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RESEARCH ARTICLE

Exploring Students' Perceptions of ChatGPT: Thematic Analysis and Follow-Up Survey

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ABSTRACT ChatGPT has sparked both excitement and skepticism in education. To analyze its impact on teaching and learning it is crucial to understand how students perceive ChatGPT and assess its potential and challenges. Toward this, we conducted a two-stage study with senior students in a computer engineering program ($n = 56$). In the first stage, we asked the students to evaluate ChatGPT using their own words after they used it to complete one learning activity. The returned responses (3136 words) were analyzed by coding and theme building (36 codes and 15 themes). In the second stage, we used the derived codes and themes to create a 27-item questionnaire. The students responded to this questionnaire three weeks later after completing other activities with the help of ChatGPT. The results show that the students admire the capabilities of ChatGPT and find it interesting, motivating, and helpful for study and work. They find it easy to use and appreciate its human-like interface that provides well-structured responses and good explanations. However, many students feel that ChatGPT's answers are not always accurate and most of them believe that it requires good background knowledge to work with since it does not replace human intelligence. So, most students think that ChatGPT needs to be improved but are optimistic that this will happen soon. When it comes to the negative impact of ChatGPT on learning, academic integrity, jobs, and life, the students are divided. We conclude that ChatGPT can and should be used for learning. However, students should be aware of its limitations. Educators should try using ChatGPT and guide students on effective prompting techniques and how to assess generated responses. The developers should improve their models to enhance the accuracy of given answers. The study provides insights into the capabilities and limitations of ChatGPT in education and informs future research and development.

INDEX TERMS ChatGPT, students' perceptions, education.

I. INTRODUCTION

A chatbot is a computer program that simulates a conversation with users through natural language or text, giving the illusion of communicating with a human [1], [2]. Early chatbots relied on simpler pattern matching and string processing, but more advanced ones now use complex knowledge-based models [3]. Chatbots have long found their way to formal and informal education [4], [5]. They have been used to support learning [6], [7], increase students' engagement [8], [9], assess students [10], [11], and perform various administrative functions [12], [13].

Educational chatbots, however, face various limitations and challenges [14], [15]. These include difficulties in dealing with misspellings, understanding colloquial language, processing student inputs, and mimicking natural conversation flow, resulting in a transactional experience devoid of human emotion [9]. Moreover, some researchers highlight the lack of sufficient datasets as a common challenge in educational chatbots leading to learning difficulties and frustration [16]. Chatbots tend to lose their novelty effect over time, as reported in [17]. The authors also highlighted the challenge of comparing results across studies due to the lack of a standard construction protocol for chatbots [17]. As noted in [18], the sustainable use of chatbots for learning depends on their ability to provide smooth access to

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knowledge through efficient storage and retrieval techniques, i.e., knowledge application. To ensure sustainable use, service providers should prioritize the design of chatbots with features that provide reliable information and the ability to learn and browse in ''anytime and anywhere'' settings [18].

The emergence of chatbots that utilize large language models (LLM) represents a breakthrough in AI-powered human-computer interaction for knowledge creation. ChatGPT is such chatbot that can generate advanced text and engage in convincing conversations with users. It can help perform various tasks such as writing essays, brainstorming research ideas, conducting literature reviews, enhancing papers, and writing computer code [19]. The abilities of ChatGPT are expected to rapidly expand as it continues to receive new data through user interactions [20].

In education, ChatGPT was received both with admiration and controversy. Some authors believe that AI-based applications such as ChatGPT will inevitably become an integral part of writing, much like calculators and computers have become commonplace in math and science [21]. Therefore, some recommend involving students and instructors with such tools to facilitate teaching and learning, rather than prohibition [22]. In their position paper [23], the authors highlight the opportunities and challenges of ChatGPT for learning and teaching at all levels of education. Accordingly, ChatGPT can help students develop different skills including reading, writing, information analysis, critical thinking, problem-solving, generating practice problems, and research. It supports group and distance learning and empowers learners with disabilities [23]. Teachers can use ChatGPT for lesson planning, student assessment, and professional development. On the other hand, the authors highlight multiple key challenges including copyright issues, bias, fairness, excessive reliance on ChatGPT by students and teachers, lack of expertise in integrating this technology in teaching, the difficulty of distinguishing model-generated from student-generated answers, cost of training and maintenance, data privacy and security, and sustainable usage [23]. Furthermore, ChatGPT operates differently from search engines like Google as it doesn't scan the internet for up-to-date information, and its knowledge is limited to what it acquired before September 2021. Therefore, its inconsistent factual precision has been acknowledged as a notable drawback according to [24].

Academic integrity is probably the most discussed challenge ChatGPT will pose to education [23]. A few studies provide insights into ChatGPT's abilities to answer test questions. In a preprint, [25] assessed ChatGPT's ability to generate human-like responses to non-trivial university-level questions in various disciplines. To test this, ChatGPT was asked to create challenging critical thinking questions related to education, machine learning, history, and marketing that targeted undergraduate students. After generating the questions, ChatGPT was asked to provide answers and critically evaluate them. The author evaluated ChatGPT's responses based on their accuracy, relevance, clarity, precision, depth, breadth, logic, persuasiveness, and originality. He found out that ChatGPT displayed a high level of critical thinking rather than simply retrieving information. The responses generated by ChatGPT were clear, precise, relevant, logically coherent, and had sufficient depth and breadth. The author concluded that ChatGPT is a *potential threat to the integrity of online exams, particularly in tertiary education settings where such exams are becoming more prevalent*, [25]. In [26], the authors evaluated ChatGPT's performance on four sets of multiple-choice questions from the United States Medical Licensing Examination (USMLE). The authors manually entered the questions into ChatGPT and evaluated the answers according to the selected choice as well as the provided explanation in terms of its logical justification and the presence of information internal and external to the question. ChatGPT achieved 42%, 44%, 57.8%, and 64.4% in the four question sets, respectively. However, the performance decreases for questions with a higher difficulty index. The authors concluded that ChatGPT marks significant progress in large language models on the tasks of medical question answering. By performing more than 60% on one question set, the model achieves the equivalent of a passing score for a third-year medical student. Additionally, ChatGPT could provide logic and informational context across most answers. The authors recommended using ChatGPT as an interactive tool for medical education to support learning [26]. In [27], the authors carried out a similar study and assessed ChatGPT's effectiveness in the USMLE exam. They selected three question types: open-ended prompts without answer choices, and multiple-choice questions with and without mandatory justification. The authors discovered that ChatGPT attained scores near or at the passing threshold without specialized training or reinforcement. Moreover, ChatGPT's explanations were coherent and insightful. The authors suggested that ChatGPT could be used in medical education and potentially support clinical decision-making [27].

Although these studies provide initial insights into the potentials and challenges of ChatGPT, they do this from an educator rather than a student perspective. In particular, in all the cited papers, the system was prompted and the responses were evaluated by the researchers rather than by students. To fully understand ChatGPT's impact on education, we need to investigate students' experience with this language model and their perceptions of it. Students' perceptions are highly relevant for education as they can have a significant impact on their motivation, engagement, and academic achievement [28]. When students have positive perceptions of their learning experience, they are more likely to be engaged and motivated to learn, which can lead to better academic outcomes. On the other hand, when students have negative perceptions of their learning experience, they may become disengaged, less motivated, and less likely to achieve academic success [29].

To our knowledge, students' perceptions of ChatGPT have not yet been addressed in the literature. The presented study

aims to close this gap by addressing the following research questions:

1) How do students perceive ChatGPT in the context of learning?
2) What are ChatGPT's pros and cons from students' perspectives?

To assure that the students express their perceptions based on experience, they were asked to complete some activities using this application before they responded to our surveys. To explore students' thoughts without restriction, we first asked them to use their own words to express their opinions as a response to an open-ended question. Their comments were then analyzed thematically to identify relevant strengths and weaknesses of ChatGPT. The outcomes of this thematic analysis were then used to develop a questionnaire to assess these pros and cons quantitatively from students' perspectives. A framework for using ChatGPT was created that informs educators and researchers about relevant aspects of ChatGPT in education and necessary actions and research in this area.

The rest of the paper is structured as follows. Section II outlines the methods used in this study. Section III summarizes the results and Section IV discusses them. Section V describes the implications of this research and its limitations and concludes the paper.

II. METHODS

The methods employed in this study are illustrated in Figure 1, where the blocks on the left side depict the contributions made by the students.

A. PARTICIPANTS

The participants of this study are 56 senior students (66% males) taking a core course on embedded systems in a computer engineering program in Spring 2023.

B. CONTEXT

The course teaches the foundations of embedded systems including microcontroller system architecture, memory optimization, hardware/software interfacing, register-level programming, interrupts, timers, analog signal processing, pulse wide modulation, serial communication, and real-time operating systems. A lecture-free method is used for teaching the course, where the students receive an Ardunio-based kit and complete learning activities using Moodle in the classroom or at home [30].

C. ChatGPT-BASED ACTIVITIES

We created four ungraded quizzes on Moodle that the students had to complete using ChatGPT. We made sure that the questions relate to topics that were not yet taught in the course so that the students make genuine efforts in prompting ChatGPT to get the answers. The activities included conceptual questions, code completion tasks, and code analysis questions. The students prompted ChatGPT to obtain the answers to these questions, entered these answers into Moodle, and checked their correctness. This way, the students could evaluate the accuracy of the ChatGPT. Figure 6 in the appendix shows two examples of these questions. To ensure that students used ChatGPT to answer the questions, they were required to include their conversations with ChatGPT in the text fields of additional essay questions within the same quizzes. Note this study focuses on students' perceptions of ChatGPT and does not analyze their performance in the activities.

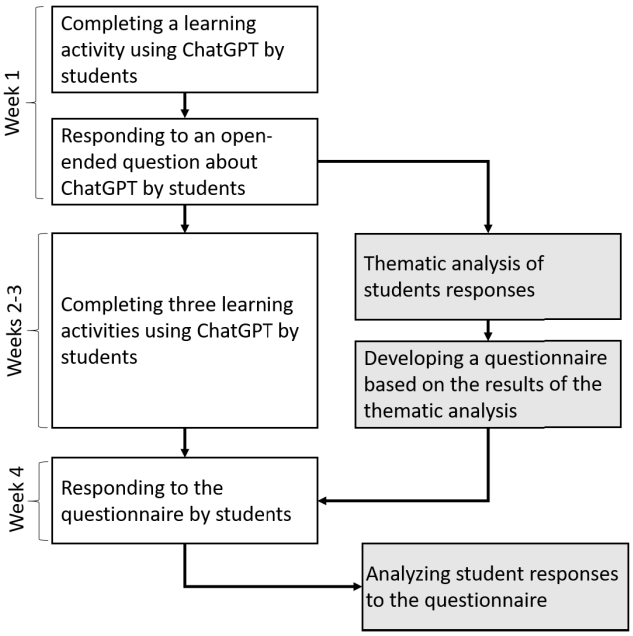

FIGURE 1. Methods used in this study.

D. OPEN-ENDED QUESTION

After completing the first activity, the students were asked to respond to the following open-ended question through Moodle:

"What do you think of ChatGPT? Think deeply and write down whatever comes into your mind!".

The purpose of this question is to efficiently solicit students' opinions without limitations as a basis for generating specific questionnaire items in the second stage of the study.

E. THEMATIC ANALYSIS OF STUDENTS' RESPONSES

Students' responses to the open question were cleaned and analyzed using Taguette [31]. This free application supports analyzing qualitative data such as interview transcripts, survey responses, and open-ended survey questions. Taguette enables users to encode different segments of text data, making it easier to identify patterns or themes. Figure 2 shows a screenshot of Taguette with the processed response file. To encode a text segment, we highlight it and assign a tag. New tags (codes) are added when needed. Taguette allows multiple tagging if a text segment contains different ideas. The left-side tab in Figure 2 shows part of the evolved tags

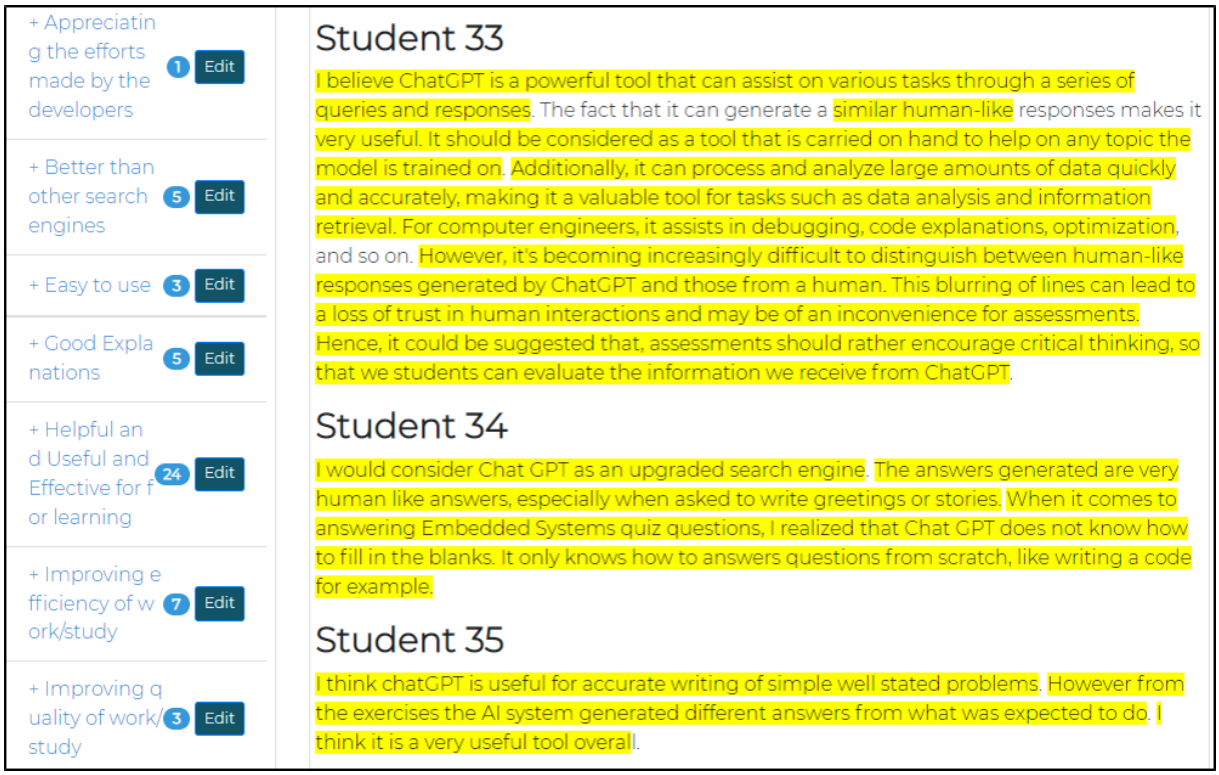

FIGURE 2. Taguette-The software used for coding students responses to the open-ended question: "What do you think of ChatGPT? Think deeply and write down whatever comes into your mind!."

during the coding. After completion, the data were exported to Excel for further analysis. Theme building is a mental step that consists in identifying similar codes and grouping them into themes. The result section will provide insights into the evolved codes and created schemes.

F. 27-ITEM QUESTIONNAIRE

The use of an open question allowed the students to express their thoughts without limitations, and the subsequent thematic analysis aimed to categorize these thoughts into patterns (codes and themes). The aim of the questionnaire it returns these patterns to all students so that every student can assess every item which can enable a quantitative assessment of the different aspects of ChatGPT. A 27-item questionnaire was developed and posted on Moodle based on the derived codes and themes. Each item required students to indicate their level of agreement with a given statement using a 5-point Likert scale (*Yes very much*, *Yes*, *Average*, *No*, and *Not at all*). Since the questionnaire items resulted from the thematic analysis, they will be described in the result section. The students responded to this questionnaire after completing three more ChatGPT activities.

G. ANALYZING STUDENTS' RESPONSES TO THE QUESTIONNAIRE

Students' responses to the questionnaire were evaluated using frequency analysis. To compare their relevance, each item was assigned an *average rate* (*AR*) that varies between 1 and 5. *AR* is calculated as:

$$AR = 5 \times f_5 + 4 \times f_4 + 3 \times f_3 + 2 \times f_2 + 1 \times f_1,$$

where f_5, f_4, f_3, f_2, and f_1 are the relative frequencies of using the rates *Yes very much*, *Yes*, *Average*, *No*, and *Not at all*, respectively.

III. RESULTS

A. THEMATIC ANALYSIS

Table 1 summarizes some statistics related to the responses to the open question including the number of students asked and responded as well as the size of their responses in terms of

TABLE 1. Basic response statistics.

Number of students asked	56
Number of responses	48
Total number of words	3136
Average number of words per response	65.3
Number of words in longest response	238
Number of words in shortest response	10

TABLE 2. Simple statistics related to the initial codes and themes.

Number of coded comments	171
Positive comments	115 (67%)
Negative comments	56 (33%)
Number of initial codes	36
Number of themes	15

TABLE 3. Initial codes and themes.

Initial Code	Theme
+ Amazed by the capabilities	PT1: Enthusiasm and appreciation
+ Appreciating the efforts made by the developers	
+ Better than other search engines	
+ It is a revolution	
+ Indicator of the power of AI	
+ Will change education, learning, and knowledge acquisition	
+ Helpful, useful, and effective for learning	PT2: Helpful for learning
+ Good as a complementary learning resource	
+ Personal human-like and friendly impression	PT3: Human-like conversation
+ Possibilities to ask follow up questions	
+ Improving efficiency of work/study	PT4: Helpful for work
+ Improving quality of work/study	
+ Useful for computer engineering and programmers	
+ Interesting	PT5: Interesting and motivating
+ Motivated to use it more	
+ Good Explanations	PT6: Good explanation
+ Well structured answers	
+ Will become more powerful with the time	PT7: Optimism
+ Optimism	
+ Easy to use	TP8: Easy to use
- Inaccurate output-Not 100% Reliable	NT1: Inaccurate answers
- Having some faults	
- Not perfect, needs improvement	
- Knowledge cut-off date	
- Does not replace human intelligence	NT2: Does not replace human intelligence
- Needs background knowledge in the area	
- Facilitates cheating- should not be used in open exams	NT3: Negative impact on education
- Counter-effective for learning	
- Difficulty in understanding users prompt	NT4: Tricky to use
- Tricky	
- Hacking-Scary	NT5: Can facilitate malicious use
- Malicious use	
- Potential to replace jobs	TN6: Can threaten job opportunities
- Having some concerns	NT7: Uncertainty about impact
- Unclear impact on future	
- Uncertain	

the number of words. While some students were brief in their comments, others provided detailed responses. The average response length was 65.3 words.

Table 2 summarizes some relevant quantities related to the performed thematic analysis. A coded comment refers to a sentence or a part of a sentence that contains a clear idea that could be assigned to a simple code. By analyzing students' responses, we identified 171 such comments. Almost two-thirds of these comments reflect positive perceptions of ChatGPT. 36 initial codes have emerged through the coding process. After multiple rounds of similarity analysis, these codes were mapped to 15 themes.

Table 3 shows the 36 initial codes and the corresponding themes that resulted from the coding and theme-building process. We used the signs + and − in the code name to highlight whether it is positive or negative. 20 positive and 16 negative codes emerged and were mapped to eight positive themes (TP1 to TP8) and seven negative themes (TN1 to TN7), respectively. Table 4 provides examples of students' comments for each theme.

Figure 3 shows the percentage of comments that we mapped to every theme. It again reflects that 67% and 33% of the comments were positive or negative, respectively. 20% of all comments reflected students' enthusiasm about ChatGPT technology, capabilities, and possible impact on our life (PT1). Some other themes provide reasons for this enthusiasm to some extent. Themes PT2 and PT4 reflect pragmatic reasons. They indicate students' perceptions of the usefulness of this platform not only for learning and study (PT2) but also for professional life (PT4). In contrast, themes PT3, PT6, and PT8 include comments that highlight students' appreciation of how ChatGPT interacts with them in terms of its human-like (PT3) and easy-to-use (PT8) interface as well as the good explanations it provides (PT6). 5% of the comments indicate that the students are interested in this platform and motivated to use it (PT5). Several students identified issues but expressed optimism in 3% of the comments (PT7).

On the other hand, several students highlighted accuracy issues in 11% of the comments (NT1). 8% of the comments point to mitigating this issue by having a sufficient background for using ChatGPT and being careful with the

TABLE 4. Some examples of students' comments.

Theme	Examples form students comments
PT1: Enthusiasm and appreciation	It's a fascinating tool that proves how far Artificial Intelligence has become...
	It is absolutely amazing what this technology is capable of.
PT2: Helpful for learning	In my opinion Chat GPT is really helpful. It is a useful tool for studying and learning.
	Chat GPT will help us a lot in this course because it can generate Arduino codes which will help us in building some advanced projects....
PT3: Human-like conversation	It feels like having a smart friend which we ask anything and it can answer.
	[You] can ask follow up questions and it stays in the conversation.
PT4: Helpful for work	I believe that chat GPT will be an important tool for all engineers in the different fields to use.
	It will really help everyone; students and professionals.
PT5: Interesting and motivating	I find it very interning way to interact with a machine.
	I never used Chat GPT before to study and I am planning on using it in the future.
PT6: Good explanation	[It] explains any part that I might not understand or have problems with.
	..all the well-structured answers..
PT7: Optimism	I think its capability will be much increased when it starts to use the internet and real-time computation, then it will be unimaginably powerful.
	All in all, I believe ChatGPT's pros outweigh its cons and I don't think we should stop enhancing it (the sky is the limit).
PT8: Easy to use	It is very easy to use, explains the code and also the concepts behind the code, can ask follow up questions and it stays in the conversation.
	I think it will be handy for my courses when I am stuck on something.
NT1: Inaccurate answers	However, I think it's still in its early stages and a lot of work needs to be done to ensure the accuracy and the reliability of the answers.
	Though it doesn't always give the rights answers
NT2: Does not replace human intelligence	When it comes to codes generated, some of the code snippets are not quiet correct, so anyone using it should be careful and have to go through the codes thoroughly.
	However, I don not think it is a good idea to completely rely on it, as I am sometimes skeptical myself of the answers it may give.
NT3: Negative impact on education	But I also think it is too powerful to have while doing open-book quizzes since it is able to answer many questions accurately.
	Yet I feel its kind of defeating the purpose of learning all the stuff we are studying.
NT4: Tricky to use	Little tricky.
	It is good and bad because sometimes it did not understand me.
NT5: Can facilitate malicious use	Of course, people will use it to maliciously.
	Scary thing, because I think they will install the software in the robots mind and they will have information about anything.
NT6: Can threaten job opportunities	I feel like the job of a computer engineers / computer scientist will be replace by it which is sad. I feel my bachelor will not be that special anymore.
	Maybe even replace existing job and make humans not needed in some cases.
NT7: Uncertainty about impact	Other than that, there are some problems when it comes to the morality of using it, and what effect it will have on people and industries in the future.
	Even though I have some concerns.

provided answers since ChatGPT does not replace human intelligence (NT2). Some comments point to difficulties in using ChatGPT especially in forming the prompt (NT4). Themes NT3, NT5, and NT6 represent students' perceptions of various drawbacks of ChatGPT. 6% of the comments refer to a negative impact on learning and education through heavy reliance on this platform and academic dishonesty (NT3). A few students mentioned possible misuse of the platform, e.g., by collecting users' private data (NT5) and that ChatGPT may threaten jobs (NT6). 2% of the comments indicate that some students feel uncertain about ChatGPT and how it will affect their lives (NT7).

B. SURVEY RESULTS

The thematic analysis enabled us to explore the range of students' perceptions and set up the questionnaire items. The responses to the questionnaire items by students allow us to assess the level of these perceptions quantitatively. The questionnaire consisted of one two questions per theme as summarized in Table 5. Note that several items are derived from the initial codes directly.

Figure 7 and Figure 8 in the appendix show students' responses to the items for the positive and negative themes, respectively. Figure 4 shows the average rate AR (defined in Section II-G) for each item in descending order. From these results we can conclude the following:

1) Most of the highly and slightly rated items belong to the positive or negative themes, respectively. Specifically, the positive-theme items are rated 4.1, on average. In contrast, the average rate of the negative-theme items is 3.4. In other words, the students showed stronger agreement about the positive features of ChatGPT.
2) The students expressed overall positive perceptions including interest ($AR = 4.7$), admiration ($AR = 4.34$), motivation ($AR = 4.25$), and optimism ($AR = 3.85$). Almost 96% of the students find ChatGPT interesting or very interesting. Around 83% of them feel motivated to use it. On the other hand, there are modest perceptions of uncertainty ($AR = 3.18$) and concerns about the impact of ChatGPT ($AR = 3.0$).
3) The most agreed-upon issue of ChatGPT is that it does not replace human intelligence ($AR = 4.32$) and that

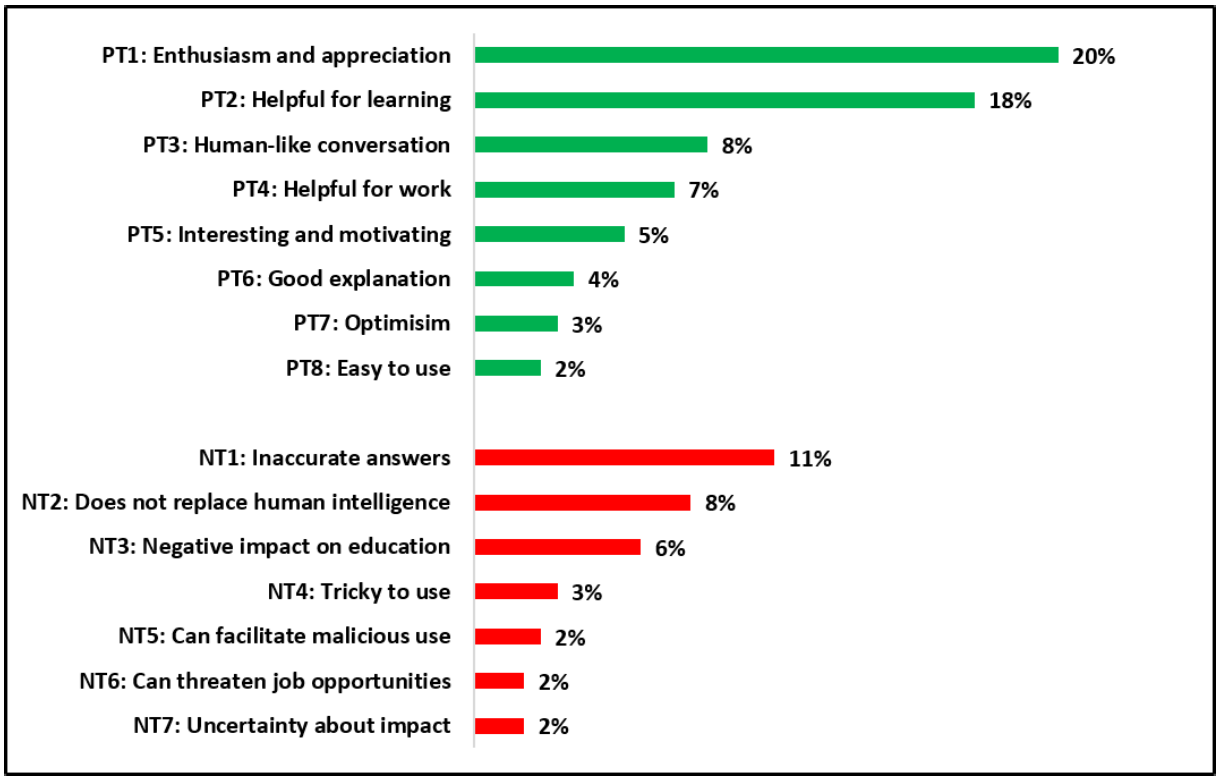

FIGURE 3. Relative frequency of students' comments per theme.

TABLE 5. Questionnaire items per theme.

PT1: Enthusiasm and appreciation	I am amazed by the capabilities of ChatGPT!
	ChatGPT is better than other search engines like google!
PT2: Helpful for learning	ChatGPT is a helpful and effective technology for learning!
	ChatGPT is good as a complementary learning resource!
PT3: Human-like conversation	ChatGPT makes human-like friendly impression!
	Asking follow-up questions helps ChatGPT find the correct answer!
PT4: Helpful for work	ChatGPT allows me to study more efficiently!
	ChatGPT is a helpful and effective tool for programming and computer engineering work!
PT5: Interesting and motivating	ChatGPT is interesting!
	I feel motivated to use ChatGPT more!
PT6: Good explanation	ChatGPT provides good explanations!
	ChatGPT answers are well structured!
PT7: Optimism	I think the quality of ChatGPT will improve soon!
	I feel optimistic about ChatGPT!
PT8: Easy to use	ChatGPT is easy to use!
NT1: Inaccurate answers	ChatGPT answers are accurate!
	ChatGPT is not perfect and needs to be improved!
NT2: Does not replace human intelligence	To work with ChatGPT you still need the human intelligence!
	To work with ChatGPT, you need some background knowledge in the area of your question!
NT3: Negative impact on education	ChatGPT will make academic cheating easier!
	ChatGPT will affect learning negatively because students will find answers and solutions without effort!
NT4: Tricky to use	ChatGPT does not understand my questions!
	Formulating questions for ChatGPT is tricky!
NT5: Can facilitate malicious use	ChatGPT will open the door for manipulations and malicious use!
NT6: Can threaten job opportunities	ChatGPT will threaten people jobs!
NT7: Uncertainty about impact	I am concerned about the impact of ChatGPT!
	I feel quite uncertain about the impact of ChatGPT and how it will change our life!

you need to have the sufficient background knowledge to benefit from it ($AR = 4.06$).

4) When it comes to the actual interaction with the system, the majority of the students find ChatGPT easy to use ($AR = 4.16$) although formulating prompts is moderately tricky ($AR = 3.50$). Still, the students feel that asking follow-up questions can help in finding the correct answer ($AR = 3.83$)

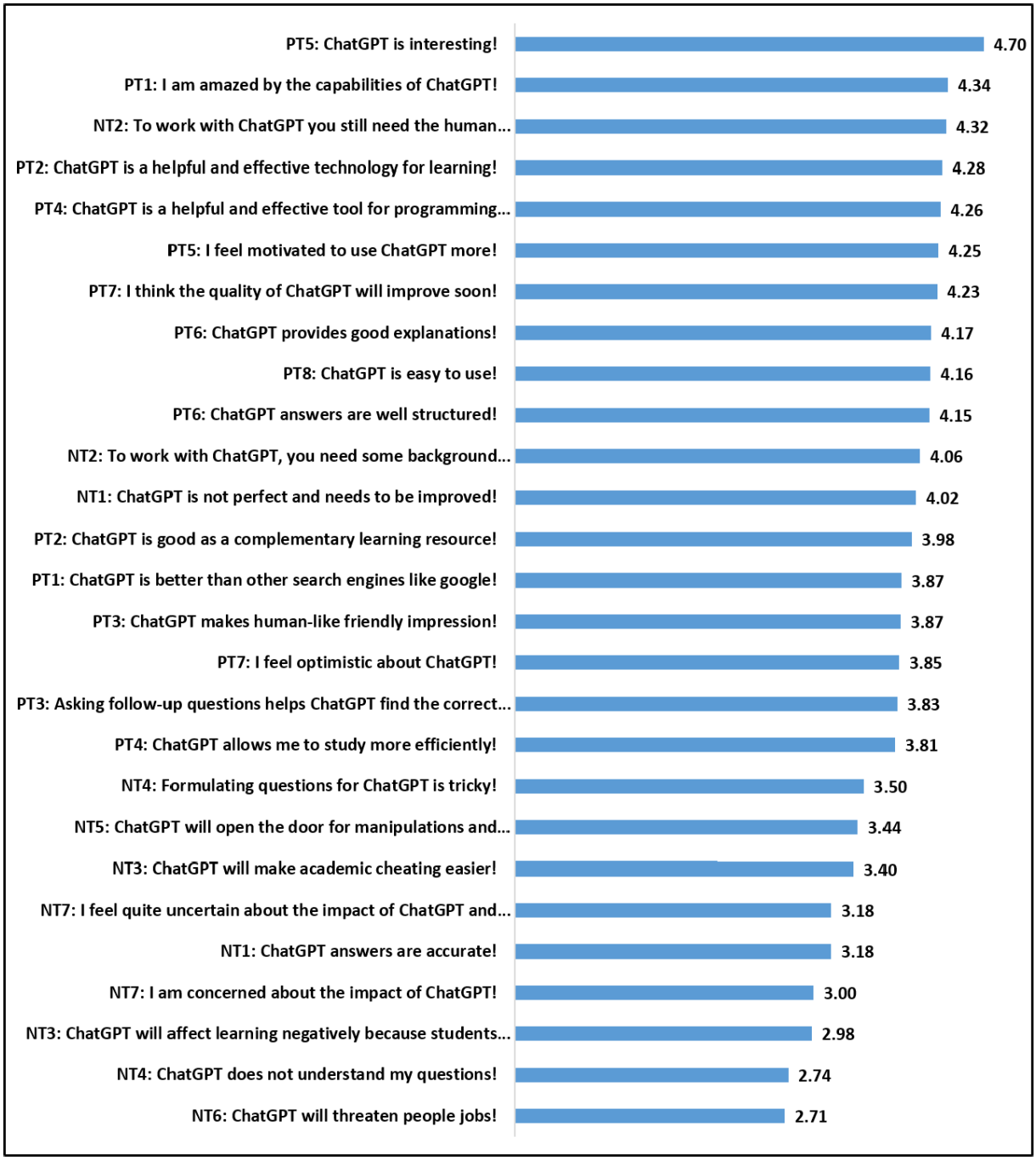

FIGURE 4. Average rate of the survey items from largest to smallest.

which makes an impression of human-like interaction ($AR = 3.87$).

5) With respect to generated answers, the accuracy of ChatGPT was rated moderately ($AR = 3.18$). This is confirmed by the observation that most students find it not perfect and needs improvement ($AR = 4.02$). Nevertheless, the majority of the students think that ChatGPT provides good explanations ($AR = 4.16$) and well-structured answers ($AR = 4.0$).
6) As for the impact on learning, most students find that ChatGPT is helpful for learning ($AR = 4.28$) and can be used as a complementary resource for learning ($AR = 3.98$). Interestingly, however, fewer students feel that ChatGPT would improve the efficiency of their study ($AR = 3.81$). The students perceive the negative impact of ChatGPT on academic integrity and learning as modest according to their responses to NT3 items ($AR = 3.4$ or 2.98, respectively).

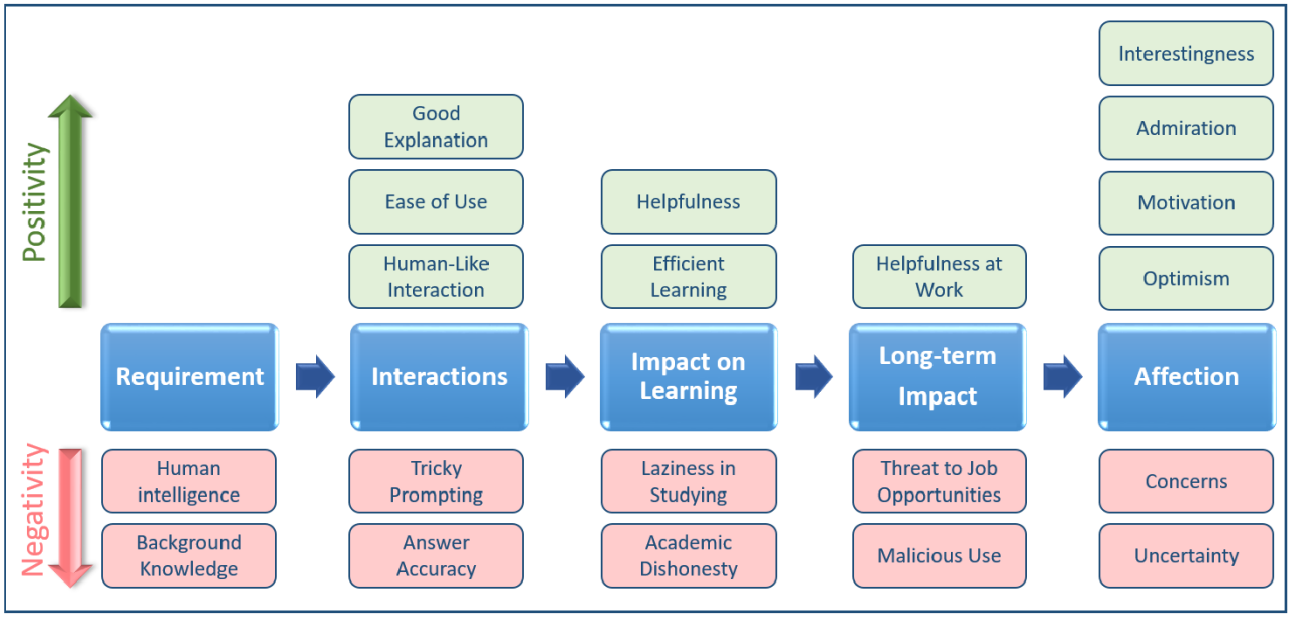

FIGURE 5. Study summary as a framework for using ChatGPT in education.

7) With respect to ChatGPT's impact beyond study, most students anticipate that it will help programmers and computer engineering in their professional life ($AR = 4.26$). This is in line with their moderate perception of ChatGPT as a threat to future jobs ($AR = 2.71$). However, the students tend to think that this platform will pose other threats such including manipulations and malicious use ($AR = 3.44$).

IV. DISCUSSION

With the emergence of large language models, a principal question arises for education: Will these models be a chance or a challenge to today's teaching and learning systems? Students are core players in this context. Understanding their perceptions is indispensable for addressing this question. In this study, the students have provided comprehensive and insightful thoughts about ChatGPT that helped in designing questionnaire items. The responses to the questionnaire allowed us to assess the relevance of various aspects of using ChatGPT in education. Figure 5 summarizes the main findings of this study as a framework for using ChatGPT in education. The middle branch represents five core components including basic requirements, students' interaction with the system, its impact on learning, its long-term impact, and the development of affections.

To utilize ChatGPT effectively, students must have an adequate background in the relevant field of study so that they can generate appropriate prompts and critically evaluate the responses provided by the system. This suggests that ChatGPT, at least at the current time, should not be relied on as a sole resource for learning by students who don't have sufficient prior knowledge. But what about using ChatGPT by students who have this knowledge? Isn't this a risk to academic integrity? Our students assessed this risk moderately. In contrast, some researchers highlight academic dishonesty as a major challenge of large language models [25]. This suggests that educators and educational institutions must reconsider how to assess students and implement new measures to prevent academic misconduct. In [24], the authors presented some ideas to avoid academic dishonesty in the era of AI-powered language models. Accordingly, we should move away from overly formulaic tests and opt more for assessment methods that cultivate students' creative and critical thinking abilities. This can be achieved by implementing various strategies such as in-class assessments, presentations, and performances, allowing for student choice in topic selection, and using authentic assessment methods that reflect real-world situations [24].

Interacting with ChatGPT is made easy and engaging through its natural language conversations. Students may feel comfortable and less thoughtful when composing their queries leading to less accurate responses. Furthermore, the good explanations provided by ChatGPT can create a false sense of accuracy. Therefore, it is crucial for educators and instructors to guide students on effective techniques for generating prompts and evaluating responses. Large language models like ChatGPT don't just retrieve information like traditional search engines but generate new knowledge by inference starting from user prompts. Prompt engineering is an emerging topic in large language models that provides an understanding of how prompting affects the performance of these models [32], [33].

Despite the trickiness of prompting and the modest accuracy, the students perceive ChatGPT as a helpful and efficient tool for learning and professional life. The perceived usefulness and ease of use are determinants for the

If you run the code below and enter 5 in the serial monitor, you will get the following:

Output

```
1! = 1
2! = 2
3! = 6
4! = 24
5! = 120
```

Complete it!

Code Q16

```
int* ptr;
void setup() {
  Serial.begin(9600);
}
void [      ]() {
  if (Serial.available() > 0) {
    x = Serial.parseInt();
    ptr = (int*)[      ]((x + 1) * sizeof(int));
    for (i = 0; i <= x; ++i) {
      int fact = 1;
      if (i != 0) {
        for (int j = 1; j <= i; j++)
          fact = [      ] * [    ];
      }
      ptr[i] = fact;
    }
    for (i = 1; i <= x; ++i) {
      Serial.print(i);
      Serial.print("! = ");
      Serial.println(ptr[i]);
    }
    for (i = 1; i <= x; ++i) {
      Serial.print(i + (": ") + ptr[i]);
    }
    [      ](ptr);
  }
}
```

Given the following code!

Original Code

```
void setup() {
  Serial.begin(9600);
}
void loop() {
  for (int i = 1; i < 5; i++)
    Serial.println("Hello");
}
```

Optimize its memory usage!

Optimized Code Q17

```
void setup() {
  Serial.begin(9600);
}
void loop() {
  for (      i = 1; i < 5; i++)
    Serial.println(      "Hello");
}
```

FIGURE 6. Examples of questions students used ChatGPT to answer. The missing words in the left-side question are *loop*, *malloc*, *fact*, *j*, and *free* in order. The missing words in right-side question are *byte* and *F* in order.

behavioral intention to use technology according to the technology acceptance model (TAM) [34]. On the other hand, the students evaluate the disadvantages of ChatGPT for learning moderately. So, they don't see the system as a major threat to learning or academic integrity. This is in line with and probably due to their perception that ChatGPT is not a golden source of knowledge. Rather, using it requires background knowledge and thoughtful engagement in crafting the prompts and evaluating the responses. Similarly, the negative impact of ChatGPT on job opportunities is evaluated moderately. Again, this is in line with other perceptions, e.g., that ChatGPT does not replace human intelligence and is good a complementary rather than sufficient resource.

The students expressed high levels of interest, admiration, and motivation toward ChatGPT. Interest is highly relevant for learning since it enhances students' self-regulation, collaboration, problem-solving, and joy of learning [35]. Many factors may have contributed to these attitudes such as the good explanations, the ease of use, the human-like conversation, and the usefulness for learning. However, this study did not establish correlations between these factors and the perceived level of interest. It would be desirable to understand

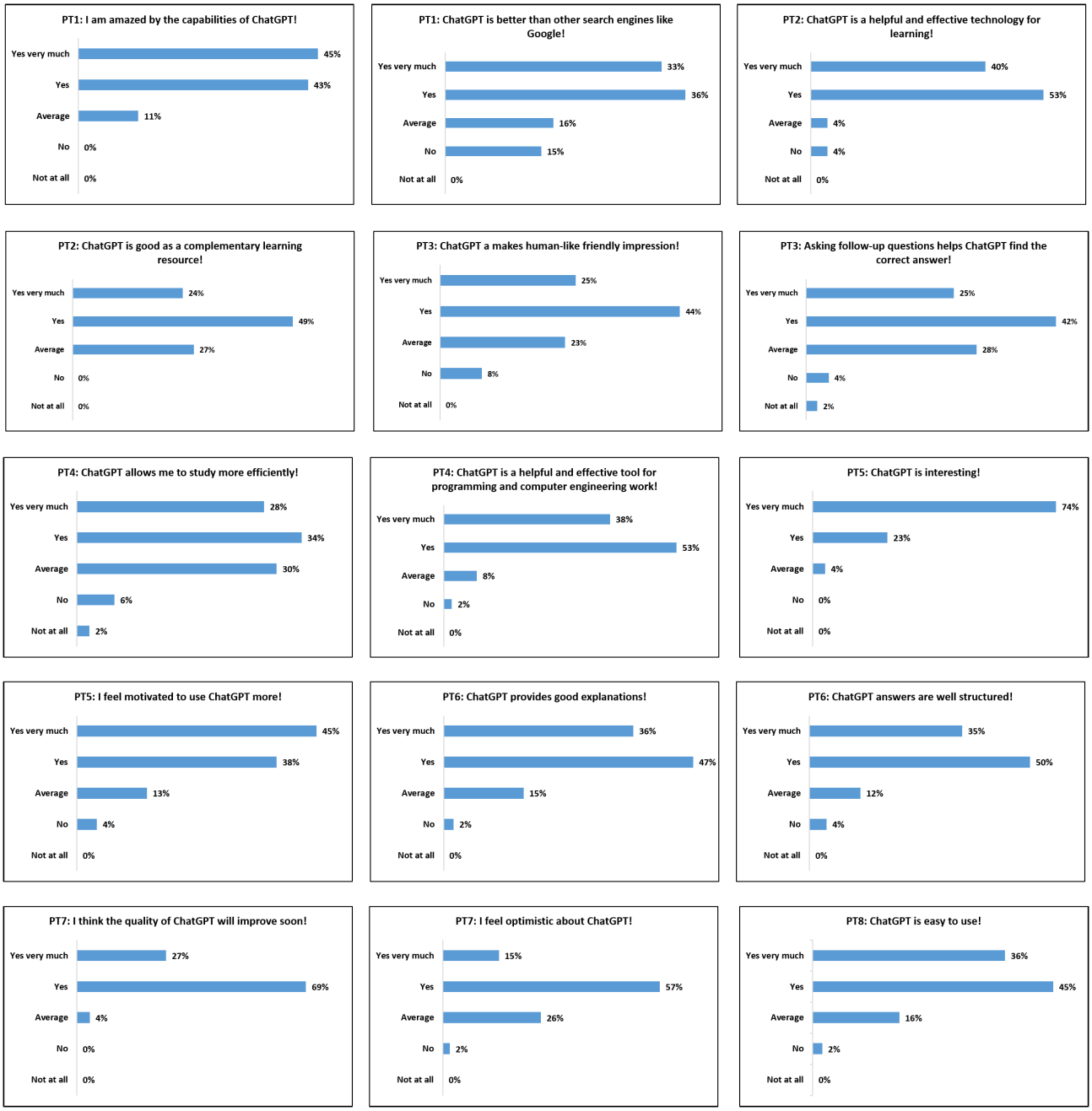

FIGURE 7. Students' responses to the items related to the positive themes.

how this situational interest can develop into individual interest that motivates the long-term usage of this technology [36].

V. IMPLICATIONS, LIMITATIONS, AND CONCLUSION

This study has several implications for education and research:

1) Despite its moderate answering accuracy, ChatGPT seems to be an attractive platform for students. They are impressed, interested, motivated, and optimistic about it. Educators should investigate how to make the best out of this interest. They should explore the capabilities and deficits of ChatGPT in their fields and teach students how to use it beneficially.
2) Research in educational psychology is needed to understand what makes ChatGPT so attractive and what can be done to maintain students' interest in this platform. This study has pointed to some factors that can be considered such as the explanation quality and the human-like interaction.
3) The study has highlighted some factors that are typically relevant for technology acceptance including the usefulness and ease of use. More research is needed to understand these and other factors using

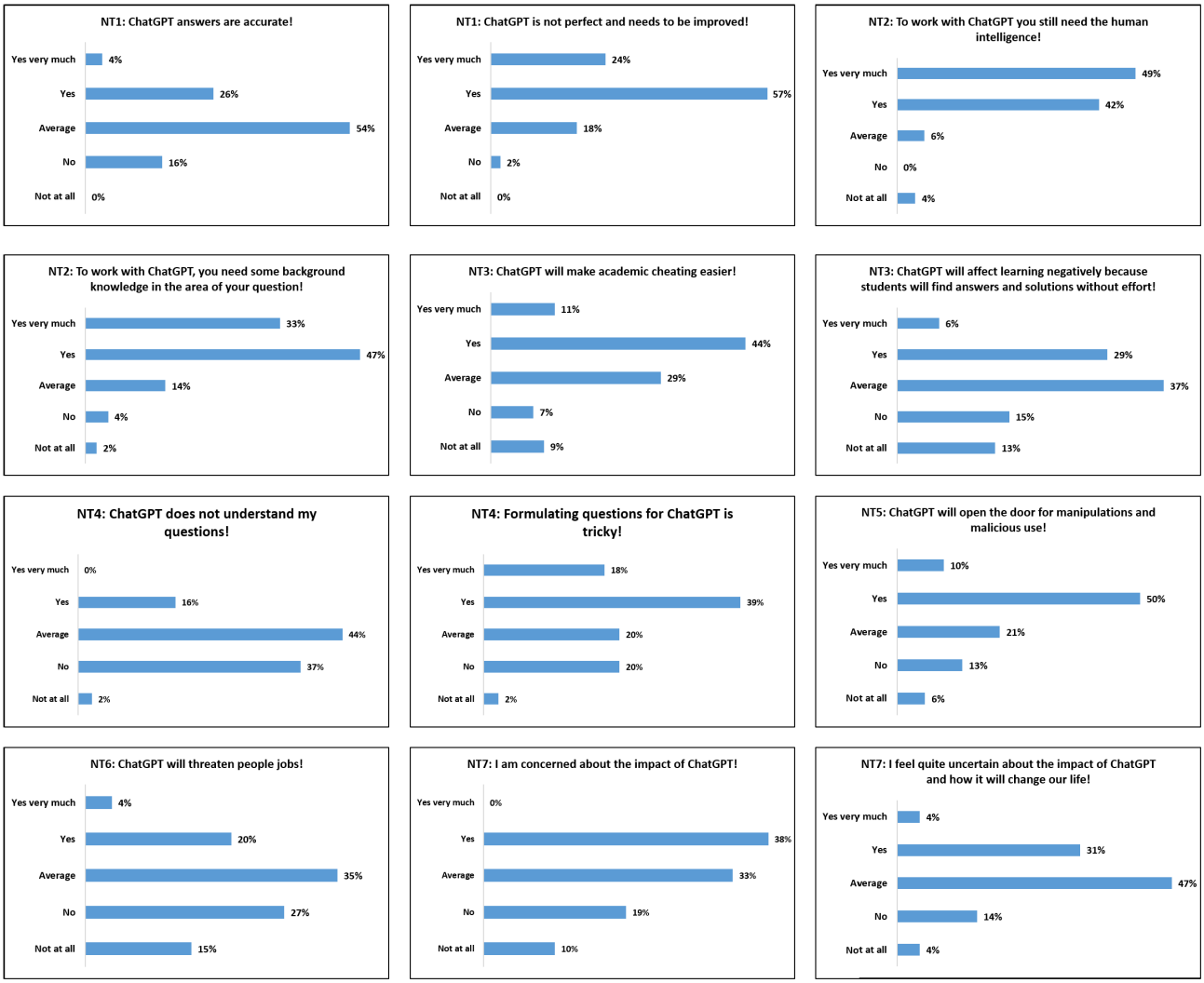

FIGURE 8. Students' responses to the items related to the negative themes.

modern models such as the unified theory of acceptance and use of technology (UTAUT) [37]. This theory explains the behavioral intention to use technology by four constructs: performance expectancy, effort expectancy, social influence, and facilitating conditions. For instance, ChatGPT has enjoyed enormous attention in media and societies. Were students' perceptions affected by this hype? Furthermore, UTAUT considers several moderators such as gender, age, and experience. More research is needed to understand the impact of these moderators.

4) The role of human intelligence and background knowledge is not yet understood. Empirical research is needed to link these factors to the quality of students' prompts and ChatGPT's responses. Prompt engineering is an emerging field that addresses such questions not only for training large language models but also for using these models [38].
5) ChatGPT shows good performance on certain tasks such as writing essays, and it is expected to improve soon. Educators should get ready for the time when ChatGPT and other large language models will become more capable and accurate and less dependent on prompt quality. This will not only transform the way students acquire knowledge but also disrupt current assessment methods. It is not too early to start thinking about creative assessment techniques for the AI era.

This study has several limitations:

1) The participants of the study are computer engineering students and the activities were related to a specific subject. Although most student responses were general and not specific to their area of study and the course, replicated studies for other educational levels, other programs, and other subjects are needed to confirm the findings of this study.
2) The thematic analysis used multiple rounds of coding and theme building and multiple refinements based on some expert feedback on a best-effort basis. The study would have benefited from multiple coders and an

inter-rater reliability analysis but, unfortunately, other raters were not available. Note that student responses to the questionnaire support the reliability of the thematic analysis to some extent. For example, students' comments with positive attitudes towards ChatGPT in the thematic analysis were confirmed by high rates of the related items of the survey.

3) The study did not establish correlational links between different codes, themes, or responses to questionnaire items. Creating such relationships require dedicated studies in the future.

In conclusion, AI-powered large language models including ChatGPT will shape a new era of information technology. With the unprecedented interest in ChatGPT and unprecedented interaction through hundreds of millions of users, we should expect to see a boost in quality soon. Accuracy issues will get less. The better this technology will get, the higher the chances to benefit students' learning, but the higher the challenge to academic integrity. This revolution in information technology should be best accompanied by revolutionary thoughts about our current methods of teaching and assessment.

A. DATA AVAILABILITY STATEMENT

The data supporting the findings of this study are available from the corresponding author on request.

APPENDIX A
EXAMPLES OF QUESTIONS STUDENTS USED CHATGPT TO ANSWER

See Figure 6.

APPENDIX B
STUDENTS RESPONSES TO THE QUESTIONNAIRE

See Figures 7 and 8.

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