting code, again mostly for school assignments; (3) Social Science and humanities: mostly about schoolwork (e.g., asking about historical events or social science theory); (4) Math: questions about mathematical and statistical concepts (e.g., p-value, kurtosis); (5) Computer Science: discussing computer science concepts (e.g., operating systems); (6) Internship: preparing for an internship by working on the CV and a design assignment for the job interview; (7) Music: asking about music concepts (e.g., pitch); (8) Synonym: finding synonyms for words; (9) email: asking ChatGPT for assistance in writing emails, especially important and formal emails; (10) Polite interactions: using words like thank you, sorry etc.; (11) Financial: asking about financial concepts and recommendations; and (12) Citation: producing citations for generated materials or searching for information sources.

4.2 Qualitative Coding

Since BERTopic results only show limited discovery of the subcategories under nature of tasks and student-ChatGPT, we began our analysis with a qualitative examination of the collected data. Using inductive coding, we analyzed both

[1] https://hdbscan.readthedocs.io/en/latest/parameter_selection.html?highlight=min_cluster_size#selecting-min-cluster-size
[2] https://radimrehurek.com/gensim/models/coherencemodel.html
[3] When"topics are merged, then a weighted average of topic embeddings is taken based on the initial topic sizes." Source: https://maartengr.github.io/BERTopic/api/bertopic.html#bertopic._bertopic.BERTopic

the user text and ChatGPT-generated responses. This process allowed us to condense raw data into categories and themes through valid inference and interpretation [108]. One of the authors conducted the coding using NVivo, a qualitative data analysis software.

Our units of analysis were individual themes in each student's historical conversations with ChatGPT [108]. While the data was formatted in tables, with conversations separated into student entries and ChatGPT responses, we didn't limit our analysis to these physical linguistic units. We recognized that a single code or theme could appear across different conversations, such as students' changing attitudes toward ChatGPT over time.

Our analysis, informed by grounded theory [30], consisted of two stages. The first stage, open coding, aimed to identify general categories related to students' various uses of ChatGPT and the interactions between students and the AI. The second stage, axial coding, involved comparing open codes and their relationships to organize the data into meaningful categories.

Given the extensive nature of our dataset, which included students' conversations with ChatGPT spanning over a year, a comprehensive qualitative coding of all log data was not feasible. We initiated our coding process with the complete historical data from the first twelve students recruited during the initial round of data collection. This involved hand-coding 1,882 user text and ChatGPT responses, providing a foundation for our codebook development.

To expand our analysis and achieve thematic saturation, we conducted two rounds of purposive sampling from the remaining 24 students' log data [34] [14]. In the first round, we randomly selected and coded 10 conversations from each student's historical data. This process led to the identification of a high-frequency category, prompting a second, more targeted sampling round. The second sampling round focused on conversation length and the frequency of title changes within one week. We selected up to 20 conversations per quartile based on these criteria, ensuring a representative sample of diverse interaction patterns. All sampled conversations were then coded using our established scheme. Notably, this second round did not yield any new emerging codes, suggesting approaching saturation.

To ensure we had indeed reached thematic saturation, we conducted a final review of the uncoded data [34]. This multi-stage approach allowed us to develop a comprehensive codebook while efficiently managing the large-scale dataset, providing a robust foundation for our subsequent analyses of student-ChatGPT interactions.

The coding process was iterative and collaborative. Two authors began by conducting two stages of coding on the complete historical data from the first twelve students. This initial coding resulted in a preliminary codebook that included different levels of codes, rationales for code names and relationships, example text from the original data, and additional notes. The coders provided detailed explanations for each code name and included illustrative examples. After this initial phase, the coders compared their codebooks to identify major differences and reach initial agreement. They then proceeded to code the data sampled in subsequent rounds, further refining the initial codebook. Regular meetings were held to discuss and resolve any disagreements, ultimately leading to a consolidated and final codebook. In line with current qualitative research practices, we prioritized reaching consensus between coders rather than calculating inter-rater reliability scores [61].

Our coding process ultimately yielded five primary categories that encapsulate the key aspects of student-ChatGPT interactions: Content Generation (GA), Information Seeking (IC), Language Use (LU), Student Interaction with ChatGPT (SC), and, ChatGPT's Response (CR). The first three categories – Content Generation, Information Seeking, and Language Use – provide insight into the primary ways students utilize ChatGPT in their daily academic activities. The last two categories – Student Interaction with ChatGPT and ChatGPT's Response – offer a more nuanced perspective on the dynamics of the student-AI relationship. Our complete categorization was on multiple levels (described in the Appendix),

where we expand on the sub-codes under the five main categories to illustrate how students use ChatGPT in their everyday lives and interact with it. We provide a short description of the top level categories below.

(1) **Information Seeking**: This category is centered on the retrieval of factual information, clarification of concepts, or answering specific questions. The primary goal here is knowledge acquisition and understanding. It makes up around 41% of the content we coded. Within this category, we have sub-codes that reflect students' everyday information needs [84] when student use ChatGPT for information seeking, such as academic content job application, medical issues, social and cultural issues, and so on.
(2) **Content Generation**: This category focuses on the creation of original or creative content, such as stories, essays, poems, scripts, code, or other written forms. It makes up around 30% of the messages we coded. In this context, students provide prompts, and ChatGPT generates new text based on these inputs, emphasizing creativity, originality, and stylistic elements. Within this category, we have identified several sub-codes representing content generation across different topics, such as academic content generation in different subjects, job application content generation, brainstorming of ideas besides academic and job application content, and so on.
(3) **Student ChatGPT Interaction**: This category focuses on the human aspect of the student-ChatGPT interaction, particularly how students respond to ChatGPT's answers and communicate with the AI in specific ways. It makes up 15% of the messages we coded. Under this category, we identified the sub-codes such as asking following up questions or commands, pushing back ChatGPT's answers, emotional expressions towards ChatGPT, parasocial relationships between student and ChatGPT, and so on.
(4) **Language Use**: This category (making up 7% of the messages) involves the manipulation of language in various forms, including sub-codes on paraphrasing, finding synonyms or antonyms, adjusting rhetorical style, translating text, and performing grammar checks. In this category, students provide text, and ChatGPT executes specific language tasks.
(5) **ChatGPT's Reaction**: This category highlights ChatGPT's role in the interaction with students, focusing on how the AI engages with users through its responses. Sub-codes in this category explore how ChatGPT adapts its language, style, and complexity to meet diverse student requests, such as ChatGPT's misunderstanding of the student prompt, . Special attention is given to instances where conversational issues arise – those interactions that may be problematic or unsatisfying for the user [80].
(6) **Role Play and Chat**: This category emphasizes students' use of ChatGPT for role-play and conversational simulations, where they engage the ChatGPT as a fictional character in scenarios that mimic real-life social interactions or hypothetical conversations. We found only 1% of our samples belong in this category, corresponding to one student in our sample, so we did not assign a sub-code under this category.

The prevalence of these categories is shown in Figure 2.

4.3 Automated Classification of Categories

Using the categories identified from the initial qualitative coding as a foundation, we proceeded to develop a classifier to analyze the larger dataset derived from the 24 users in the second phase of data collection. To construct this classifier, we employed word n-grams within the range of (1,3) as features, aiming for a nuanced capture of linguistic patterns across the user prompts. Given the variability in the dataset with twelve different classes, the distribution of samples across these classes was not uniform, introducing a notable class imbalance. To address the imbalance, we applied the

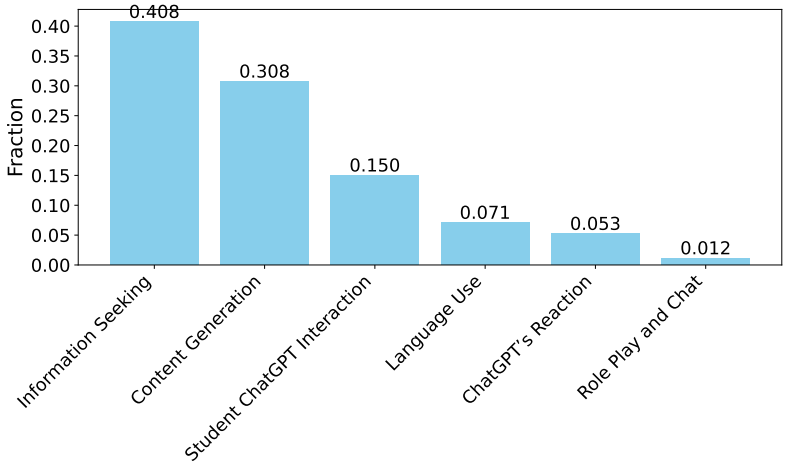

Fig. 2. Command categories and their prevalence after qualitative analysis

ADASYN algorithm [31] to oversample the minority classes, thereby enhancing the representativeness of each category within the model training process.

The process of transforming user prompts into n-grams (1, 3) facilitated a multi-class classification approach. To optimize the classifier's performance, we utilized GridSearchCV[4] to determine the best set of hyperparameters for the logistic regression model. The optimal configuration included L2 regularization and the lbfgs solver, with an adjustment for the class imbalance through the implementation of balanced class weights. We trained the classifier for all categories and subcategories where the accuracy was satisfactory (over 85%) to apply to the full dataset. The results of this classifier's performance, including accuracy and class-specific metrics for the top level categories is summarized in Table 2. The full results for all the subcategories is shown in the Appendix.

Table 2. Predicted category, prediction model metrics.

Category	Accuracy	Precision	Recall	F1	AUC ROC
Content Generation	0.903	0.920	0.956	0.938	0.843
Information Seeking	0.916	0.928	0.976	0.951	0.785
Students' Interaction with ChatGPT	0.910	0.950	0.872	0.909	0.911
ChatGPT's Response	0.821	0.205	0.708	0.318	0.768

5 Findings

Using a deductive qualitative approach [96], we used Li et al's [49] framework to group our qualitative results. The results of the twelve BERTopic analyses and the qualitative analysis of the chatGPT logs revealed three primary categories: (1) different subjects or topics, such as social sciences and humanities, natural sciences, and formal sciences (e.g., computer science and mathematics); (2) varying scenarios and the nature of tasks, such as email generation and writing improvement; and (3) the interactive relationship between students and ChatGPT, including polite and collaborative

[4]https://scikit-learn.org/stable/modules/generated/sklearn.model_selection.GridSearchCV.html

Table 3. Total categories from qualitative analysis (Q) and BERTopic topic modeling (B). Only categories making up at least 5% of the content are shown below. The full table with all categories can be found in the Appendix.

Category	#	Frac.	Source
Information Seeking	9,010	0.855	Q
Content Generation	8,213	0.780	Q
Student ChatGPT Interaction	5,217	0.495	Q
Science, Technology and Management	3,005	0.285	B
Coding	2,608	0.248	B
Social Science and Humanities	2,514	0.239	B
Math	1,241	0.118	B
Content Generation → multiple choices and filling in blanks questions	1,188	0.113	Q
Computer Science	512	0.05	B

Table 4. In this table, we break down our themes from inductive qualitative analysis into three main components: (1) Learning Area (e.g., academic subjects like social studies); (2) Nature of tasks (e.g., content generation); (3) Student-GPT (e.g., repairing communication breakdowns)

Learning Area	Nature of Tasks	Student-GPT Interaction
Academic subjects	Information seeking	ChatGPT's failures/non-progress/ bias/ misinformation
Health	Content generation, academic, email/letter generation, job application materials generation, content generation on personal topics /social media codes/coding formula calculation	ChatGPT's repairing strategies
Social and cultural issues	Brainstorming of ideas	Students' coping strategies
Social media	Providing feedback or evaluation	Students' negative/positive emotions expression towards ChatGPT
Internship and job applications	Language use	Parasocial relationships
Other personal topics (finance; life style; socializing)	Role Play/Chat	Follow up conversations/ debates between students and ChatGPT
Writing and rhetorics		
Language learning and Translation		
ChatGPT		

interactions. BERTopic results mainly discover the learning areas, with limited discovery of the subcategories under nature of tasks and student-ChatGPT. Table 4 provides a summary of the codes derived from this descriptive analysis.

In the following sections, we present the results of our detailed examination of how students engage with ChatGPT across different tasks and topics, supported by illustrative examples. The results contain the following analysis:

(1) **Descriptive Analysis of Students' Daily Learning Needs on ChatGPT and the Integration of Multiple Learning needs:** We explore the ways students utilize ChatGPT for multiple learning areas and various tasks. (subsection: begins with topics; and then nature of tasks)

(2) **Comparative Analysis of Interaction Patterns within Different Tasks and Topics**: We examine differences in student-ChatGPT interactions across disciplines, types of tasks, and individual approaches to integrating

ChatGPT into diverse learning activities. This includes the concept of parasocial relationships as students navigate their interactions with ChatGPT. In the second part of this section, our findings pay specific attention to the positive student-ChatGPT interaction, when the interaction facilitate students' self-directed learning. We also identified the limitations within student-ChatGPT interaction, caused by ChatGPT's non-progress, misunderstanding, biases, errors, leading to conversation breakdowns. At the same time, out findings revealed how both students and ChatGPT adapt strategies to address these challenges.

(3) **Problematic Interaction**: Lastly, we examined potentially problematic aspects of student-ChatGPT interactions, highlighting ethical considerations associated with analyzing these interactions in real-world, non-classroom settings.

5.1 Students' Daily Learning Needs in ChatGPT Usage

The diverse daily learning needs of students reflect the expansive capabilities of ChatGPT as an educational and personal support tool. According to the first and second columns of **Table 3** (link needed), our findings show how students utilized ChatGPT across various learning areas, including academic subjects, writing, public speaking, language acquisition, and professional tasks such as internship and job applications. Students also explored ChatGPT's application in non-academic domains, such as health, social and cultural issues, social media, and the entertainment industry, as well as its role in addressing other personal topics. Students increasingly used ChatGPT to integrate learning tasks across these domains, blending academic and non-academic inquiries into a cohesive learning strategy. By investigating these patterns, this section aims to illuminate how students navigate and synthesize different learning areas to meet their complex and evolving learning goals.

5.1.1 Academic Subjects. Students employ ChatGPT across various academic subjects.

Natural and Life Sciences. Undergraduate students used ChatGPT in natural and life sciences to enhance their understanding of complex concepts, tackle open-ended questions, explore real-world applications, and prepare for assignments and exams.

A significant use is clarifying concepts within specific contexts. For example, one student asked ChatGPT "*What is the structure of hydrophobic hairs or ridges on the body that allow insects to carry water in aquatic habitats?*" and to *"Define burnout and discuss why it is so dangerous for patients when health professionals feel burnt out"*. ChatGPT delivers clear, contextually relevant explanations organized into concise bullet points, and with some practical applications.

Some students used ChatGPT as a resource for addressing open-ended questions that require critical thinking and nuanced responses. One example is that one student asked *"What strategies might be useful to combat burnout for medical care professionals?"* ChatGPT supports the exploration of real-world applications, such as analyzing the practical impacts of medical decisions or ecological interactions.

Students also rely on ChatGPT to generate study aids, such as summarizing course materials or slides into digestible formats such as bullet-point list or creating mnemonics for memorizing and understanding key points. This helps streamline their review process for exams. For example, one student asked *"Based on the slides for lecture xxx, what is one reason to avoid cesarean deliveries of babies? Make them into short bullet points"* Another example is that one student asked ChatGPT to "*create a concept map DNA replication*".

For assignment aids or exam preparation, students asked ChatGPT to answer detailed questions (ususally multiple choices questions about structures or functions in natural or life sciences. Examples include *"Which characteristics are*

associated with dragonfly larvae gills? A. Group of answer choices B. Internal gills in abdomen C. External gills in abdomen D. Internal gills in thorax"

Formal Sciences. Students used ChatGPT for clarifying foundational concepts, methods, or applications. For example, students may ask ChatGPT to explain abstract ideas such as *"What is a p-value, and how does it help us decide to reject the null hypothesis?"* or to define applications like *"What is sentiment analysis?"*

Students also used ChatGPT for problem-solving through mathematical and probabilistic challenges. For instance, one student requested help with question *"What is the probability that at least 1 error is made?"* or ask for clarification on solutions, such as *"Can you go over this solution: P(A|B) = P(A)P(B|A) = .36 = 36?"* These explanations reinforce analytical thinking and comprehension of formal methods. supports problem-solving.

Students also tested hypothetical scenarios using ChatGPT. For instance, a student asked "Would Bernoulli random variables help here?" to explore alternative approaches or refine their problem-solving strategies. This interactive experimentation helps students build confidence in applying theoretical models.

Student also used ChatGPT to assist in analyzing datasets or simulating data to gain hands-on experience. For example, one student asked "*How to use linear regression for predicting models?*". Another prompt is that student asked ChatGPT to "*Write Python code to generate a dataset of 1000 values from a normal distribution with a mean of 50 and a standard deviation of 10.*" Student also asked ChatGPT to "*Give me real bad examples of a visual presentation of data*" to understand pitfalls in presenting statistical information effectively.

Debugging and programming code generation are also among the most frequent uses. Students encountering errors can ask ChatGPT to identify and resolve issues, such as debugging a loop that isn't producing the expected output. Programming code generation is another valuable application, with students requesting functional code snippets in languages like Python, R, Java, and C++. For example, they provided specific instructions or ask ChatGPT to achieve a goal using alternative methods or by replacing segments of existing code.

Social Sciences . In social sciences, students utilized ChatGPT to enhance their understanding of theories, connect ideas to real-world applications, analyze case studies, and assist with assignments and writing tasks.

Students used ChatGPT to clarify complex concepts and theories where ChatGPT provides simplified explanations and examples. For instance, one student asked "*Explain what actor-network theory means in the easiest way, give an example*" to break down abstract ideas into accessible terms.

Students also used ChatGPT to connect theoretical frameworks to real-world applications, enabling them to understand social trends and advancements. For example, one students explored "*Cultural and technological events significant to the development of video games*" to evaluate how societal and technological changes have shaped the gaming industry. These interactions allow students to assess the social impacts and consequences of historical and contemporary phenomena within specific contexts. Another example is one student asked "*Did slavery and racial prejudice gradually evolve in Virginia during the half century following the arrival of the Angolans, or did de facto enslavement of Africans begin in 1619?*"

Case study analysis is another important application, particularly in areas such as finance, business, and management. ChatGPT can help break down a company's financial performance or management practices, providing structured insights for assignments or discussions. Students sought guidance in interpreting market trends or evaluating business strategies. For example, one student asked, "*Expanding globally is much more challenging than expanding nationally. The political system, economic conditions, laws and regulations, and cultures are often very different in other countries. You*

cannot assume that what allowed you to successfully expand domestically can simply be repeated globally. Please help me analyze the Tesla's global expansion over the past year. "

Lastly, ChatGPT supports assignment completion and writing assistance, especially in generating academic essays or organizing arguments to meet specific requirements. Students asked for structured essays on topics of interest or for advice on refining their writing to align with academic standards. ChatGPT helps students in social sciences bridge theoretical knowledge with practical applications, bolstering their analytical and communication capabilities.

Humanities and Art. In humanities and art, students used ChatGPT to clarify theoretical concepts, analyze movements and trends, interpret creative works, and assist with their academic writing.

Same as the previous subjects, under humanities and art, students used ChatGPT to clarify theoretical concepts, though they focuses more on the connection and comparison between different theories and concepts instead of seeking clarification for just one concept. For example, one student asked, *"Explain the importance of truth as Nietzsche connects it to the figure of Socrates in The Birth of Tragedy."*

Students also used ChatGPT to aid in analyzing movements or historical and social trends, exploring the cultural, political, or social factors that have shaped artistic or understanding of phenomenon. For example, one student asked "*How does the Tang Dynasty's artistic style impact on East Asian art styles?*".

When analyzing literature or artwork, students asked ChatGPT to provide insights into themes, symbolism, and stylistic elements. Students asked for interpretations of specific works to deepen their understanding of the creators or authors' intentions and the cultural significance of the piece. Additionally, students asked ChatGPT to support close reading practices by breaking down complex passages from conceptual papers, or philosophical prose, help them have better understanding of the content. For example, one student asked, "*what did lil baby mean in the song when he said 'they know we a problem together, they know we can storm any weather'?*" Students also used ChatGPT to inspire comparative analysis between different works and authors. For example, a student might compare perspectives on existentialism in the writings of Sartre and Camus, fostering a broader understanding of philosophical and literary connections.

Finally, stduents asked ChatGPT to provide robust writing assistance, helping students generate academic essays tailored to specific requirements. It provides structured outlines, refines arguments, and ensures clarity in expression, supporting students in articulating complex ideas effectively. These applications make ChatGPT a versatile and valuable resource for students in humanities and art disciplines.

Students also asked ChatGPT to brainstorm ideas for their creating. For example, one student asked ChatGPT, "*Can you help me brainstorm a short science fiction story set in a dystopian future where environmental pollution has reached catastrophic levels?*"

While students' use of ChatGPT varies across academic subjects, as noted above, certain applications are common across fields. One is students' use of ChatGPT to identify relevant academic resources for assignments, essays and research projects and make summary of these academic resources.

5.1.2 Writing, Public Speaking, and Language. Students frequently utilize ChatGPT for various writing and speaking-related tasks.

Academic Writing: Citation Support and Paper Critique Analysis. Students asked ChatGPT to generate citations in formats like APA, MLA, or Chicago to simplify the referencing process, ensuring precision and efficiency.

Students also asked ChatGPT to critique their essays from different perspectives. One student asked, "*please academically critique my essay*", seeking feedback to refine their arguments, structure, and clarity. Besides academic critiques, students also asked ChatGPT to provide professional perspective, one asked, "*if you were an IT professional, how would you use the evaluations I provided?*" after providing the review on one technical report.

Grammar Check. This feedback helps students refine their content, either by adding material if the speech is too short or condensing it if it exceeds the allotted time. By streamlining this aspect of preparation, ChatGPT supports students in effectively managing and tailoring their presentations.

Students often employ ChatGPT as a grammar checking tool, leveraging its natural language processing capabilities to identify and correct grammatical errors. This usage extends beyond simple proofreading, as students frequently ask ChatGPT to explain the grammatical rules underlying the corrections. For instance, students might submit entire paragraphs or essays for review, seeking not only corrections but also explanations of complex grammatical structures such as conditional clauses or proper use of gerunds and infinitives.

Rewording. Rewording emerged as a significant use case, with students requesting ChatGPT to rephrase sentences, paragraphs, or entire documents. This application serves multiple purposes, including improving clarity, adjusting tone, and avoiding plagiarism. Students often provide specific instructions for rewording, such as simplifying complex text, adopting a more formal or informal tone, or maintaining the original meaning while completely changing the sentence structure.

Rhetoric. Students turn to ChatGPT for assistance with rhetorical devices and strategies, demonstrating an interest in enhancing the persuasiveness and impact of their writing. Requests in this category include generating examples of specific rhetorical devices (e.g., metaphors, analogies, or parallelism), analyzing the rhetorical structure of given texts, and advice on constructing arguments for debates or persuasive essays.

Synonyms or Antonyms. The use of ChatGPT for finding synonyms and antonyms is widespread among students, indicating a desire to expand their vocabulary and enhance the variety of their language use. Students often request synonyms for common words to avoid repetition in their writing, or seek more sophisticated alternatives to elevate the tone of their text.

Translation. ChatGPT's translation capabilities are frequently utilized by students for various purposes. Beyond simple word-for-word translation, students often seek cultural context and idiomatic expressions in the target language. They may ask for translations of colloquialisms or request explanations of how certain phrases might be interpreted in different cultural contexts. Some students use ChatGPT to compare translations from multiple sources, asking the AI to explain discrepancies or nuances between different versions.

Checking length of the Speech . Students used ChatGPT to estimate the length of their speeches by providing the written text and asking it to calculate the approximate delivery time. This allows them to ensure their speech aligns with time constraints, such as those for presentations, debates, or classroom assignments and stremline their preparation work. For example, one student asked, "*how long would this take to speak?*"

5.1.3 Internship and Job Applications. Students primarily seek guidance on resume writing advice, such as content inclusion, behavioral questions like post-interview follow-ups and salary negotiations, and cover letter composition.

Some students attempted to use ChatGPT for gathering current job listings, but its performance was unsatisfactory due to the lack of real-time internet connectivity in the version used.

Many students utilized ChatGPT for job-related content, including generating answers to interview questions, creating resumes, and composing cover letters. Students often requested "*sophisticated yet personalized*" content that portrayed them as "*professional*" Some students provided paragraphs of previous experiences and asked ChatGPT to convert them into bullet points or to generate different versions of resumes tailored to specific job positions.

5.1.4 Health. Students turned to ChatGPT for information on disease treatments, health-related guidance, and historical insights into medical issues. Some students asked for the causes and general advice on improving their mental or physical health. For example, one student asked "*Can period cramps cause sciatic nerve pain?Can period cramps cause sciatic nerve pain? How can I help lessen this pain?*". Another case was that one student asked "how can I quickly stop the bleeding if I cut my finger" Students also sought clarification on specific treatments, such as "*Is notebook therapy legit?*". Additionally, students used ChatGPT to explore medical history, including the origins and evolution of significant diseases. One student questioned the geological origin of COVID-19, "*did covid-19 start in China?*", where ChatGPT provided contextual information about the pandemic's emergence and its global impact.

5.1.5 Social and Cultural Issues. Students explored various topics, including legal frameworks and social movements of specific historical periods, historical perspectives on current political and military debates, and geographic disputes, religious customs, and cultural practices.

5.1.6 Social Media and Entertainment Industry. Students also used ChatGPT to engage with topics related to social media and the entertainment industry, exploring its capabilities for various creative and informational purposes. For instance, students asked ChatGPT to generate catchy social media captions tailored for platforms like Instagram or TikTok, helping them craft engaging posts that resonate with their followers. Additionally, some students asked ChatGPT about entertainment gossip and updates on trending celebrity news, seeking quick summaries or context about popular topics in the entertainment world. Some student used it to stay informed about the latest trends on TikTok, exploring viral challenges, music, or content strategies. Students used ChatGPT as a tool for navigating the dynamic landscape of social media and entertainment.

Activity Plan and Organization. Students employed ChatGPT for brainstorming beyond academic and job-related contexts. This included generating jokes on specific topics, ideas for social media content (e.g., blog topics, captions), and activity plans (e.g., birthday parties, book talks, travel plans, product promotions).

Information seeking for personal topics. Students' use of ChatGPT extends beyond academic matters to personal interests, including lifestyle-related queries such as meal planning and vacation planning. Some students asked investment-related questions, which ChatGPT cannot answer due to OpenAI policy. Notably, some instances of potentially malicious use were identified, such as seeking private information or tax avoidance strategies, raising privacy and ethical concerns.

Administrative Communication. Email and letter generation primarily focused on administrative content. These often involved complex or uncommon situations requiring careful attention to tone and wording. Examples included requests for financial aid from university departments or appeals for additional exam opportunities.

Role Play and Chat. Our qualitative analysis revealed an emerging trend of students using ChatGPT for role play and conversational simulations. This usage pattern demonstrates students' exploration of AI's capabilities beyond academic and professional applications, venturing into social and emotional domains.

One notable case involved a student engaging with ChatGPT as a friend, expressing a desire for social interaction. Despite initial hesitation, the student quickly immersed themselves in conversation, discussing topics such as music and television series, and soliciting ChatGPT's opinions. This behavior suggests a potential use of AI as a social surrogate, particularly for individuals experiencing feelings of isolation or loneliness. The student's initial message (paraphrased) exemplifies this sentiment, "*This feels a bit unusual, I must admit. However, I really want to talk with someone. Might you be open to a chat like a friend with me?*" Throughout the conversation, the student conveyed a sense of loneliness and a desire for casual dialogue. This interaction highlights the potential for AI to serve as a conversational partner, albeit with significant limitations.

However, this case also illustrated the current constraints of AI in fulfilling complex social roles. The student often used declarative sentences without clear requests or questions, which led to ChatGPT repeatedly asking for specific instructions based on its function. This interaction pattern resulted in the student expressing frustration and questioning ChatGPT's ability to understand them.

5.1.7 What's in a chatGPT?! Students queried ChatGPT about its own capabilities, limitations, and best practices for effective use in academic and personal contexts. This behavior demonstrates students' AI literacy and desire to optimize their interactions with the tool. It also highlights the importance of critical thinking when relying on AI for self-description and the need for cross-checking information from multiple sources. This information-seeking behavior regarding ChatGPT itself emphasizes the dynamic relationship between users and AI tools, underscoring the importance of developing critical evaluation skills in the context of AI-assisted learning and information retrieval.

5.1.8 Students' Integration of Different Learning areas and Learning Tasks on ChatGPT. We analyzed full historical log data of 12 students, the lengths of history vary from xx to xx. The amount of messages vary from xx to xx. We examine how students integrate different tasks and topics in their long-term use of ChatGPT.

Students often navigate through a variety of learning tasks and topics using ChatGPT by seamlessly integrating the tool into their academic and personal workflow, adapting it to meet the specific demands of multiple tasks.

For example, a student working on a writing assignment might begin by using ChatGPT to generate ideas or draft an outline. Once the basic structure is in place, they may switch to using the tool for language refinement, asking it to suggest improvements in clarity, coherence, and style. Afterward, the student might shift focus to another task, such as solving a math problem or understanding a technical concept in a science course.

By seamlessly transitioning between these varied tasks, students demonstrate how ChatGPT can be a versatile and adaptable learning aid, supporting both academic rigor and creative exploration. However, this integration also requires an active and critical approach to ensure the tool enhances learning without fostering overdependence or bypassing important cognitive processes.

5.2 Interaction Patterns Across Topics, Tasks, and Personal Questioning Styles

Student interactions with ChatGPT reflect diverse and nuanced patterns, shaped by the interplay of nature of tasks, subject matter, and individual questioning styles. This section examines these interaction dynamics in depth, beginning with a comparative analysis of how tasks and topics influence student engagement patterns. It further examines the dual role of ChatGPT as both a facilitator and a constraint in students' learning process, highlighting its potential to

enhance understanding and learning while also revealing its limitations. To address these challenges, students adopt various coping strategies, which are explored to illuminate their adaptive approaches. The section also investigates the development of parasocial relationships between students and ChatGPT, offering insights into how these relationships impact usage. Finally, our qualitative analysis reveal students' evolving attitudes toward ChatGPT over time.

5.2.1 Comparing Interaction Patterns within Different Tasks and Topics. Our data revealed that students' interaction patterns with ChatGPT vary depending on the topic of discussion and the individual's approach to questioning. This variability is primarily reflected in the style of questioning and the length of conversations, especially when follow-up questions are involved.

Our previous section show that undergraduate students' interactions with ChatGPT vary across academic subjects, reflecting the distinct demands and epistemological approaches of each field.

In formal sciences such as mathematics, statistics, and computer science, students used ChatGPT more for problem-solving, coding assistance, and clarifying some concepts and methods, valuing its precision and logical reasoning, and application capabilities. For topics such as coding and mathematical problem-solving, students tend to engage in longer, more detailed interactions. These conversations often include multiple exchanges, where students ask follow-up questions or request clarifications. For instance, when a student received a response on a mathematical equation, they followed up with, "*Wouldn't it make more sense to write it as ... [mathematical equation differing from ChatGPT's answer]*." This iterative dialogue allowed students to refine their understanding and received further targeted guidance through problem-solving steps tailored to their specific needs. Student-ChatGPT interaction articulated these step-by-step process.

In natural and life sciences, our data showed that interactions centered around assisting assignments and generating study aids, where the ChatGPT's ability to simplify technical language and provide structured explanations proves beneficial. In the natural sciences, fill-in-the-blank and multiple-choice questions are particularly prevalent as assessment formats. More students used ChatGPT to seek answers for this type of tasks.

Social science students, on the other hand, engage with ChatGPT to explore theoretical frameworks, social trends, draft essays, and case study analysis, appreciating its adaptability in addressing multifaceted and context-dependent questions.

In the humanities and arts, students emphasize creative engagement, such as brainstorming ideas, refining writing style, or exploring historical and cultural perspectives, leveraging ChatGPT's function of generating diverse interpretations and stylistic variations. **(the above content is repetitive of section 5.2)**

Across all disciplines, interactions between students and ChatGPT are notably less frequent for multiple-choice and fill-in-the-blank questions. These interactions are often straightforward, consisting of simple question-and-answer exchanges. For example, there are many cases in which students input a specific multiple-choice question, received an immediate response, and then move on to the next question without further engagement. The transactional nature of these interactions reflects the limited scope of such questions, which are primarily focused on factual recall or selecting the correct option from a set of choices.

When questions were factual or descriptive with a clear, definitive answer, the interactions also tend to be brief. Examples include queries like, "Which insect is considered aquatic collector feeders?" or "Which renowned composer is Brahms paying tribute to in his Symphony No. 1, evidenced by the use of a recognizable motif and the tonal progression from C minor to C major?" In these cases, the straightforward nature of the questions and the expectation of a specific answer limit the depth and duration of the conversation.

For many open-ended questions, such as those related to social sciences or cultural topics, interactions are typically more succinct. These conversations usually consist of a single query and a direct response, with students seeking generalized information or conceptual explanations rather than engaging in extended discussions. This pattern suggests that students might perceive these topics as requiring less detailed exploration or iterative feedback compared to technical subjects.

Meanwhile, we also found some students were inspired by ChatGPT when seeking answers for open-ended questions. Based on ChatGPT's first answer, the students added more details or narrowed down the scope of the question to get more targeted answers. We will further analyze this kind of interaction in the following section on how student-ChatGPT's interaction facilitates student's learning.

Another notable pattern was students' repeating the same questions to ChatGPT when they asked answers for open-ended questions, seemingly to explore different responses. This behavior may stem from students' understanding of how ChatGPT generates answers, as its mechanism introduces some randomness, resulting in variations in phrasing, examples, and focus even for identical prompts. By rephrasing or repeating their questions, students can leverage this feature to gain multiple perspectives, enriching their understanding of a topic or problem.

Students' questioning approaches also vary significantly. Some students ask fully detailed questions, clearly articulating the context and the specific information they need, which often results in more precise and relevant responses from ChatGPT. Others, however, use minimal keywords or phrases, relying on ChatGPT to infer their intent, which necessitates a higher degree of interpretive flexibility from the AI.

5.2.2 Navigating Student-ChatGPT Interaction: Technological Affordances and and Coping Strategies.

Facilitation in Students' Learning Process. Our examination of student-ChatGPT interactions revealed that, under certain contexts, ChatGPT facilitated students' learning processes by encouraging fact-checking, clarifying complex concepts, bridging knowledge gaps, fostering critical thinking, and promoting active engagement through personalized interactions. These functions may collectively enhance students' understanding, critical thinking skills, and self-directed learning capabilities.

ChatGPT encouraged students to engage in fact-checking, particularly when their inquiries involve time-sensitive information. For example, one student posed a question, "*what are the vaccines for [...] (a certain disease)*" ChatGPT 3 emphasized its last knowledge update, encouraging that student to verify facts independently since there might be new vaccines. Though the student's inquiries did not show the time-sensitive keywords, based on the context, ChatGPT's answer added such suggestion. This process may enhance the accuracy of students' knowledge and also cultivate students' habit of critical evaluation of information sources.

In clarifying complex concepts, ChatGPT demonstrated its ability to simplify intricate ideas and present them in segmented parts with clear headings. This structured breakdown facilitates targeted questioning and deeper exploration of subtopics. For example, when the student asked ChatGPT to "*draw a concept map of nuclear power as a technological artifact*," ChatGPT provided the concept map, and also provided detailed explanation for each part of the map, organized into concise bullet points, enabling students to create a structured framework for further research and help with their memorizing the theories.

This breakdown of complex concepts or theories also gave the opportunity for students to search more and learn more, and to better connect theoretical concepts with practical applications, such as case analysis, further encouraging students' critical thinking. For example, when one student asked ChatGPT, "*Compare and contrast the social service delivery in health care historically and presently.*", one bullet point ChatGPT offered was "*[...]the challenge of access to the*

healthcare espicially for marginalized and underserved populations". This response not only addressed the student's initial query but also encouraged them to delve deeper by posing a follow-up question focusing on a specific marginalized population. Then that student asked following questions specifically on one marginalized population and digged deeper into that context. By transitioning from a general comparison to a targeted inquiry, the student was able to examine how historical inequities in health care delivery continue to impact specific groups in contemporary systems.

ChatGPT's adaptive responses also inspired students to explore complex topics more critically by articulating their thoughts, posing follow-up questions, and refining their understanding through iterative dialogue. Logs indicate that ChatGPT encouraged exploration of multiple perspectives when one student asked ChatGPT to critique the academic essay written by that student. ChatGPT encouraged the student to consider the difference between different populations and locations, relating the case to broader contexts, thereby deepening the student's analytical insights.

ChatGPT also filled students' knowledge gaps by providing insights or information students might have overlooked or misunderstood. For instance, when one student provided incomplete code but only inquired about next steps, ChatGPT identified limitations in the student's existing code and suggested more efficient approaches. This type of interaction articulated that besides addressing students' immediate gaps, ChatGPT can also guide students toward better problem-solving techniques, enhancing their problem solving skills. For social sciences, humanities, or art, ChatGPT filled stuents' knowledge gaps by providing different perspectives or alternative perspectives. Some students provided their written paragraphs and asked ChatGPT to expand the writing. ChatGPT then provided another perspective of explanation and interpretation.

ChatGPT's pointing out of students' knowledge gaps sometimes led to dynamic "debates" between students and ChatGPT, creating an interactive learning environment that facilitated deeper engagement with the material or understanding of the problem. This type of interaction usually happened when students sought instructions on programming codes or mathematical formula reasoning. When students pushed back against ChatGPT's certain steps, whether their critiques were accurate or not, the act of challenging and questioning served as a powerful mechanism for learning. These debates required students to articulate their thoughts clearly, justify their reasoning, and identify weaknesses or gaps in their or ChatGPT's understanding, all of which are critical components of higher-order thinking []. These debates also fostered an environment of active learning, where students were not passive recipients of information but rather active participants in constructing their knowledge. This interaction nurtured critical thinking skills and intellectual curiosity. The collaborative nature of these exchanges also emphasized problem-solving strategies, as students worked with ChatGPT to address misunderstandings or refine their approach to a task. This type of interactive engagement mirrored the dynamics of real-world academic or professional debates, prepared students to critically analyze information, defend their perspectives, and adapt their thinking based on new insights.

ChatGPT also filled students' knowledge gaps by providing tailored explanations or perspectives that students might not be familiar with. By offering guidance customized to a student's specific needs or queries, ChatGPT expands the boundaries of their understanding. For example, as the previous section showed, beyond providing academic evaluations of a student's work, ChatGPT were also asked by student to analyze their work from the perspective of a specific professional role, such as a hiring manager or industry specialist. This type of insights are often outside the realm of students' current expertise, not only address immediate knowledge gaps but also equip them with transferable skills for professional development. By exposing students to diverse viewpoints and problem-solving strategies, ChatGPT fostersed students' deeper understanding and encourages them to approach different problems or tasks with a more nuanced and flexible mindset, preparing them for both academic, professional, and other real-world scenarios.

Additionally, ChatGPT's adaptability assisted students with varying learning styles or challenges. ChatGPT's seamless switch between different tasks, topics, and modes of explanation ensured that students can receive guidance or information in a format that resonates most effectively with their individual preferences or special needs. The findings on how students navigated ChatGPT's limitations—such as its lack of progress, errors, biases, and mistakes—highlighted how they developed the ability to craft precise and effective prompts, refining their communication and collaboration with AI systems to extract the most useful outputs. Additionally, students gained critical evaluation skills, distinguishing between valuable insights and potential inaccuracies or mistakes in AI-generated content. Furthermore, students discovered how to integrate ChatGPT into collaborative workflows, such as utilizing it for brainstorming, improving writing, drafting case study reports, programming tasks, and assisting with mathematical formula reasoning.

Limitation of ChatGPT and Coping Strategies.

ChatGPT's Failures, Biases, or Mistakes Though in the above section, we identified ChatGPT's affordances that support students' self-learning, we also identified ChatGPT's limitations and constraints in the student-ChatGPT interactions.

ChatGPT's responses to students often reveal its limitations and boundaries in handling specific requests. Common issues include: (a) explicitly stating its inability to address certain topics due to neutrality requirements, such as not holding personal beliefs; (b) outdated knowledge, given that its information base is not continuously updated; (c) execution issues, such as its inability to run code directly; (d) access limitations to external databases or personal files; (e) insufficient input from students, leading to incomplete responses; (f) legal constraints; and (g) restrictions on providing financial or investment advice.

Sometimes, even when ChatGPT provides an answer, it clarifies its limitations, acknowledging potential gaps in its abilities. However, ChatGPT also encounters notable failures, such as providing different answers to the same question when asked repeatedly by a student, causing confusion. Other failures include not understanding the question, misinterpreting prompts, or generating fabricated information that appears plausible but is false. Additionally, ChatGPT occasionally produces unintended or biased responses. For instance, when asked about a book's discussion on racism, ChatGPT denied any such content despite its presence. In another case, ChatGPT responded defensively when questioned about the reusability of code it provided, insisting it should generally be reusable, even when it was not.

ChatGPT's Reparing Strategies ChatGPT often attempts to mitigate misunderstandings by apologizing for errors or inaccuracies. While these apologies can convey a sense of politeness and personification, such as "*Apologies for the confusion earlier*," the repetitive and formulaic nature of these responses often diminishes the potentially perceived authenticity and effectiveness. This programmatic approach highlights the AI's limitations in addressing the nuances of human requests and expectations, as it lacks the emotional intelligence and contextual understanding required to adapt responses in genuinely meaningful ways. Additionally, ChatGPT's repair strategies are constrained by its inability to fully grasp the underlying intent of user interactions. For instance, when faced with ambiguous or complex queries, ChatGPT restated or rephrased its responses, which can result in user frustration if the original issue remains unresolved. T

Students' Reactions and Coping Strategies When the non-progress, mistakes, and misunderstanding happened, though ChatGPT tried to repair these issues by asking users to clarify their questions or refine their prompts, these interactions required students to take responsibility for guiding the conversation effectively. Students employ various strategies to cope with ChatGPT's failures or errors. Commonly, they revise their initial questions to simplify them, making them easier for ChatGPT to understand, particularly when ChatGPT fails to grasp or misinterprets the original prompt. In

some cases, students ask ChatGPT to refine its previous answers by providing more detailed instructions or additional context.

Students frequently challenge ChatGPT's incorrect responses, particularly in programming and mathematical proof contexts, where precision is critical. They often push back against ChatGPT's mistakes, pointing out specific errors and demanding corrections. When ChatGPT generates false or misleading information, some students even attempt to correct or educate the chatbot, engaging in an unusual reversal of roles where the user teaches the AI.

We also observed an evolution in students' coping strategies. Initially, students tended to overwhelm ChatGPT with overly detailed prompts, leading to misunderstandings. Over time, they adapted by breaking down information into smaller, manageable sections, prefacing their input with clarifications like, "I am going to teach you a ... topic, it is long so I will send it to you section by section." This shift demonstrates a growing sophistication in how students manage their interactions with ChatGPT, reflecting their ability to adapt their communication style to the AI's constraints.

5.2.3 Parasocial Relationship between Students and ChatGPT. Our analysis shows that students often engage with ChatGPT in a human-like manner, using polite and socially coded language. Common behaviors include exchanging greetings like "Hi!" or "Hello!" and expressing gratitude with phrases such as "Thanks!" Additionally, students frequently use modal verbs like "would," "could," and "should," reflecting a polite, conversational style.

Many students, whether consciously or unconsciously, provided human-like feedback to ChatGPT, expressing appreciation or positive reinforcement during interactions. Examples include responses like "Right!", "Cool!", "Yeah," or the use of emoticons and emojis (e.g., " "), often followed by a subsequent question. In other instances, students displayed more casual or emotional reactions, such as starting with "Are you kidding?" or sharing personal feelings like "I feel crazy right now," "I am super unhappy," or "I am feeling weak."

We also observed instances of role-playing and casual conversations, suggesting a parasocial relationship between students and ChatGPT. When students perceived a lack of mutual understanding from ChatGPT, they expressed feelings of resentment and disappointment. This interaction pattern indicates potential false expectations, where students view the AI's discrete outputs as part of a continuous, shared communicative context, leading to emotional engagement and misplaced anticipation of mutual understanding from the AI.

5.2.4 Students' Changing Attitudes/Emotions Towards ChatGPT. In the early stages of interacting with ChatGPT, students often used polite and socially coded language, including modal verbs like "could," "would," and frequent expressions of gratitude, reflecting a desire to communicate respectfully beyond what was necessary for ChatGPT's comprehension.

While most students maintained a consistent tone throughout their interactions, we observed that one student's attitude shifted noticeably after about a week of frequent use. Initially polite and formal, the student's communication style became more direct and devoid of social pleasantries, marked by an icy tone and straightforward commands. This change suggests an evolving comfort level with the AI, as students adjust their communication to prioritize efficiency over social norms, reflecting a shift from human-like engagement to a more utilitarian interaction.

Students displayed heightened positive emotions when working on specific topics or under certain circumstances, such as reasoning through mathematical formulas or debugging code. As they progress step by step toward the correct result or solution, their sense of accomplishment becomes evident through expressions of gratitude and encouragement. For instance, when ChatGPT provides effective guidance in troubleshooting a coding error or helps clarify a complex mathematical derivation, students frequently respond with enthusiastic praise, such as commending ChatGPT's assistance or explicitly thanking it for its clarity and support. These interactions highlight the motivating

role ChatGPT plays in fostering a sense of achievement and confidence as students tackle challenging tasks. This dynamic also suggests that ChatGPT's adaptive and iterative approach can significantly contribute to maintaining student engagement and creating a more enjoyable learning experience.

5.3 Students' Potential Problematic Use of ChatGPT

Dependency on AI for learning. Our findings also revealed a growing dependency on AI tools like ChatGPT for learning, which could have negative implications. For instance, some students consistently used ChatGPT to solve problems without attempting to engage with the underlying concepts, such as let ChatGPT generate large amount of academic paragraphs in a short time without further exploration. This may reduce opportunities to build critical thinking and problem-analyzing abilities.

The parasocial relationship identified in previous section also has the potential to impact students' willingness to seek help from peers or instructors, further complicating academic integrity concerns. It highlights the importance of balancing AI use with human-centered support systems to maintain authentic learning experiences.

Academic Integrity . Our findings identified several instances of students engaging in academically dishonest behaviors, such as using ChatGPT to complete assignments without proper attribution or generating group discussion posts that bypass collaborative efforts. Some students directly copied and pasted assignment instructions into ChatGPT, including details such as scoring criteria, to generate responses. As for discussion post generation, some student directly copied other students' discussion content and asked, "*Create a 25-word question I may have after reading the following prompt...*" These behaviors reflect a lack of engagement with the learning process and demonstrate the potential for misuse of ChatGPT as a shortcut to complete tasks, undermining the development of critical thinking and problem-solving skills.

Privacy Concern . The use of ChatGPT for personal tasks, such as generating CVs, also raised significant privacy concerns. our data showed that students often shared personal information to request tailored outputs, potentially exposing sensitive data. However, many generated CVs lacked personalization if the student did not provide targeted requirement, resulting in templated outputs that may not effectively represent the individual. This finding emphasizes the dual risks of privacy breaches and reliance on generated outputs. Additionally, one student asked ChatGPT to draft a letter to their doctor requesting a prescription, inadvertently revealing their medical information during the interaction. This example underscores the risks of sharing sensitive personal details with AI tools, which may not guarantee secure handling of such data.

Malicious Use. Instances of potentially malicious use were also observed. Some students used ChatGPT to seek advice on questionable activities, such as avoiding taxes or retrieving sensitive personal information. These behaviors illustrate the darker possibilities of AI misuse, highlighting the need for robust monitoring and ethical guidelines.

6 Discussion

Our findings provide critical insights into how students engage with ChatGPT as a tool for self-learning outside classroom, offering both theoretical and practical contributions. Our first part of discussion presents a theoretical extension of the Self-Directed Learning Model within the context of generative AI, drawing on the theory of technological affordances to explain how ChatGPT supports or challenges students' learning processes. By examining the dynamic interplay between students and ChatGPT, this framework enriches our understanding of undergraduate students'

everyday learning in Generative AI environments. Reacting to socialtechnical poliy design approach call [76], our second section discusses policy and design implications aimed at enhancing students' ability to effectively integrate ChatGPT into their everyday learning practices outside the classroom environment. By addressing issues such as equitable access, user and instructor training, and adaptive design features, we propose strategies to maximize the educational potential of generative AI while mitigating its limitations. Together, these contributions underscore the transformative yet nuanced role of ChatGPT in current learning ecosystems.

6.1 Theoretical Implications: Extension of the Self-Directed Learning Model in Generative AI Context

As with Li et al.'s earlier study [49]that extend Song and Hill [91]'s original model of Understanding Self-Directed Learning in Online Environments (), we propose new constructs that can be added to the three perspectives of self-directed learning model in the context of generative AI and provide more detailed understanding of the complex and dynamic interaction between the various components using empirical evidence. Our proposed framework refines and extends previous models by incorporating unique constructs emerging from the empirical evidence of real student-ChatGPT interaction, with special focus to the sociotechnical impacts brought by ChatGPT and students' interaction with ChatGPT. Our findings reveal the changing landscape of students' learning outside of the classroom using ChatGPT and how their interaction with ChatGPT shapes their learning process. These proposed additions are represented in **Table 4** (marked with an asterisk).

Unlike studies focused on single application domains (e.g. coding, language learning, or writing) in terms of real student-ChatGPT[60] [57] [50] [17],our research transcends disciplinary boundaries and facilitates interdisciplinary dialogues. We even transcends academic-non academic boundaries to consider students' comprehensive learning in everyday setting. In addition, we incorporate long-term observational and "wild" data, providing a richer and more nuanced understanding of students' interaction with ChatGPT for self-learning and the role of ChatGPT in this process.

Building on Li et al.[49]'s findings, we triangulate our results with observational data on students' real-world interactions with ChatGPT. While Li's work focuses exclusively on language learning, we respond to their call for further research by testing, validating, and extending their framework across multiple learning areas and diverse learning environments. This broader approach enables us to offer deeper insights into the dynamics of ChatGPT-facilitated self-directed learning.

Table 5 Categories and indicators of SDL in ChatGPT Context

Personal Attributes. In Song and Hill's original model of SDL [91], the personal attributes are characteristics learners bring to a specific learning context. Our findings enrich the implications of indicators of *resourse use*, *strategy use*, and *attitude* proposed by existing studies [91][49] by adding nuances from students' log data with ChatGPT in real learning situations.

Resource use emphasizes a learner's ability to effectively utilize available information, tools, and references in the learning process[91][49][]. In the context of ChatGPT, this strongly requires only gathering information but also verifying the accuracy and reliability of the AI's generated responses[]. Our findings revealed that some students cross-referenced ChatGPT's information with other resources to assess its correctness, engaged in critical debates with ChatGPT, and even provided corrections when inaccuracies were identified. However, we also found instances where some students continued to rely on fabricated bibliographies generated by ChatGPT and further their discussion on the fabricated content, which highlights the potential pitfalls in uncritical acceptance of AI outputs. Such practices underscore the importance of developing critical information literacy and resource use skills, particularly given the

Category	Subcategory	Indicator	Extension of Indicator
SDL	Personal Attributes	Resource Use	*Verify the accuracy and reliability of Chat-GPT generated content
		Strategy use	*Prompting strategies and Coping strategies
		Attitude	
	Autonomous-Adaptive Process	Planning	
		Monitoring	
		Adapting	
		Evaluating	
		*Integrating	
Learning Context (Chat-GPT)	Design Elements	Resources	
		Structure	
		Nature of Task	
		*Technological Affor-dances	
		*Explanation	
	Suppor Elements	Non-human	*Technology-enhanced scaffolding
			*User-ChatGPT collabo-rative worflows
	Social Elements	Institutional Policy for Al Adoption	
		Sociocultural and geopolitical norms	
		*Parasocial Relation-ship	

Table 5. Categories and indicators of SDL in ChatGPT Context

potential biases and errors inherent in generative AI. As ChatGPT and similar tools increasingly become part of students' everyday learning, the ability to critically evaluate and synthesize information from multiple sources is essential to ensure meaningful and accurate learning outcomes.

Strategy use refers to applying efficient methods and techniques during interactions with ChatGPT to achieve specific objectives or get different nature of tasks done [49]. Building on Li et al.'s [50] findings on user coping strategies when facing conversational issues with the chatbot, such as rephrasing questions, repeating inputs, or shifting to a new topic, our research highlights additional strategies employed by students when interacting with ChatGPT. Our findings revealed that students employed diverse and flexible prompting strategies to optimize ChatGPT's performance across different tasks. For instance, when seeking concise definitions, students would use direct and specific prompts such as, "*Provide the definition of [...] (a concept) in less than 5 sentences* ." On the other hand, for deeper explorations, students phrased their prompts to elicit detailed responses, such as, "*Explain [...] (a concept) with examples and its relevance in [...] (ceratin context).*" Similarly, some students used multi-step prompting by first asking for a general overview and then narrowing the focus through follow-up questions, such as "*Give me an overview of [...](certain topic or theory)*"

followed by "*what does [...](one component of the topic) relate to [...](a broader topic or other components of the topic)?*" Additionally, students demonstrated creativity by tailoring prompts to specific learning objectives, such as letting ChatGPT critique their work from multiple professional perspectives or count the length of the written speech. In problem-solving contexts, such as coding or math, students often requested step-by-step solutions to understand the process better. Combining with students actively pushing back against incorrect or incomplete responses from ChatGPT in the previous discussion, these interactions and strategies highlight students' agency and critical engagement. Strategy use is crucial for enabling students to transition from passive recipients of AI-generated content to active participants who adapt their approaches to optimize learning outcomes across diverse contexts.

Attitude contains individuals' dispositions, emotions and perspectives towards ChatGPT as the learning context[49]. Our findings revealed nuanced differences in attitudes toward ChatGPT across various topics and learning contexts. For example, some students exhibited positive emotions and confidence in ChatGPT's outputs when engaging with technical subjects, such as coding, probably due to the clarity and precision of responses, while showing neutral attitude in other learning areas. Our findings highlight the variability of attitudes not only among different learners but also within the same individual when using ChatGPT to deal with different tasks and learning domains. Previous studies have often focused on generalized attitudes toward online learning contexts while neglecting the task- and domain-specific variations within the same learner. This variability underscores the importance of considering task-specific and contextual factors when evaluating attitudes toward AI tools in learning environments.

Autonomous-Adaptive Process . Besides the current indicators in the autonomous-adaptive learning process—planning, monitoring, adapting, and evaluating [49]—we propose adding a new indicator, *integrating*. This addition reflects the evolving nature of self-directed learning in the context of generative AI, which aligns with modern learning trends such as fragmented and interdisciplinary learning[76]. These trends emphasize the need to search and learn across multiple domains while adapting to students' diverse learning needs. Existing studies often focus on students' use of ChatGPT for single subjects or tasks [4, 41]. The process of students' use of ChatGPT to integrate or switch between various tasks and topics is under explored, failing to capture the nuanced, day-to-day ways in which students use ChatGPT for diverse learning. The section in our finding shows that students are now embracing integration as a key strategy to navigate fragmented and interdisciplinary learning trends. These learners use ChatGPT to seamlessly switch between tasks and topics, catering to their diverse needs and keeping the learning process engaging and efficient.

6.1.1 ChatGPT as the Learning Context. Design Elements refer to the features and characteristics of a learning context or technology that shape how learners interact with and navigate their learning experiences[91] [49]We propose adding two new indicators, *explanation* and *technological affordances*.

Explanation refers to the provision of clear, detailed, and relevant information or guidance on ChatGPT's ability and limitations. ChatGPT's ability to generate explanations emerged as a critical design element supporting students' learning processes. Based on our findings in *section 5.2*, in cases where ChatGPT failed to provide progress or delivered incomplete answers, its explanations were critical for guiding students to reformulate their questions or adjust their approach.Our findings also showed that ChatGPT in some contexts provided extra explanation, information, or guidance when the student's question could be potentially time-sensitive. This aligns with the broader literature on the importance of explanations in AI systems for supporting learning and fostering iterative problem-solving, such as providing explanations can reduce overreliance on AI by helping users understand the reasoning behind AI-generated solutions and thus foster critical thinking to address complex tasks[106]. Additionally, the field of explainable AI (XAI) focuses on making AI systems more transparent and understandable for building trust and facilitating effective

human-AI collaboration[22]. ChatGPT's explanations not only helped students recognize gaps in understanding but also encouraged active engagement.

We also propose one indicator, *technological affordances*, in the design elements. Technological affordances refers to the features and capabilities of a technology that enable or constrain user actions within a specific context[29][71]. According to our findings in *section 5.2*, ChatGPT's ability to provide instant feedback, adaptive responses, and personalized content exemplifies its facilitative affordances in students everyday learning. However, limitations such as ChatGPT's potential for generating incorrect information or lacking contextual nuance or coherence also highlight its constraints. These affordances significantly shape how students navigate their learning processes, underscoring the need to consider both the enabling and restricting aspects of technology in SDL frameworks.

Support Elements Support elements refer to the resources, technology, and guidance provided to assist learners in navigating challenges and achieving their learning goals [91][49]. We expand the current indicator of *non-human support* in Li et al.[49]'s model to *technology-enhanced scaffolding* and user-ChatGPT collaborative workflows. Technology-enhanced scaffolding refers to the effectively leveraging capabilities of digital tools or platforms to assist learners in achieving educational goals by adapting to their individual needs and promoting the development of skills for independent learning [42] [53]. It involves structuring the progression of learning through layered concepts and increasing complexity to guide exploration and reinforce understanding at each step [86] . Our findings in *section 5.2* articulate that ChatGPT can provide dynamic scaffolding by adapting its responses to learners' input, offering tailored suggestions, explanations, and prompts to guide students toward their learning goals step by step. This form of support fosters autonomy while ensuring that students have access to the assistance needed to overcome challenges.

Our findings also suggest that students often engage with ChatGPT in a collaborative manner, using it as a co-learner or partner to brainstorm ideas, refine drafts, or explore alternative approaches. This collaborative interaction represents a new dimension of support that is distinct from traditional non-human assistance.

Social Elements Echoing with existing studies[49][68], our findings also showed that incorporating social elements is of great importance in the integration of ChatGPT for students' self directed learning. Adding to Li's model[49], we add one indicator, *parasocial relationship*, under the social elements under the category of *learning context*. ChatGPT does have personification and social intelligence [12] that promotes human-like conversation and parasocial relationships [59]. These relationships are one-sided connections where users feel a sense of familiarity or emotional bond with an entity that does not reciprocate feelings, such as ChatGPT. While these human-like interactions can provide entertainment and a sense of engagement, they fall short of fulfilling deeper human needs, such as genuine friendship, emotional support, and mutual understanding [90]. Our findings revealed that while some students found ChatGPT's conversational style engaging and supportive, they also recognized its limitations in addressing more complex emotional or social needs. The integration of parasocial elements has both positive and negative implications for SDL. On the positive side, ChatGPT's conversational features can help reduce feelings of isolation often experienced in online learning environments, offering a sense of companionship and motivation. However, over-reliance on these interactions may lead to unmet emotional needs or unrealistic expectations about AI's capabilities. We add this indicator to highlight that to enhance the role of social elements in SDL, it is crucial to design AI tools like ChatGPT with a balanced approach.

6.1.2 Interactive Relationship between Different Components of Understanding Self-Directed Learning in Generative AI Context . We also articulate nuanced *interactive relationship* between different components, reflect the dynamic perspective of this model, which is critical aspects of SDL in the context of rapidly changing landscape with generative AI [91] [49]. The interplay between personal attributes and the autonomous-adaptive process reveals how learners with

varying levels of self-direction and strategy use approach SDL differently. For example, highly self-directed students actively refined their prompts and adapted their strategies when ChatGPT provides ambiguous or unsatisfactory responses. Conversely, some other students struggled to engage critically with the AI's output, relying heavily on its suggestions without iterative refinement. These differences highlight the importance of fostering metacognitive skills and adaptive capabilities to maximize the benefits of generative AI in learning.

Our findings show that personal attributes, such as emotions, are not static during their learning process. This demonstrated a bidirectional influence between personal attributes and the ChatGPT learning context.

The autonomous-adaptive process, which encompasses students' ability to evaluate their work, adapt strategies, and make decisions, interacts dynamically with the ChatGPT context. ChatGPT's responses impacted how students assessed their progress and decided on subsequent actions. For example, a student revised their perspective based on ChatGPT's suggestions, such as seeking additional references or restructuring arguments.

6.2 Policy and Design implications

For HCI researchers, these findings underscore the importance of designing AI-driven educational tools that align with students' needs while mitigating the risks associated with misuse [5] [39] [107]. ChatGPT's ability to simulate human-like conversation and provide personalized feedback resonates strongly with students, suggesting that future AI design should prioritize adaptability and responsiveness to user input [59]. Our study also reveals the emotional and parasocial dynamics that can develop between students and AI, pointing to a need for more sophisticated design strategies that account for user expectations, emotional engagement, and the risks of anthropomorphism.

Furthermore, the findings carry significant implications for the CHI community, as they highlight the need for HCI researchers to rethink the design and deployment of AI tools in educational settings. Our work suggests that simply banning or limiting the use of AI like ChatGPT is unlikely to be effective. Instead, there is a critical need to develop AI systems that are transparent, ethically sound, and capable of guiding students towards responsible use. This includes incorporating features that can help identify and correct misuse while still supporting legitimate learning activities.

Moreover, the repeated evidence that students use ChatGPT almost exclusively for academic purposes—and at times, for directly completing assignments—raises important ethical and pedagogical questions. It calls for educational institutions to proactively address these challenges by establishing clear guidelines on the responsible use of AI. This should include strategies for integrating AI literacy into the curriculum, equipping students with the skills to critically evaluate AI-generated content and use it to enhance their learning responsibly.

Concretely, we call upon the CHI community to help design the next generation of AI tooling particularly targeted towards two stakeholders: (i) Educational institutions, and, (ii) LLM providers.

Universities should expand current guidelines for ChatGPT use by encouraging students to critically engage with the AI's responses. For example, alongside existing instructions on using ChatGPT for writing assistance, students should be advised to challenge and critically evaluate the AI's outputs. Educational materials should emphasize that students can and should question ChatGPT's answers, especially in areas requiring critical thinking or nuanced understanding. More importantly, universities should organize workshops that focus specifically on the ethical implications of using AI in academic settings. These workshops could cover topics like plagiarism, academic integrity, and the responsible use of AI tools. Through case studies and interactive discussions, students can explore real-world scenarios that highlight both the positive applications and potential pitfalls of using ChatGPT.

OpenAI (and other LLM providers) could include an 'education mode' provided to universities which provides certain features such as: (i) transparency notices in its responses, especially when dealing with complex or sensitive topics.

For example, adding disclaimers like, "This response is based on information that may be outdated or incomplete" can remind students that AI-generated content should not be taken at face value. (ii) automatically flagging potentially problematic interactions, such as repeated attempts to get direct answers for assignments, (iii) Encourage students to reflect on their interactions with ChatGPT by maintaining a log of their queries and reviewing them periodically. Reflection prompts such as "Did ChatGPT help you understand this topic better?" or "What other ways could you have approached this question?" could be integrated into the learning process, fostering self-awareness and critical thinking skills.

7 Limitations and Future Work

This study utilizes deeply personal data obtained through a data donation model, prioritizing the privacy and anonymity of student participants. While conducting follow-up interviews could have enriched the analysis by providing additional context and deeper insights into the interactions, we deliberately chose to forgo this approach to protect participants' confidentiality. This commitment to privacy is central to our research design, though it does present certain limitations.

One key limitation of our study is the potential for sampling bias inherent in the data donation model. As participation is voluntary, there is a likelihood of self-selection, where individuals who choose to contribute their data may differ in meaningful ways from those who do not, despite efforts to emphasize the anonymity and security of the process. This could result in an under-representation of certain user behaviors or demographics, thus limiting the generalizability of the findings.

Regarding future work, the data donation model offers a scalable and flexible approach that preserves participant privacy, making it a promising method for expanding this research. Although our current study involves a relatively small sample size, the model can be extended to multiple sites and institutions, allowing for broader data collection across diverse student populations. Scaling the data donation model could provide a more comprehensive understanding of ChatGPT usage patterns, capturing a wider range of interactions and contexts.

There is significant potential for future studies to leverage this approach across various educational settings, enhancing the robustness and applicability of the findings. Expanding this work could facilitate comparative analyses between different academic institutions, disciplines, and student demographics, providing deeper insights into the evolving role of AI in education. Ultimately, our model not only safeguards privacy but also opens new avenues for large-scale research on human-LLM interactions, contributing valuable knowledge to the field of HCI and beyond.

8 Conclusion

With the proliferation of Chatbots and Large Language Models like GPT, there is a need for a more thorough understanding of the use Generative AI system in everyday life. In this study, we use mixed methods to analyze the digital archives of thirty six undergraduate students to analyze their use of ChatGPT. Using self-directed learning as a basis for our analysis, we reflect on how our findings push current SDL theories forward especially in relation to generative AI. We discuss the parasocial relationship between our respondents and ChatGPT as well as how it changed over time, especially in regards to conversational repair processes. We reflect on how our findings build on earlier work in human-chatBot interactions and provide design recommendations for better interactions with chatbots.

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9 Appendix

Table 6 shows the classifier results on all the categories and subcategories. Only categories and subcategories where the performance was satisfactory are being shown.

Table 7 shows the results from applying our classifier on the qualitative coding (Q, Section 4.2) and BERTopic (B, Section 4.1).

Table 6. Predicted category, prediction model metrics.

Category	Accuracy	Precision	Recall	F1	AUC ROC
Content Generation	0.903	0.920	0.956	0.938	0.843
Information Seeking	0.916	0.928	0.976	0.951	0.785
Students' Interaction with ChatGPT	0.910	0.950	0.872	0.909	0.911
ChatGPT's Response	0.821	0.205	0.708	0.318	0.768
Student Interaction with ChatGPT → students' positive feedback towards ChatGPT's answer	0.929	0.289	0.846	0.431	0.889
Information Seeking → academic content → questions on the coding errors	0.917	0.279	0.800	0.414	0.861
Information Seeking → academic content → ask Chat GPT to critique students' essay	0.919	0.029	1.000	0.057	0.959
ChatGPT's Response → apologizing for previous response	0.838	0.178	0.684	0.283	0.765
ChatGPT's Response → misunderstanding students' commands	0.914	0.162	0.600	0.255	0.761
Content Generation → multiple choices and filling blank questions	0.701	0.951	0.658	0.778	0.763

Table 7. Total categories from qualitative analysis (Q) and BERTopic topic modeling (B).

Category	#	Frac.	Source
Information Seeking	9,010	0.855	Q
Content Generation	8,213	0.780	Q
Student ChatGPT Interaction	5,217	0.495	Q
Science, Technology and Management	3,005	0.285	B
Coding	2,608	0.248	B
Social Science and Humanities	2,514	0.239	B
Math	1,241	0.118	B
Content Generation → multiple choices and filling in blanks questions	1,188	0.113	Q
Computer Science	512	0.049	B
ChatGPT's Response	445	0.042	Q
Chatgpt's Response → apologizing for previous response	351	0.033	Q
Student Interaction with ChatGPT → asking to rewrite student text	337	0.032	Q
Information Seeking → questions on coding error	226	0.021	Q
ChatGPT's Response → repairing misunderstandings	216	0.021	Q
Information Seeking → critique student essay	212	0.020	Q
Student Interaction with ChatGPT → casual talk	193	0.018	Q
Internship	177	0.017	B
Student Interaction with ChatGPT → Student's positive feedback towards ChatGPT	159	0.015	Q
Music	143	0.014	B
Synonym	98	0.009	B
Email	97	0.009	B
Polite	75	0.007	B
Financial	55	0.005	B
Citation	47	0.004	B