Exploring Student Interactions with I in C Programming Training

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ABSTRACT

In recent years, the integration of artificial intelligence AI) in education has collected significant attention due to its potential to revolutionize learning experiences and support student skill development. This study delves into the dynamics of student interactions with AI support within the domain of C programming education, with a specific focus on the utilization of ChatGPT, a conversational AI model, during training sessions. Through manual clustering analysis, this research unveils distinct patterns of student engagement, elucidating diverse problem-solving approaches and varying levels of interaction with ChatGPT. Our findings underscore the importance of acknowledging individual differences in learning strategies and preferences, highlighting the necessity for personalized educational interventions tailored to meet the diverse needs of learners. However, despite the strides made in AI-supported learning, gaps persist in the existing literature, particularly concerning our understanding of how students approach prompts and exercises when utilizing AI-driven educational tools. This research aims to address this gap by shedding light on the nuanced dynamics of student-AI interactions during training of C programming, offering insights into effective pedagogical strategies and instructional design principles for integrating AI technologies into educational settings. This study makes a significant contribution to the continuous endeavors of educators and AI developers by furthering the discussion on AI-facilitated learning. It aims to enhance student engagement, learning outcomes, and overall educational experiences through the integration of technology into learning environments.

KEYWORDS

Large Language Models, Programming Education, Learning Strategies, ChatGPT, Learning Support Systems, AI Assistance

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1 INTRODUCTION

In recent years, artificial intelligence AI) has emerged across various domains, revolutionizing processes and approaches in fields ranging from healthcare to finance, and notably, education. AI technologies offer unprecedented opportunities to revolutionize traditional teaching methods, providing personalized learning experiences [28, 32], and supporting students in mastering complex subjects. Within the realm of education, AI-driven tools hold immense potential for enhancing student engagement [3, 29], improving learning outcomes [7, 30], and fostering skill development [2]. In particular, AI has gained significant attention in the field of computing education and programming [6, 13]. As computing skills become increasingly essential in today's digital age, educators are exploring innovative ways to teach programming concepts [23, 26] and facilitate students' understanding of coding principles [1, 39]. These studies have explored various AI techniques, ranging from machine learning algorithms [34, 37] to natural language processing systems [35, 36], to develop intelligent tutoring systems [27] and educational platforms [38] tailored to the needs of programming novices. Furthermore, within the broader landscape of educational AI, there has been a growing interest in the utilization of generative AI models [5, 11, 12], such as ChatGPT, for educational purposes. ChatGPT, in particular, has gained popularity as a conversational AI model capable of generating human-like text responses based on input prompts. While initially developed for general conversational purposes, ChatGPT and similar generative AI models have been increasingly explored in educational contexts, offering potential applications in tutoring [25], content generation [24], and student support [15]. However, despite the increasing amount of research in both AI-driven computing education and the use of generative AI models in educational settings, there remains a notable gap in the literature regarding the intersection of these two domains. Specifically, there is a lack of comprehensive studies that investigate the use of generative AI models, such as ChatGPT, in C programming education for novices. This gap is particularly significant considering the unique challenges faced by novice programmers, who often require additional support and guidance in mastering C programming concepts.

This paper explores student interactions with AI support, specifically ChatGPT, during C programming training sessions. It investigates student behaviors, demographic profiles, and performance outcomes to understand the diverse strategies learners employ when using AI assistance in educational contexts. The study utilizes manual clustering analysis to categorize students based on problem-solving approaches and engagement levels with ChatGPT. This reveals distinct clusters of student behavior, highlighting the variability in AI system interactions. The findings contribute to a deeper understanding of student engagement with AI support in C programming education, offering insights for educators and AI developers aiming to enhance AI-driven learning environments.

The structure of this paper is outlined as follows. Section 2 offers an overview of previous research in the domain of AI-driven educational interventions. In Section 3, we elaborate on the methodology utilized in our study. Section 4 presents the outcomes of our analysis, elucidating distinct patterns in student problem-solving behaviors. Finally, Section 5 provides concluding remarks and outlines potential directions for future research in this field.

2 PREVIOUS RESEARCH WORKS

The use of AI in education has evolved significantly over the past decade [19], offering personalized solutions to enhance student learning outcomes [21]. AI-driven interventions have been explored across various educational domains, aiming to revolutionize traditional teaching methods [10, 20]. Within the context of programming education, researchers have investigated the effectiveness of AI-based tools in supporting novice learners in mastering coding [9] concepts and problem-solving skills [41]. Studies in AI-driven programming education have examined the use of intelligent tutoring systems [33], adaptive learning platforms [22], and automated feedback mechanisms [8] to provide personalized assistance to students. Furthermore, researchers have explored the role of AI-driven feedback mechanisms in programming education [4, 40], by using automated grading systems, which enable rapid assessment of coding assignments, identification of errors, and provision of immediate feedback to students.

Despite advancements in AI-driven educational interventions for programming education, it is still challenging to understand the nuanced interactions between students and AI systems during learning activities. Only a limited number of studies have analysed the impact of using ChatGPT in programming education on learning processes and outcomes [31, 42]. It is crucial to gain insights into students' perceptions and interactions with AI tools to obtain a comprehensive understanding of their experiences and needs. Therefore, further research is warranted to explore the effects of AI-supported pedagogical approaches on student engagement, motivation, and learning outcomes. Additionally, investigations into the ethical implications, equity considerations, and long-term effects of AI integration in programming education are imperative for guiding evidence-based practices and fostering inclusive learning environments.

3 METHODOLOGY

In this section, we provide an overview of the methodology utilized in our study to investigate students' interactions with ChatGPT during C programming training sessions. Figure 1 illustrates the process adopted, offering a visual representation of the key steps involved in the study's execution.

3.1 Data Collection: Participant Recruitment

We recruited participants for our study from the pool of first-year computer science students at the University of Cagliari, who were beginning their second semester. Our recruitment process aimed to ensure a representative sample, avoiding biases towards specific individuals' opinions. We employed a randomized selection method to choose participants from this population. The process was conducted over two sessions held on separate days to accommodate scheduling constraints and maintain participant anonymity [1]. Additionally, to minimize potential biases, we provided clear instructions regarding the purpose of the study and assured participants of the confidentiality of their responses.

Before the sessions began, invitations were distributed to all first-year undergraduate computer science students, with the registration form open for one week to provide sufficient time for participation. Upon receiving the invitation, participants completed a questionnaire covering demographic details and their familiarity with AI tools, including prior use of ChatGPT. The questionnaire aimed to collect data anonymously, maintaining confidentiality and ethical standards. A total of 110 students completed this questionnaire. Each participant received a unique identifier via email to link their responses across the study phases, facilitating streamlined data analysis.

3.2 Questionnaire Structure

The questionnaire was designed to gather comprehensive demographic information and insights into participants' experiences with AI tools, with a specific focus on ChatGPT. The structure of the questionnaire [2] ensured clarity and ease of completion, facilitating accurate data collection. Participants were asked to provide demographic details such as age group, gender, and educational background, enabling characterization of the sample population. Questions pertaining to participants' prior experience with AI tools, including any previous usage of ChatGPT, aimed to assess their familiarity and comfort level with such technologies. Participants were specifically queried about their prior interactions with ChatGPT as a study aid, if any, to gauge their exposure to AI-driven educational support systems.

Additionally, during the training session, half of the participants 49, in total) were provided with a guide containing prompts on how to interact with ChatGPT, while the other half did not receive the guide. During the training session, participants were instructed to interact with ChatGPT to resolve C programming exercises, allowing them to seek support from the AI model. The guide was made available for reference and consultation throughout the training session, assisting participants in formulating effective prompts and interactions with ChatGPT. Those who received the guide had a full day to consult it, providing them ample time to familiarize themselves with its content.

[1] We encouraged voluntary participation and informed students of their right to withdraw from the study at any time without facing consequences.

[2] A copy of the questionnaires is available at https://shorturl.at/erHIV. The first part of the questionnaire structure follows our previous works [16, 17].

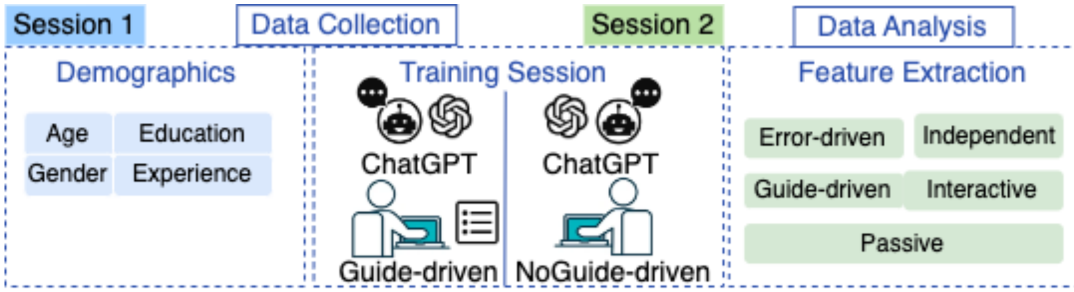

Figure 1: The methodology employed in this study involved data collection over two distinct periods, denoted as Session 1 and Session 2. During Session 1, participants completed a demographic questionnaire to provide essential background information. During Session 2, participants were divided into two groups: one group received instructions on effectively utilizing ChatGPT, while the other group did not. Both groups engaged in a training session aimed at utilizing ChatGPT for C programming exercises. The final process related to data analysis categorizes students according to different features.

Overall, the questionnaire structure ensured systematic data collection, enabling a comprehensive understanding of participants' backgrounds and experiences relevant to the study objectives.

3.3 Data Analysis: Feature Extraction

In this subsection, we detail the methodology used to analyze student interactions with ChatGPT during the training session, focusing on addressing our research question regarding the identification of different student groups based on their interactions with ChatGPT.

We decided to use a manual categorization approach instead of automated clustering algorithms like K-means. This involved thoroughly examining each chat transcript between the student and ChatGPT, using predefined criteria derived from conversation content to assess interaction nature and determine corresponding characteristics. These criteria spanned various dimensions of student behavior, including problem-solving approaches and AI system engagement levels. Following manual categorization, students were grouped into distinct clusters based on identified interaction patterns. Five key features were selected during this process: interactive problem-solving, passive problem-solving, independent problem-solving, error/optimization-driven problem-solving, and guide-driven problem-solving.

The clustering process facilitated the identification of diverse engagement patterns among students, providing valuable insights into the various approaches employed in utilizing AI-driven educational tools. Figure 2 summarizes the top five key features considered in the analysis, along with corresponding student percentages, guide usage percentages, and the first author of the initial solution related to the training session. This table serves as a reference for understanding feature composition and prevalent interaction patterns observed within each cluster.

Overall, the manual clustering technique enabled a detailed exploration of student behaviors during the training session, facilitating the identification of distinct profiles based on a qualitative assessment of chat transcripts. The use of manual clustering to analyze student interactions with AI might reveal nuances that automated methods could miss, allowing for a deeper understanding of the diverse engagement patterns observed.

3.4 Guidance for Effective Prompt Formulation

To facilitate students in formulating effective prompts for ChatGPT and obtaining the desired assistance, a series of guidance prompts were provided[3]. These prompts were designed to aid students in crafting clear and concise requests, leading to more precise and helpful responses from the AI model. The guidance was offered to half of the participants who took part in the pre-test 49 out of 98 students in total). The decision to provide this guidance was driven by the desire to improve the quality of interactions between students and the AI system, following the best practices in the field of AI-assisted education [14, 18]. Out of the 49 students who received the guidance, only 14 declared having received it, and among these, only 8 stated having read and fully understood it. It is important to consider that the limited number of students who reported reading the guidance attentively may be attributed to the constrained time available during the questionnaire and the potential lack of incentive to dedicate the necessary attention to this questionnaire.

The guidance prompts covered various aspects of code optimization, testing, and error handling. Within the code optimization category, prompts aimed to enhance code efficiency by advising students on improving algorithms, eliminating inefficiencies, and enhancing program speed. Conversely, prompts focusing on testing and error handling aimed to assist students in identifying and comprehending errors, both syntactical and semantical. By systematically analyzing errors, students gained insights into debugging their code and implementing effective error-handling mechanisms, including anticipating errors, validating inputs, and managing unexpected situations to prevent undefined behaviors.

The provision of guidance prompts empowered students to effectively communicate their needs to ChatGPT, thereby facilitating tailored assistance for their coding challenges. This approach not only enhanced interaction with ChatGPT but also encouraged students to deepen their understanding of coding principles and problem-solving strategies. By articulating queries more effectively, students maximized the utility of the AI model and improved their coding skills.

[3]The guidelines provided to participants are freely available at https://shorturl.at/aceH0.

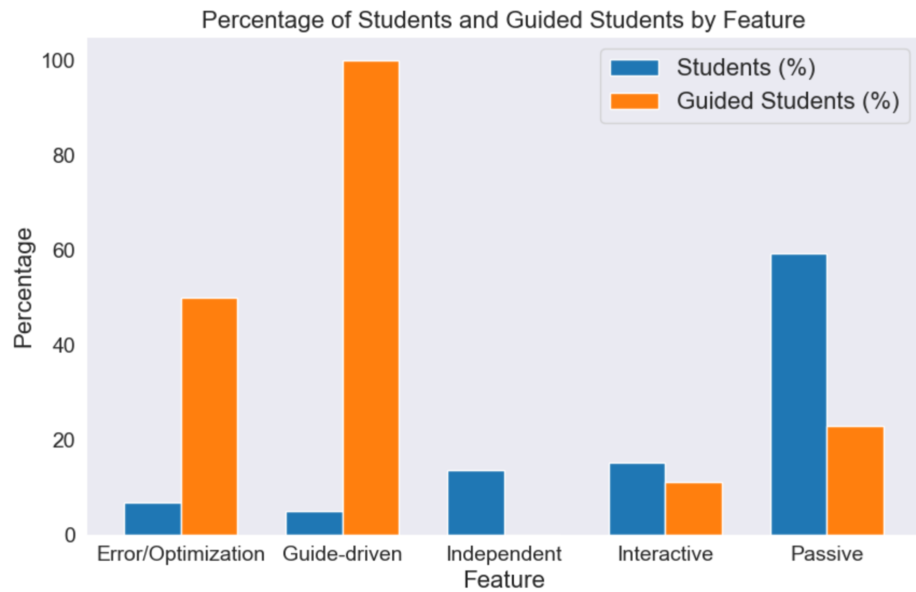

Figure 2: This figure presents the characteristics of students identified during the training phase based on manually extracted features reflecting their problem-solving approaches. The percentages indicate the proportion of students within each feature, alongside the percentage of students who received guidance during the training session.

In summary, the guidance prompts proved to be a valuable tool, enabling students to navigate coding tasks more efficiently and effectively, leading to a more productive learning experience.

4 RESULTS

In this section, we delve into the study's findings regarding students' interactions with ChatGPT during programming training sessions. The analysis focuses on the behaviors observed among students, particularly in their problem-solving approaches with ChatGPT's assistance. During our analysis of training responses, we identified five distinct patterns of student engagement with AI systems. These patterns represent various problem-solving approaches exhibited by students during the training phase. Figure 2 summarizes these engagement patterns along with the percentage of students within each category and the percentage of students who received guidance during the training session.

Error/Optimization-driven Problem-solving: Students in this category request solutions from ChatGPT and then refine their own code based on the suggestions provided. They demonstrate a proactive approach in identifying errors, as well as optimizing their code for improved efficiency and performance.

Guide-driven Problem-solving: These students follow predefined guidelines for using ChatGPT, suggesting a structured approach to problem-solving based on provided prompts.

Independent Problem-solving: This group consists of students who exhibit a degree of independence in solving exercises without relying solely on ChatGPT. They ask support for some exercises but autonomously tackle others without engaging with the AI system.

Interactive Problem-solving: In this group, students actively engage with ChatGPT by requesting modifications or optimizations to the provided solutions. They demonstrate an active role in problem-solving, offering suggestions for code improvements.

Passive Problem-solving: Students in this category accept solutions provided by ChatGPT without further engagement. They typically present exercise prompts without requesting modifications or enhancements.

The majority of students **59.32**) exhibit *passive problem-solving*, accepting solutions without further modifications. A smaller proportion **6.78**) engage in *error/optimization-driven problem-solving*, refining their code based on ChatGPT suggestions. Among them, **6.78**) demonstrate *independent problem-solving*, preferring their own solutions. Students engaging in *interactive problem-solving* **15.25**) actively interact with ChatGPT, requesting modifications. *Guide-driven problem-solving* **5.08**) indicates a tendency to follow predefined guidelines.

Research Findings. A diverse range of engagement patterns was observed among students during the training phase, encompassing passive, error-driven, independent, interactive, and guided problem-solving approaches.

5 CONCLUSIONS AND FUTURE WORK

Our study delved into the dynamics of student interactions with AI systems, particularly focusing on their engagement patterns during programming training sessions. Through manual categorization, we identified distinct clusters of student behavior, shedding light on the diverse approaches employed in utilizing AI-driven educational tools. The findings underscore the importance of recognizing individual differences in learning strategies and preferences, as evidenced by the varied engagement patterns observed across student clusters.

However, it is important to point out the following limitations. Our study focused solely on first-year computer science students, limiting the generalizability of our findings to other disciplines or educational levels. Additionally, we primarily analyzed student interactions with ChatGPT during training sessions, neglecting other potential factors influencing student performance, such as user interface characteristics, students performances with pre and post test. Moreover, the short timeframe of our analysis may not fully capture the long-term impact of AI assistance on learning outcomes. It is worth noting that the categories were identified by a single annotator using a systematic approach, and in future research, it may be necessary to involve multiple annotators to compare results.

Future research should address limitations by exploring alternative AI assistance strategies, such as adaptive learning techniques, and investigating the lasting effects of AI integration in education. Understanding socio-cultural influences on student interactions with AI systems and addressing ethical considerations surrounding AI adoption in education are also crucial. This study focuses on identifying different student profiles and their interactions with ChatGPT, with detailed survey analysis deferred to future work. This allows for a comprehensive investigation into factors influencing student engagement with AI systems and their impact on learning outcomes.

In summary, this study contributes to the understanding of the impact of AI in education and provides valuable insights for educators, policymakers, and AI developers, aiming to enrich learning experiences and foster student success in the evolving landscape of machine learning education.

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