Exploring the use of ChatGPT as a learning tool in programming education

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Abstract

AI-powered tools such as ChatGPT have received increasing attention in education, business and everyday life. They have the potential to transform learning, content creation and delivery, and student engagement. ChatGPT has become especially popular among students in computing fields, therefore, it is important to understand its impact in programming education and the ways it can be integrated as a supporting tool. This study addresses the utilization of ChatGPT in higher education in general with a focus on programming education through an extensive review of existing literature. It highlights benefits, challenges and issues related to its adoption. In addition, it presents research themes and considerations for future research.

Keywords**:** programming education, programming instruction, ChatGPT, generative AI, artificial intelligence, computing education, educational technology

INTRODUCTION

The launch of ChatGPT, an artificial intelligence (AI) chatbot developed by OpenAI, in November 2022, marked a pivotal moment in integrating AI in everyday lives and business. In August 2024, OpenAI reported that ChatGPT has more than 200 million weekly users, which is double the number from the previous year (Reuters, 2024). The chatbot has been used in various domains, such as customer service, healthcare, finance, education, and content creation, to name a few. Its popularity has brought attention to benefits as well as issues surrounding its use and other similar AI tools. Educators are currently in the process of understanding and employing this technology and there is a significant debate on whether these tools should be adopted and how. The research in this area is in its early stages. The purpose of this study is to conduct a literature review to explore the current body of knowledge on adoption of AI tools in higher education and identify gaps that could inform future research. The focus is specifically on adoption of ChatGPT in teaching programming and computing courses in general. Educators in computing fields need to understand the benefits, limitations, and methods of using AI technologies to complement traditional instructional methods.

This article is organized as follows: first, a brief overview of AI and its evolution is provided followed by an examination of research on adoption of AI-powered tools in higher education. Next, a summary of research on the use of ChatGPT in programming courses is presented, which includes main themes explored and suggestions for future research.

ARTIFICIAL INTELLIGENCE AND CHATGPT

Evolution of AI with Structured Data

The evolution of artificial intelligence has been a journey marked by continuous innovation, with each phase unlocking new capabilities and applications. Initially, AI's focus was on structured data, where algorithms such as genetic algorithms, decision trees, random forests, support vector machines (SVM), and k-means clustering were employed to analyze well-organized datasets. These techniques proved highly effective in fields like finance, healthcare, and logistics, where pattern recognition, classification, and predictive analytics were essential (Dwivedi et al., 2023).

Evolution of AI with Unstructured Data

As the digital world became more complex, the limitations of relying solely on structured data became evident. The surge in unstructured data, collected and stored in a wide range of forms such as text, images, audio, and video, demanded more sophisticated approaches. This shift led to the advent of deep learning and reinforcement learning, revolutionizing AI by enabling machines to process and interpret vast and varied datasets. Deep learning, a branch of machine learning, drove advances in image recognition, speech recognition, natural language processing, and recommendation systems (Marquadson, 2024).

As AI's capabilities grew, so did the availability of data and computational resources. The proliferation of big data, bolstered by advanced data centers offering abundant storage and processing power, allowed AI to scale to unprecedented levels. Recurrent neural networks (RNNs) and their variants, such as Long Short-Term Memory (LSTM), advanced natural

language processing (NLP), enhancing the accuracy of tasks like translation, sentiment analysis, and speech recognition. A significant breakthrough in AI was the development of Large Language Models (LLM). LLMs are deep learning models that are trained on vast amounts of data and are capable of generating natural language to perform various tasks (Ray, 2023). One example of an LLM is ChatGPT.

ChatGPT: Redefining AI

The recent introduction of ChatGPT, powered by advanced deep learning and the Generative Pre-trained Transformers (GPT) architecture, represents a significant leap in chatbot technology. By predicting word sequences that mirror natural human interactions, these language models, trained on extensive and diverse datasets, generate responses that closely resemble human expertise. ChatGPT, particularly the GPT-3 model with its 175 billion parameters, has been fine-tuned through both unsupervised pre-training and supervised learning to excel in a variety of tasks, from software development to creative writing (Dwivedi et al., 2023).

ChatGPT's development has been marked by significant advancements. It began with GPT-1 in 2018, featuring 117 million parameters, and evolved with GPT-2 in 2019, which had 1.5 billion parameters. The release of GPT-3 in 2020 brought a major leap with 175 billion parameters. The launch of ChatGPT in 2022 and the subsequent release of GPT-4 further enhanced the platform's capabilities. ChatGPT-4, the latest iteration introduced in 2023, is more advanced in its reasoning capabilities, more creative and collaborative. This version can now accept images as input. It leverages more data and more computation and provides longer context, by being capable of handling over 25,000 words of text (OpenAI, 2024). This can be useful for content creation, document search and analysis.

ChatGPT's Explosive Growth Compared to Other Online Services

The meteoric rise of ChatGPT is a notable development in technology. After its launch in November 2022, it reached 1 million users within just five days, a feat unmatched except by Threads, which achieved this milestone in one hour in 2023 (Time, 2023). This rapid adoption outpaced even well-known platforms such as Instagram, which took 2.5 months to reach 1 million users, and Spotify, which took 5 months. By January 2023, ChatGPT had amassed 100 million monthly active users, becoming the fastest-growing application until Threads took that title in July of 2023 (Hu, 2023). At its peak in April 2024, ChatGPT was receiving nearly 2 billion monthly visits, making it one of the most-visited websites globally. However, traffic has since decreased, with current estimates around 600 million monthly visits (Duarte, 2024).

Despite fluctuations in traffic, ChatGPT continues to be a major force in the AI domain. According to OpenAI, 92% of Fortune 500 companies are using its products (Reuters, 2024).

ChatGPT's Transformative Impact: Shaping Education, Work, and Beyond

The confluence of advances has led to AI's pervasive influence across industries and everyday life. AI-driven technologies have evolved from specialist tools to integral components of consumer products, services, and decision-making processes. ChatGPT's versatility extends across various domains, profoundly impacting education, the workplace, and beyond. In education, ChatGPT is transforming how students engage with learning by offering personalized

learning and tutoring (Ray, 2023). For example, it can provide writing assistance by generating tailored writing prompts based on a student's past work or interests, guiding them through the writing process in a way that aligns with their unique needs. This personalized approach not only makes assignments more engaging but also helps students develop stronger writing skills by providing real-time feedback and suggestions for improvement.

In the workplace, ChatGPT is equally transformative, particularly in fields like human resources (HR) and marketing. It automates routine tasks such as composing emails, generating legal documents, and managing recruitment processes, thus freeing up professionals to focus on more strategic activities. In HR, ChatGPT can assist with onboarding new employees, drafting training manuals, and even conducting sentiment analysis to gauge employee morale. For digital marketers, it offers an edge in creating compelling ad copy, suggesting content ideas, and structuring campaigns, thereby boosting efficiency and creativity (Budhwar et al., 2023).

ChatGPT's ability to evaluate and summarize large volumes of text makes it an invaluable resource in areas such as market research, where it can analyze customer reviews to assess brand sentiment or summarize key trends from industry reports. As AI becomes more integrated into daily operations across various sectors, tools like ChatGPT are not just enhancing productivity but also enabling more informed decision-making and personalized user experiences.

Generative AI like ChatGPT is set to significantly shape the future of critical thinking, problem-solving, and communication skills in both education and the workplace. However, the introduction and adoption of AI tools has raised various concerns such as ethics, mis-information, bias, and privacy (Pit et al., 2024). The rapid adoption of this technology has sparked debates, especially within academic and educational spheres, where distinguishing AI-generated content from human-authored work poses a growing challenge. As AI continues to evolve, the role of tools like ChatGPT will only expand. This underscores the need for ongoing research to explore the opportunities, challenges, and impact of AI-based technologies in education, business, and everyday life. The following section provides an overview of the current research on using generative AI in higher education.

REVIEW OF RESEARCH ON ADOPTION OF CHATGPT IN HIGHER EDUCATION

There has been a significant number of publications in this area, exploring benefits and issues associated with this technology as well as ways it is being used. Bansal et al. (2024) presented the perspectives of academic leaders in their report of a panel of university chancellors and presidents. Key challenges highlighted by the panel include the need for universities to keep pace with a rapidly changing job market driven by AI, ethical considerations, and the difficulties in implementing AI due to limited expertise and resources. On the opportunity side, AI can enhance education by enabling personalized and interactive learning experiences, advancing research, and fostering new academic programs focused on AI. The panelists emphasized the importance of preparing students for a workforce that collaborates effectively with AI, underlining the role of self-directed learning in cultivating adaptability.

An article authored by 21 academics and professionals from across the world (Gill et al., 2024), concluded that AI with tools such as ChatGPT are leading a significant transformation in education, involving a wide range of educational activities, from improving the techniques for active learning to developing course content. They identified several issues related to ChatGPT adoption. Content authenticity can be an issue when this tool is used to develop course content.

Plagiarism could be a problem, as ChatGPT generated content can get past plagiarism detection tools. Additionally, ChatGPT could be inaccurate, biased, and content may not be current.

In an effort to investigate early adopters' utilization of ChatGPT in education, Mogavi et al., (2024) conducted an in-depth analysis of social media content from several platforms. Results indicated these typical uses of ChatGPT in higher education: content creation and editing such as writing and proofreading, preparation of lecture notes and slides and literature reviews; collaborative data analysis; student evaluation and peer-review processes. Their study also found that the early adaptors in higher education were Social Sciences, Business and Management and STEM education. Pit et al. (2024) identified two research themes related to the use of AI in higher education, one addressing the impact of AI on teaching and the other the impact on student learning. From the student perspective, benefits included personalized learning, writing support and timely feedback. However, several disadvantages were also emphasized in the current research such as over-reliance and abuse, low information quality and bias propagation (accepting incorrect information provided by these tools as valid), lack of trust in AI feedback and inequity of access.

In addition to these general reflections on adoptions of ChatGPT in higher education, the review of existing literature identified several empirical studies that focused on specific aspects of utilization and experiences with this tool. Some of them presented experiences with the design of instructional activities utilizing ChatGPT. Marquadson (2024) reported on the use of ChatGPT in a self-directed learning assignment within a cybersecurity course. Students were encouraged to use ChatGPT to help them develop a learning proposal on a topic of their interest, carry out the learning plan, and reflect on the process. The study found that students' perceptions varied depending on the task, but overall, they found ChatGPT helpful, easy to use, and intended to continue using it in the future. The author concluded that the students' level of subject mastery may have contributed to the successful use of ChatGPT, as this was a capstone course where students already had a strong foundation of knowledge. For beginners, determining the accuracy of ChatGPT's responses could have been more challenging. Memmert et al. (2023) utilized Generative Language Models to create an AI-based scaffolding tool in a design science research (DSR) course. The authors developed an illustrative prototype to help novices learn how to apply DSR principles and assist them in tackling open-ended, ill-structured problems using DSR. The tool was evaluated by 13 experts who perceived it as helpful for students. However, they expressed concerns about novices accepting suggestions without reflection, recommending the inclusion of a reflection phase to prevent the unintended use of the tool.

Another group of studies focused on the performance of ChatGPT in specific educational contexts. Ding et al. (2023) used ChatGPT in a physics course as a virtual tutor for students taking a test. They identified three groups of students in terms of the trust towards ChatGPT: "trust group", that agreed with all ChatGPT's answers in spite of their correctness, "partial trust" group that partially agreed with the answers and the "distrust group" that disagreed with the answers. Authors suggested that it's important to teach AI literacy to maximize the benefits of this technology. Many students fell into the trust group, which suggests the importance of developing skills to critically assess the information provided by these tools as well as skills related to prompt engineering to help students ask the right questions. Another experimental study investigated how ChatGPT performs compared to students in answering open-ended exam questions in an Information Systems course (Hobert et al., 2023). The results showed that all ChatGPT-generated exams received a passing score, with performance varying by question type. It also outperformed students in knowledge reproduction questions, knowledge transfer tasks, as

well as in modeling tasks. However, for hands-on tasks involving visual input, like database screenshots, students performed better, likely because AI could not interpret the provided visual input.

Most of the studies on the adoption of ChatGPT explored students' perceptions and experience. Katavic et al. (2023) explored how students are using ChatGPT and its impact on their learning. Students reported using the tool when facing three types of difficulties: lack of skill or knowledge, information gathering, and idea generation. Compared to other tools, such as Google, students found ChatGPT more helpful and more efficient when dealing with difficulties. It enhanced their learning experience when used appropriately. Tossell et al. (2024) explored students' perceptions before and after using ChatGPT to complete a writing assignment. They found that ChatGPT did not make the assignment easier for students, but it changed their perceptions of ChatGPT. They rated it as more valuable for learning and more ethical than they had it previously perceived. Similar findings were reported by Hsin (2024). This study explored the use of ChatGPT in a computer networking course. Students reported highly positive perceptions of ChatGPT as a tool to assist them in understanding networking concepts. In addition, student performance improved compared to prior semesters that did not involve the use of ChatGPT. Elkhodr et al. (2023) compared students utilizing ChatGPT for exercises versus those who did not. These exercises were related to Human-Computer Interaction and involved analyzing case studies and developing user interface (UI) models. Students performed significantly better when using ChatGPT. However, performance improvement was not as high for tasks related to UI content and hierarchy. This could be due to the fact that these tasks involve graphical elements while ChatGPT generated text-based answers.

Many of the studies addressing students' perceptions utilized a well-known model in information systems research, the Technology Acceptance Model (TAM), to explore factors that impact intention to use ChatGPT. In many of them, the model was extended to include constructs that are relevant in the context of AI tools. Farrell et al. (2023) employed TAM to explore factors influencing students' intention to use ChatGPT, extending the model by adding a new factor: Perceived Ethics. This factor refers to the extent to which ChatGPT can be used in accordance with academic integrity. The study found that students' perceived usefulness and perceived ease of use positively influenced their attitude towards ChatGPT and their intention to use it. Regarding perceived ethics, students' intention to use ChatGPT was not significantly impacted by their ethical considerations. Al-Abdullatif (2023) combined TAM and the Value-Based Adoption model to examine students' acceptance and perceptions of using chatbots. They found that perceived usefulness and perceived value were positively related to the students' attitude towards chatbots, while perceived ease of use, perceived enjoyment and perceived risks were not related to attitude. In addition to attitude, perceived value was a strong predictor of acceptance of chatbots. Albayati (2024) extended TAM with constructs for privacy, security, social influence and trust, to examine factors that influence students' acceptance of ChatGPT as a regular assistance tool. In this study, both perceived ease of use and perceived usefulness were important factors that influenced students' acceptance and usage. Privacy and security considerations were important among students' perceptions and social influence was found to have a significant impact on attitude towards ChatGPT.

Social influence and perceived risk were also combined with TAM in a study by Abdaljaleel et al. (2024) that investigated students' perception of ChatGPT. In this study, another factor was added, anxiety, which refers to the fear that AI tools like ChatGPT will negatively impact critical thinking skills or over-dependence on technology. Results indicated a highly

positive attitude towards ChatGPT. The majority of students perceived it as easy to use and useful. Social influence was also found to be a major factor driving the adoption of ChatGPT. Students in this study reported low levels of perceived risks and "anxiety" scores.

While ChatGPT has potential to enhance learning in various fields of study, the main purpose of this study was to evaluate the use of ChatGPT as a tool to support learning and teaching in programming education, the current state of its adoption and related experiences. Another goal was to evaluate the current state of research on this topic, uncover themes that are relevant for research and practice and identify areas that need further research. The following section presents the findings of this review.

USE OF CHATGPT IN PROGRAMMING EDUCATION

Learning to program can be a challenging experience for students, prompting educators to continuously seek ways to facilitate the learning process. Increasingly, there is interest in using AI-enabled tools to teach programming. These tools, trained on billions of lines of open-source code, can be highly effective in this context. ChatGPT, for instance, supports programming through its code generation and code explanation capabilities (Lao and Guo, 2023). Code generation capabilities include specification-to-code, conversational specification-to-code, code completion, code refactoring, code simplification and test generation. Examples of code explanation capabilities are debugging help and conceptual explanation with code examples. Studies show that software engineers find the tool beneficial to improve efficiency and useful for tasks such as debugging, learning new features and generation of code snippets (Russo, 2024). ChatGPT also has potential in addressing common software engineering challenges such as code refactoring and adhering to patterns and principles. Anagnostopoulos (2023) suggested that future versions of ChatGPT will further improve capabilities, particularly in natural language processing (NLP) and reducing biases. Lastly, by allowing users to communicate using a natural language, ChatGPT is easy to use for people without programming knowledge, which makes it a useful tool for beginners.

Given this potential, it's important to explore how ChatGPT and similar tools can be used in programming education. Currently, there is a lack of in-depth understanding of how AI technology like ChatGPT will influence IS education (van Slyke et al., 2023). One of the challenges is cheating, as ChatGPT has made it both easier and harder to detect it. Becker et al. (2023) pointed out that AI-generated code can enhance efficiency, but raises ethical concerns, necessitating careful integration into learning environments. Faculty may need to rethink assessment methods since tools like ChatGPT can easily generate code, reducing the effectiveness of traditional assessments. To address these challenges, van Slyke et al. (2023) encourage IS faculty to embrace AI tools to support learning and design activities that promote ethical and effective use of AI that focus on higher-order thinking tasks. Additionally, contextualized and reflection-based assessments can help ensure genuine student understanding. Educating students on the ethical use of AI, highlighting its capabilities and limitations, is also crucial. It is important that universities adapt to prepare students for AI-enabled careers. The challenge for educators is to do so while maintaining academic integrity.

The rest of this section presents the findings of the existing research on the utilization of ChatGPT in programming education. Due to the multidisciplinary nature of computing research, multiple databases were searched, however the publications included in this review were limited to two main fields: 1) computing fields such as management information systems, computer

information systems, information technology, software engineering and computer science, and 2) instruction and pedagogy in higher education. The list of publications is presented in Table 1 (Appendix). The review identified a few themes of this stream of research, as highlighted below.

Theme 1: Impact on students' educational experiences and performance

The studies evaluating the impact on student experiences and performance highlight various outcomes and considerations. Gottipati et al. (2023) observed that ChatGPT can be a valuable supporting tool in advanced programming courses. It enhances student engagement and problem-solving skills. Yilmaz & Karaoglan Yilmaz (2023a) found that an important benefit for students was the speed and effectiveness these tools provide answers to questions. Other benefits included help with debugging, support with development of critical thinking and getting ideas to solve complex problems. Disadvantages included the fact that ChatGPT responses were not always correct. Students surveyed in a study by Shoufan (2023) found ChatGPT helpful for learning, interesting, motivating, and easy to use. However, they also noted that sometimes it provided incorrect answers, and they observed difficulties with understanding the user prompts. Singh et al. (2023) surveyed graduate students who reported they do not use ChatGPT on a regular basis and they lack in-depth knowledge and skills related to its use. Students also showed concern about its misuse and potential negative impact on critical thinking. However, they indicated that ChatGPT could support learning by providing clarifications about assignment related questions and help with code generation.

Sun et al. (2024) considered the impact of using ChatGPT on programming behavior and observed that the personalized feedback from ChatGPT facilitates the programming learning. However, the performance of students using ChatGPT did not differ significantly from those of students in the self- directed learning group. Students interviewed in this study indicated favorable views about ChatGPT, such as its perceived usefulness and ease of use. Kosar et al. (2024) also reported no effect on student performance in course activities as a result of using ChatGPT, noting that effective course design can mitigate potential negative impact. In this study, assignments were modified to minimize student's full reliance on ChatGPT and its code generation capabilities. Examples of modifications were providing minimal text and supplementing with UML diagrams, asking students to incorporate given code in their solution, extending a previous assignment and including assignment defense. Yilmaz & Karaoglan Yilmaz (2023b) reported that the use of ChatGPT significantly boosts computational thinking skills, programming self-efficacy, and student motivation. They observed that instead of spending time writing the code, students focused more on developing the algorithm to solve the problem. Then they combined the code fragments generated by ChatGPT to follow this algorithm. Qi et al. (2024) also found that ChatGPT had a positive influence on student's self-efficacy, their affective engagement as well as the learning outcomes.

Theme 2 - Assessment of capabilities and performance of AI tools for programming

In spite of the potential that ChatGPT has to support programming and software development in general, there has been limited research to explore its actual capabilities and performance in the workplace or education.

In the educational context, Ouh et al. (2023) investigated the effectiveness of ChatGPT as a tool for code generation. They used ChatGPT to generate solutions for exercises in an

undergraduate programming course and concluded that ChatGPT was not always accurate in the initial attempts. Solutions were effective when instructions were clear and straightforward, but in the case of complex instructions, solutions were partially correct. In addition, ChatGPT was less effective in cases where the exercise involved interpretation of UML diagrams. In spite of these findings, the authors believe that ChatGPT can be a valuable resource for students. In order to interpret and use the solutions, students would be required to rely on their subject knowledge.

In a similar study by Wieser et al. (2023), ChatGPT was used to solve exercises in an introductory programming class. They found that ChatGPT generated the correct answer with the first attempt for 59% of exercises, with the second attempt for 28% and for the rest of exercises after additional clarifications were provided. They concluded that ChatGPT is able to solve almost all tasks in an introductory course. Sharpe et al. (2024) also reached similar conclusions in the same context, an introductory programming course. They used a two-stage approach that involved reformulating the prompts to ChatGPT when it did not provide the correct answer or when the solution involved concepts that were too advanced for the course level. Results showed that using re-prompting, ChatGPT can either perfectly or almost perfectly solve every problem, so it can adequately pass the course.

Given the implications that the ChatGPT's code generation capabilities have for academic honesty, educators are trying to find solutions to prevent plagiarism while using this tool to enhance learning. A study by Ellis et al. (2024) investigated whether educators can differentiate the solutions generated by ChatGPT from those of students. They also used an AI detector tool to assess the likelihood of the student submission being AI generated code. The results of this study showed that the AI tool had mixed results in assessing student solutions and it was not a viable approach to accurately detect academic misconduct. Similarly, human graders had mixed results. Authors suggested strategies to deal with using ChatGPT such as preparing assignment prompts that are less specific and requiring students to add comments throughout their code in a specific manner. The latter will at least ensure that students understand the code if it was AI generated. In general, asking students to use only the techniques or standards discussed in class could also be an approach to manage unauthorized use of AI tools. Finally, they suggested instructors use ChatGPT to generate solutions for their assignments. These solutions can be used to identify patterns that may be observed in student submissions.

Some other aspects of ChatGPT's performance that have received attention are its ability to serve as a digital tutor and grading capabilities. Phung et al. (2023) evaluated ChatGPT (based on GPT-3.5) and GPT-4 and compared their performance to human tutors in an introductory Python context. They noted that GPT-4 generally outperformed ChatGPT and for many scenarios its performance is close to human tutors' performance. However, it struggles with areas such as grading feedback and task synthesis. Weiser et al. (2023) also found that ChatGPT's grading consisted of incorrect assessment or inconsistent scoring. Instructors concluded that they would not use it as the only assessment tool, but it could be useful for a second option. In terms of tutoring capabilities, they found that without a defined learning goal, the tool's recommendations were very generic. They suggested that ChatGPT could be more useful if instructors assist students in defining the subject area and how to formulate the request.

Theme 3- Intentions and methods of using ChatGPT

Studies examining the intentions and methods of using ChatGPT in programming education highlight how students and educators approach the integration of AI tools.

Lau & Guo (2023) interviewed educators to learn about their plans to incorporate AI tools like ChatGPT into their courses. They identified varied attitudes among educators, with some advocating for AI integration to personalize support, streamline grading, and redesign courses. In the short term, many were worried about cheating and even considered banning these tools. However, in the long term, opinions split: some educators were against using AI tools, fearing they could undermine learning the basics of programming and raise ethical and legal issues. One of the reasons to embrace AI tools was to prepare students for a workforce where these technologies are likely to play a big role.

In a similar study involving programming educators by Husain (2024), they identified both advantages and disadvantages related to ChatGPT adoption. Some of the advantages for students were personalized learning, interactive learning that can increase motivation and engagement, accessibility, and ability to interact using natural language. ChatGPT can support instructor activities by engaging students in programming tasks outside class to allow more time in class for other complex new programming concepts, assist instructors in creating more realistic programming examples and demonstrations, preparing quizzes, exams, or suggesting lesson plans. In terms of disadvantages, the main concern was potential abuse by students seeking an easy-to-obtain programming solution that undermines their learning. Another concern was the potential for interaction with ChatGPT to replace human interaction with instructors, an important aspect in early stages of learning programming. Overall, educators participating in this study suggested embracing ChatGPT to enhance traditional programming teaching methods if measures are taken to mitigate its negative impacts.

From the student perspective, Manley et al. (2024) explored the use of ChatGPT by students in computer science programming courses. Most of the students surveyed used ChatGPT to seek help with debugging or with a specific issue within a larger project. Sometimes it was difficult to avoid ChatGPT from providing more help than was asked of it, or solutions that were above the student's level. This study also provided suggestions on how educators can mitigate the negative effects such as establishing an easy way for students to cite AI assistance in their code, providing incentives for reflective learning and coaching students on good ways to use AI.

An interesting application of ChatGPT is developing instructional tools based on it. Chen et al. (2023) introduced GPTutor, a plugin for Visual Studio extension, that is powered by ChatGPT. This tool could be used by students to get personalized help, or by new employees needing to quickly catch up. They reported initial positive experiences from users.

Theme 4 - Factors affecting the outcomes of using ChatGPT

A less explored theme by the current research was identifying factors that affect the outcome of ChatGPT adoption in programming courses. This is an important stream of research that could inform educators about best practices of using this tool. However, very few studies have explored this aspect of adoption.

Jing et al. (2024) explored the factors that affect the effectiveness of using ChatGPT to solve programming problems, focusing on students' AI literacy, programming knowledge base, their cognitive level regarding ChatGPT, and intention to use ChatGPT. All these factors were found to be significantly related to the effectiveness of using ChatGPT. The results implied that developing AI literacy is crucial for learners to efficiently leverage this technology. Denny et al. (2024) addressed this aspect by introducing a new type of exercise, "prompt problems". The goal

was to help students learn to craft effective prompts for code generation when using AI tools. Students found that these types of problems engaged their computational thinking skills and valued the exposure to new programming constructs.

CONCLUSIONS

In the realm of education, AI's impact has been particularly transformative, with intelligent systems playing an important role in personalized learning, student assessment, and curriculum development. The purpose of this study was to explore the current state of research on adoption of ChatGPT in programming education aiming to identify its potential as well as issues associated with it. Although ChatGPT has been available for a relatively short time, a significant amount of research has already been published on its use in education in general and specifically in programming education. Based on the existing body of research, ChatGPT and similar AI tools have great potential to enhance programming instruction. Their use can increase student engagement, problem-solving skills, self-efficacy, and improve the learning outcomes. In addition, employers are using them in the workplace, so higher education needs to prepare students for these new tools they may need to use after graduation.

The review points out that educators can also benefit from using AI-powered tools such as ChatGPT. These technologies can assist them in content creation, grading, administrative tasks, and allows them to focus more on direct student interaction. However, academia is still in the early stages of adopting these tools. In computing fields, these tools will likely become more advanced and more pervasive. For example, Github Copilot, an AI tool developed by GitHub and OpenAI, was launched in 2022 and has become a popular coding assistant (Lawson, 2024). Unlike ChatGPT, it is integrated within software development environments. In February 2024, Google released its own chatbot, the Google Gemini. As such, educators should be aware of them and their capabilities when designing course activities, especially assessments, to prevent academic misconduct. Suggestions identified by this review include designing course activities that require critical thinking abilities, incorporating a reflection component and in general emphasizing complex problem solving that assumes the use of AI tools.

Another concern related to ethical consideration is that over-reliance on such tools could negatively affect problem solving skills and critical thinking. Additionally, the quality of code or answers generated by ChatGPT could be an issue. Incorrect solutions or solutions too advanced for novice programmers could negatively impact learning.

Besides these implications for practice, this study identified four themes of the current research on adoption of ChatGPT in programming education: (a) impact on students' experience and performance, (b) assessment and performance of the chatbot for programming instruction, (c) intentions and methods of using ChatGPT, and (d) factors influencing the outcomes of using the tool.

Most of the studies reviewed have focused on exploring learners' and educators' perceptions and methods of use. It should be mentioned that many of them involved small sample sizes which highlights the need for more expansive studies before solid conclusions can be drawn on the benefits or issues related to these tools.

An area that has not received much attention to date is exploring the factors that affect the outcomes of ChatGPT adoption. A few studies indicate that the benefits vary based on the students' skill level, course level, type of course activity utilizing ChatGPT, and activity design. Given the limited research, this aspect could be an important direction for future research. It is

important to understand best practices that lead to effective and efficient integration of these tools in programming instructions.

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APPENDIX

Table 1. Summary of research on adoption of ChatGPT in programming education

Theme 1: Impact on students' educational experiences and performance				
Study	**Objectives**	**Domain**	**Methodology**	**Findings**
Gottipati et al. 2023	Examine students' perceptions of ChatGPT	Advanced course on Text Mining and Language Processing	Lab exercise requiring use of ChatGPT, followed by a survey	ChatGPT can be an effective tool for supporting student learning in advanced programming courses.
Yilmaz and Karaoglan Yilmaz, 2023a	Examine students' perceptions of ChatGPT	Object-oriented programming II course	Questionnaire and content analysis of student responses	Positive perceptions include fast answers to questions, help with complex problems, and help with debugging. Negative perceptions include incorrect answers provided sometime by ChatGPT.
Sun et al., 2024	Compare programming behaviors and perspectives of learners using ChatGPT to traditional self-directed programming	Python programming course	Behavior analysis, assessment of performance in programming assignments and semi-structured interviews	Learning behavior was different between the groups, but there was no difference in performance. Perceived usefulness and ease of use increased with usage.
Kosar et al. 2024	Explore impact of ChatGPT on student performance	Undergraduate programming II course using C++	Comparison of student scores and surveys. Activities modified to minimize full reliance on code generation.	No significant difference in performance between students using ChatGPT and those who did not. Students reported positive learning experiences and intent to use in the future
Yilmaz and Karaoglan Yilmaz, 2023b	Effects of using ChatGPT on the learning process	Undergraduate Java programming course	Experiment	Students who used ChatGPT demonstrated higher computational thinking skills, higher programming self-efficacy and motivation compared to the students in control group who did not use ChatGPT.

Qi at al., 2024	Effect of ChatGPT feedback on learning outcomes	Undergrad students who have taken programming classes	Survey	Feedback from ChatGPT positively affect self-efficacy, engagement and learning outcomes, although this impact is not as strong as teacher feedback.
Shoufan, 2023	Explore students' perceptions of ChatGPT	Seniors in computer engineering program	Survey	Students find it interesting, helpful, motivating and easy to use. Disadvantages include: answers are not always accurate, still requires background knowledge to formulate correct prompt and evaluate response.
Singh et al. 2023	Explored students' perceptions of ChatGPT	Graduate students in science and computing	Survey	Students had not used it regularly for academic purposes. They are concerned about potential impact it could have on critical thinking. They suggest it could be useful to provide clarifications when they encounter issues or help with code generation.
Theme 2: Assessment of capabilities and performance of AI tools for programming				
Study	**Objectives**	**Domain**	**Methodology**	**Findings**
Ouh, et al. 2023	Efficacy of ChatGPT solutions	Introductory undergraduate Java programming course	Analysis of solutions generated by ChatGPT	Positive impact on learning and valuable resource for debugging. ChatGPT solutions may not always be accurate; the tool is less effective for exercises requiring interpretation of API documentation and UML diagrams.
Wieser et al. 2023	Assess ChatGPT performance for problem solving and grading.	Introduction to Java programming course	ChatGPT was used to solve Java exercises and to assess student solutions	ChatGPT solved all problems correctly. Inconsistent scoring and incorrect assessment, but could be useful as an alternative opinion.

Ellis et al. 2024	Likelihood of instructors identifying AI-generated code	Introductory programming with Python	Evaluation of student solutions by instructors and AI tools	Experienced instructors has mixed results in detecting AI-generated code
Sharpe et al. 2024	Correctness of ChatGPT solutions	Introductory programming with Python	ChatGPT was used to solve a set of problems used in class	Chat GPT provided perfect or almost perfect solutions. However, for some problems re-prompting was needed to arrive at the acceptable solution.
Theme 3: Intentions and methods of using AI tools for computing courses				
Study	**Objectives**	**Domain**	**Methodology**	**Findings**
Lou and Guo, 2023	Understand computing educators' perceptions and intentions to use AI tools	Introductory programming courses	Interviews with educators	In the short-term, educators worried about its use. Mixed intentions in the long term; some plan to use it, some others will continue to resist its adoption.
Husain, 2024	Explore perceptions of programming instructors about use of ChatGPT	Programming courses	Interviews with educators	Educators suggest a complementary role of ChatGPT if measures are taken to reduce the negative impact.
Manley et al. 2024	Explore student usage of AI	Undergraduate students in CS1 and CS 2 classes	Survey	Mostly used for debugging and answering specific questions part of a larger project
Chen et al., 2023	Developed a ChatGPT-powered tool for code explanation	Programming instruction	Interviews with students and educators	The tool was found to be user-friendly and explains code satisfactorily
Theme 4: Factors affecting the outcomes of using ChatGPT				
Jing et al., 2024	Explore factors that affect effectiveness of ChatGPT use	Python Visualization course	Experiment involving undergraduate students	AI literacy, level of programming knowledge, cognitive level of ChatGpt and intention to use were significantly related to the effectiveness of use of ChatGpt.