Artificial Intelligence Supporting Independent Student Learning: An Evaluative Case Study of ChatGPT and Learning to Code

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Abstract: Artificial intelligence (AI) tools like ChatGPT demonstrate the potential to support personalized and adaptive learning experiences. This study explores how ChatGPT can facilitate self-regulated learning processes and learning computer programming. An evaluative case study design guided the investigation of ChatGPT’s capabilities to aid independent learning. Prompts mapped to self-regulated learning processes elicited ChatGPT’s support across learning tools: instructional materials, content tools, assessments, and planning. Overall, ChatGPT provided comprehensive, tailored guidance on programming concepts and practices. It consolidated multimodal information sources into integrated explanations with examples. ChatGPT also effectively assisted planning by generating detailed schedules. However, its interactivity and assessment functionality demonstrated shortcomings. ChatGPT’s effectiveness relies on learners’ metacognitive skills to seek help and assess its limitations. The implications include ChatGPT’s potential to provide Bloom’s two-sigma tutoring benefit at scale.

Keywords: artificial intelligence; self-regulated learning; tutoring; artificial intelligence in education; personalized learning; intelligent tutoring systems

1. Introduction

Artificial intelligence in education (AIEd) has interested researchers for decades [1–3]. In recent years, journals and organizations focusing on artificial intelligence have proliferated. However, the growth and interest appear to be in the midst of a substantial increase. Year-by-year comparisons of worldwide Google searches for “AI Education” indicate a quintupling of interest from October 2022 to October 2023 [4].

This dramatic increase is likely due to the introduction of a free version of ChatGPT by the company OpenAI in November of 2022. ChatGPT became the fastest-growing web application, reaching 100 million users by January 2023 [5]. This quick, open introduction of a powerful AI application has greatly expanded recognition of the importance of AIEd, as evidenced by the large number of educational researcher publications in recent years [6]. A recent report indicates that 38% of students in the US are already utilizing generative AI tools [7]. Another report suggests that 20% of undergraduate students worldwide are using generative AI at least daily [8].

Artificial intelligence applications broadly impact education [9,10], and there is a history of its utilization that precedes ChatGPT and other generative AI tools. These applications include advanced data analytics work that is used to anticipate student needs [11] and more systematic investigations of enrollment and course achievement [12]. AI has also influenced the curricular side of the equation through intelligent tutoring systems [13].

Generative AI applications offer new pedagogical opportunities for learning and teaching purposes, for example, in the ability to help teachers evaluate and upgrade the teaching and learning processes in the classroom and facilitate the planning and implementation of lessons [3]. As these tools become ubiquitous, it is essential to understand better the
capabilities and limitations of these systems [14]. As such, researchers are now advocating that AI systems be studied as experimental participants [15].

One potentially revolutionary role of AI is to serve as a personal tutor. AI could address Benjamin Bloom’s famous “two-sigma” problem [16]. The problem emerged from research that indicated students learning via a tutor outperformed students learning in a conventional classroom by two standard deviations. The two-sigma problem has helped to anchor educators’ expectations regarding the effects of learning interventions [17]. It has also presented a proverbial goalpost for educators and researchers. Subsequent research has called into question the two-standard deviation difference between one-on-one tutoring and classroom-only learning [18]. One standard deviation is more accurate. It is worth noting that the advantages of interventions such as human tutoring and intelligent tutoring are related to the granularity or specificity of the support [18]. While one-on-one tutoring is effective, it is not necessarily practical. Scaling tutoring up presents a human resource problem many technology advocates have long hoped to solve. Generative AI systems may address resource and specificity problems by offering adaptive experiences that mimic the responsiveness and adaptability of a human tutor.

The purpose of this study is to improve our understanding of how generative AI can support an independent learning process. For example, how could an adolescent interested in programming use ChatGPT to accomplish their goal?

2. Self-Regulated Learning in Computer Programming

To understand the manner in which a student might utilize generative AI tools to learn computer programming, it is essential to take into account established practices. Computing education researchers have long focused on the students’ computer coding processes and performance [19]. This approach is considered a process-based analysis as opposed to an outcome-based analysis [20]. Self-regulated learning can guide the investigation of learning to program as relevant processes via planning, setting goals, organizing, self-monitoring, and self-evaluating are evident at various points [21]. Computer education researchers have found that these processes are fundamental in supporting programming problem solving [22].

Self-regulated learning (SRL) theory will guide this study [23]. SRL processes such as goal setting, monitoring for understanding, strategies, and the phases (forethought, performance, and reflection) [21] are used as heuristics to describe AI–student interactions. Although the concept of ‘monitoring for understanding’ in computer programming behavior has a long history [20], only a few studies have addressed self-regulated learning in relation to computer programming behavior in general, and none have addressed AI–student interactions in particular.

Research has indicated that computer assistance, in general, shows great promise [24]. “Computer-Assisted Learning Systems” can not only support instruction but also the development of self-regulated learning skills. A historical review of these systems demonstrates a clear progression of capabilities and impact that mirror advances in computing in general and AI in particular. The integration of technology and self-regulated learning has been studied extensively in online learning environments with encouraging results [25]. With the dramatic uptick in generative AI tools, researchers have recently begun to consider design principles to support self-regulated learning broadly [26].

A recent meta-analysis of AI research concluded that there is a need to identify the pedagogical affordances of AI [6]. This work focuses on the capabilities of the most recent and widely used general AI tools, ChatGPT and Google’s Bard, to support student learning. In particular, we delineate how these new AI tools can centralize many devices, systems, and processes in one place. Much like how the smartphone has eliminated the need for separate cameras, scanners, and GPS systems, ChatGPT and Bard have effectively consolidated the tools necessary for learning.
3. Tools for Student Learning and the Potential Role of Generative AI

A rise in the availability of instructional materials has provided students with multiple avenues for independent learning. This necessitates a more active role for students in the learning process consistent with SRL [21]. Students currently depend upon various supports in a typical study session. Supports include instructional materials (e.g., the textbook), content area tools (e.g., calculators), feedback and assessments (e.g., Quizlet), and planning tools (e.g., calendar, goal setting). In traditional settings, teachers or instructional systems almost exclusively provide the instructional materials and content area tools. The instructor commonly offers feedback and assessment tools, but highly self-regulated students will also self-evaluate and monitor. Planning and goal setting are also shared responsibilities.

3.1. Instructional Materials

Students utilize an array of instructional materials in the typical study session. No longer restricted to the textbook, their resources include online papers, lecture notes, and multimedia content. When well-designed, these resources are foundational to student learning [27]. This shift towards a multimodal approach to learning is reflective of the rapidly changing landscape of education and the need to consider student cognitive strategies. Students must manage multiple sources of information to best reflect their individual needs [28].

By using AI, it is possible to reconceptualize instructional content that suits all students, albeit in a different manner. A high-quality algorithm model can consider students’ diverse characteristics, such as knowledge levels, preferences, and interests, and create instructional materials customized to individual needs [29]. For example, Benhamdi et al. [30] proposed a new recommendation approach based on collaborative, content-based filtering to provide students with the best learning materials according to their preferences, interests, background knowledge, and memory capacity.

3.2. Content Area Tools

Each discipline incorporates specialized tools to support learning and development. One example from mathematics is the calculator. The National Council of Teachers of Mathematics suggests that relevant tools can enhance understanding and problem-solving [31]. Writers may utilize grammar support and concept map generators. In K12 education, researchers classify programming tools as textual, block, tangible, and unplugged [32]. High school students utilize textual tools incorporated into the Integrated Development Environment (IDE). A widely used and easily accessible online IDE used in introductory programming experiences is Codepen. The integrated environment can provide concurrent feedback as students are coding. This will substantially reduce extraneous cognitive load introduced by asking learners to toggle between interfaces [33].

3.3. Feedback and Assessment

Effective and immediate feedback is a vital component of learning [34]. In the typical study environment, the self-regulated learner will engage in self-monitoring [35]. That is, they will gauge the degree to which they understand the material. When reading, this is an ongoing activity. In tasks such as applying a velocity formula to solve speed and distance problems, the learner might try to solve a series of instructor or textbook-supplied problems. The self-regulated learner will know to engage in these tasks without prompting [21].

Learning to program often includes similar approaches that include solving increasingly complex problems. At the micro level (e.g., small chunks of code), designers generally incorporate programming task feedback into the IDE. Codepen, for example, will display a red exclamation point when a line of code includes an error. The feedback is less direct at the macro level (e.g., the learner understands inheritance).

Bugs in computer code can cause significant problems such as software crashes, security vulnerabilities, and data loss. Debugging code, the process of finding and fixing bugs, is a critical aspect of software development and can be time-consuming and complex [36].
ChatGPT can be used to discuss, make suggestions, and correct source code better than tools designed explicitly for code development [37]. We can ask AI for bug fixes for the selected source code and manually check whether the suggested solution is for fixing or improving the code. This can help to automate the debugging process and reduce the time and effort required to find and fix bugs.

Assessment plays a crucial role in education, enabling teachers to understand learners’ progress and challenges. One commonly used method for evaluation involves employing multiple-choice items generated by ChatGPT.

In the rubric development process, the initial step is to prompt ChatGPT to ask targeted questions, gradually gathering the information required to create a suitable rubric for evaluation. The key is to guide ChatGPT to inquire about specific aspects one at a time until all necessary data are obtained [38].

3.4. Planning

A substantive component of accepted self-regulated learning models is planning and goal setting [23]. Successful adolescent learners will commit time and energy to planning. Students who regularly use a planner (physical or digital) demonstrate higher academic achievement than those who do not [39]. Planning involves identifying goals and breaking the goals down into sub-goals and tasks. Each study session ideally is guided by the goals and tasks. This presents a substantial challenge for students that must be encouraged either from within (i.e., self-regulated) or externally. Instructors scaffold this to some degree with assignments and scheduled assessments.

4. Research Questions

This study explores how artificial intelligence, specifically ChatGPT, can facilitate independent learning processes. We use SRL as a guiding framework for classifying the learning activities. The focus is on the practical application of ChatGPT in aiding adolescents with an interest in programming, examining how the technology can assist them in achieving their learning objectives. Outcomes of this investigation include direction toward strategies and best practices for leveraging AI-driven platforms in individualized educational pursuits.

Specifically, this study will explore the following questions:

How does ChatGPT provide the learning support necessary for self-regulated learning?

How does ChatGPT provide the support necessary to learn the Python programming language?

5. Methods

5.1. Design

We used an evaluative case study design to address the research questions [40,41]. In education, research “seeks to understand specific issues and problems of practice” [42]. An evaluative case study is instrumental in supporting in-depth inquiries into the effectiveness of interventions [41]. The usefulness of the case study is increased “when the object of study is a specific, unique, bounded system...” [43]. We defined the case in this inquiry as the AI system’s capabilities to support the independent student learning of the Python programming language. The specific system we are investigating is OpenAI’s ChatGPT, version 4, with CoPilot enabled.

The supports are specific to the literature reviewed above and include instructional materials, content area tools, feedback, and planning. The prompts are summarized in Table 1. The instructional materials prompts are designed to elicit requisite content that one might gain from a textbook. The content area tools prompts seek support for tools specific to programming, such as coding and debugging tools. Feedback prompts look to elicit real-time feedback on student understanding. Finally, planning prompts are designed to support the student’s goal setting and time management.
Table 1. Prompts.

<table>
<thead>
<tr>
<th>Category</th>
<th>Prompts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Instructional materials</td>
<td>How do I use if–then statements to control the flow of a program?</td>
</tr>
<tr>
<td></td>
<td>Describe how this is achieved in the Python language.</td>
</tr>
<tr>
<td>Content area tools</td>
<td>How can I test my Python code as I learn?</td>
</tr>
<tr>
<td></td>
<td>What can I use to debug my code while learning?</td>
</tr>
<tr>
<td>Feedback and assessment</td>
<td>Give me a problem to solve that requires the use of an if–then statement.</td>
</tr>
<tr>
<td></td>
<td>Evaluate the accuracy of my response.</td>
</tr>
<tr>
<td>Planning</td>
<td>For this topic, please provide me with a sample question from the Python Institute PCAP exam.</td>
</tr>
<tr>
<td></td>
<td>I want to pass the Python Institute PCAP exam three months from now.</td>
</tr>
<tr>
<td></td>
<td>Provide a list of topics to master and a weekly schedule.</td>
</tr>
<tr>
<td></td>
<td>Provide a detailed schedule for each weekday of the first two weeks.</td>
</tr>
<tr>
<td></td>
<td>Evaluate and monitor my progress each weekday.</td>
</tr>
</tbody>
</table>

5.2. Procedures

This study follows earlier explorations of AI systems that use a vignette-based investigatory approach [15,44]. We guide the AI system to provide learner support in computer programming. In particular, we ask ChatGPT to provide guidance in learning the Python programming language.

The questions of the system align with the student support tools.

5.3. Data Sources

The data collection will consist of system inputs (prompts) and outputs.

6. Results

Below, we provide the responses of the system to the prompts within each of the instructional categories. This section is intended to be a summary description of the output and will be followed by a deeper analysis.

Instructional Materials

ChatGPT

Prompt: How do I use if–then statements to control the flow of a program? (see Figure 1)
The second prompt, “Describe how this is achieved in the Python language,” was anticipated by ChatGPT and was thus unnecessary (see Figure 2).

**Figure 2.** ChatGPT response snippet 2.

*Content Area Tools*

**Prompt:** How can I test my Python code as I learn?

ChatGPT provided a detailed response that included six approaches. The suggested approaches included (a) an Integrated Development Environment (IDE, e.g., Visual Studio); (b) an online Python interpreter (e.g., Google Colab); and (c) an educational environment (e.g., CodeAcademy). It also suggested that a beginner use an online interpreter or an educational environment.

**Prompt:** What can I use to debug my code while learning?

**Assessment**

**Prompt:** Give me a problem to solve that requires the use of an if–then statement. (see Figure 3)

**Figure 3.** Problem response snippet.

ChatGPT also provided a list of four steps to complete the problem. However, the problem presented by ChatGPT assumed some prior knowledge of the user that should be obvious. In particular, the problem presented assumes that the learner can solicit input from the user.

**Prompt:** Evaluate the accuracy of my response. [Plus code from the example provided by ChatGPT in the earlier response].

**Response:**

ChatGPT responded that the code would work as expected. It did not consider that the code did not address the question it had posed (which included user input and the use of if–else). It also did not recognize that this was taken directly from the example provided.

**Prompt:** For this topic, please provide me with a sample question from the PCAP exam.

**Planning**

**Prompt:** I want to pass the Python Institute PCAP exam three months from now. Provide me with a list of topics to master and a weekly schedule.

**Response:**

ChatGPT provided a detailed list of ten topics covered by the PCAP exam. It offered a 12-week plan of study to address all ten topics, with a week for review and a week for a mock exam.

**Prompt:** Provide a detailed schedule for each weekday of the first two weeks (see Figure 4).

**Response snippet for daily scheduling.**

7. Discussion

Generative AI tools have the potential to positively support learning in general and learning to program in particular. The results of this systematic analysis of ChatGPT’s responses to the learning prompts indicate that this promise is more than just hype. The following narrative will address how the system performed in each area of interest.

The research questions for this study included the following:
Planning
Prompt: I want to pass the Python Institute PCAP exam three months from now. Provide me with a list of topics to master and a weekly schedule.
Response:
ChatGPT provided a detailed list of ten topics covered by the PCAP exam. It also offered a 12-week plan of study to address all ten topics, with a week for review and a week for a mock exam.
Prompt: Provide a detailed schedule for each weekday of the first two weeks (see Figure 4).

Figure 4. Response snippet for daily scheduling.

7. Discussion
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The research questions for this study included the following:
1. How does ChatGPT provide the learning support necessary for self-regulated learning?
2. How does ChatGPT provide the support necessary to learn the Python programming language?

Overall, the responses provided by ChatGPT were valuable and appropriate. In each area of investigation (instructional materials, content area tools, feedback, and planning), the system seems capable of fulfilling the necessary request. Next, we will explore each area in more detail.

7.1. Instructional Materials
ChatGPT provided on-target and clear guidance regarding Python programming. The response to the prompts was comprehensive and offered suitable examples. As noted earlier, students must utilize multiple sources of information in the current learning environment [28]. However, it appears that ChatGPT can consolidate these sources to reduce or eliminate the time spent on task switching and information searching.

While the current study did not investigate the individualization capability, the limited prompts showed that this is well within the system’s capabilities. This is consistent with the predictions and observations made in prior research [29] that AI can provide personalized learning experiences.

From a self-regulated learning perspective, ChatGPT is a suitable augment to the learner’s capacity to monitor for understanding. The learner’s self-monitoring ability is critical to the utilization of AI tools. Without the will and skill to determine how well one is learning the material, the utility of AI tools is limited. The tools will only provide support upon request.
7.2. Content Area Tools

It is not surprising that this computer-based tool is capable of providing discipline-specific guidance in the area of programming. The critical roles an IDE and debugging functions play in programming are good examples of the need for content area tools. ChatGPT proved to be up to the task by again providing valuable and appropriate guidance. The suggested tools (e.g., Visual Studio and CodePen) are similar to advice from experts and the programming community, as reflected in communities such as Stack Overflow. We should expect this consistency given that the contributions to online communities appear to significantly contribute to the major LLMs (per the inclusion of the Common Crawl Data Set reported by AI researchers) [45].

For this particular exercise, ChatGPT performed well due to the ease with which it could incorporate code snippets into responses. However, it is not particularly interactive as an actual IDE might be. This activity points to the natural progression of AI adoption in that the most significant value will likely result from the integration into existing tools. GitHub’s Copilot is one such example of the power of integrating AI into existing systems. This tool has been available within the Visual Studio IDE since 2022 and has become a valuable tool for programmers [46].

One of the main functions of an effective IDE is to assist programmers with debugging as they code. From a learning perspective, immediate and precise feedback is invaluable. While there is a tendency to think of assessment in terms of outcomes and examinations, real-time formative feedback is one of the most consequential contributions a tutor can provide. For this reason, the integrated real-time debugging found in IDEs [36] (p. 1) will provide a more efficient learning model than a chat-based tool such as ChatGPT. Notably, ChatGPT anticipated this conclusion when prompted in the first section to suggest ways to test code while learning.

Integrating programming into mainstream learning environments (e.g., K-12 classrooms) presents significant challenges to educators (expertise, time, resources, and guidance) [32]. The results suggest that AI can address these challenges in the context of content area tools for programming.

7.3. Feedback and Assessment

While short-term, immediate, micro-level feedback was noted as a strength, more summative or macro-level assessments may present challenges to AI tutoring. One significant misstep of ChatGPT was in the assessment. It assumed too much in terms of user knowledge. In the assessment, ChatGPT expected that the learner already knew how to solicit user input. An additional misstep occurred in the evaluation of the submitted assessment response. The problem presented by ChatGPT required user input, but the response submitted simply set the variable in the initial code (e.g., temperature = 20 degrees). It also did not acknowledge that the response was merely a copy of the example in the previous exchange.

It is noteworthy that the user can avoid each of these missteps by modifying the prompts. The modified prompt below resulted in a problem requiring user input but provided a skeleton code that included instructions for obtaining the input.

Give me a problem to solve that requires the use of an if–then statement. The problem should consider my limited programming knowledge.

As indicated in the previous section, self-monitoring becomes a critical skill. Adjusting prompts to guide the system toward problem exercises that are at the correct difficulty level requires substantial self-awareness in terms of knowledge and understanding. The learner must recognize the need to challenge themselves by finding the extent of their ability.

7.4. Planning

Lesson planning for independent learning presents tremendous challenges. Lesson planning for experienced teachers can be time-consuming and challenging. Researchers and designers have developed numerous tools to assist educators in aggregating existing
resources to support lesson plan development [47]. Now, current AI tools perform much the same function, as evidenced by the responses generated by ChatGPT. Even if the learner is oblivious to the components of a lesson plan, AI tools can efficiently generate them, provided the user can identify the relevant standards or exams. In the scenario presented here, the learner would like to pass an industry exam demonstrating proficiency in the Python programming language. Based upon this knowledge alone, ChatGPT can ascertain the relevant topics and provide a timeline for reasonable completion.

As the introduction indicates, the primary attributes of self-regulated learning models include planning and goal setting [23]. Planning involves identifying goals and breaking the goals down into sub-goals and tasks. This activity is typically scaffolded by instructors with assignments and scheduled assessments. AI tools appear well suited to performing this scaffolding but lack the leverage that instructors often hold in the form of grades.

8. Conclusions

This study investigated the potential of ChatGPT to support self-regulated learning and learning a programming language. We examined four areas of support: instructional materials, content area tools, planning, and assessment. ChatGPT performed admirably in the areas of instructional materials and planning. There were notable challenges in providing appropriate assessments and the requisite content area tools.

ChatGPT demonstrated its usefulness and appropriateness in providing easy access to instructional materials to support learning Python. As anticipated many years ago, AI can give comprehensive responses with suitable examples and consolidate information sources to offer personally responsive learning experiences [1]. However, ChatGPT’s effectiveness depends on the learner’s SRL capacity, as it primarily supports learners upon request.

Regarding content area tools, ChatGPT effectively provided specific guidance in programming, showcasing its capability to offer expert-level advice. Nevertheless, it fell short of providing the interactive experience offered by proper IDEs, which may hinder its effectiveness in delivering hands-on programming guidance. Real-time formative feedback, a crucial aspect of effective learning, is more efficiently provided by IDEs with integrated real-time debugging features [32]. Integrating AI into existing IDE tools illustrates the potential for AI to enhance programming learning further [46].

ChatGPT excelled in providing short-term, immediate feedback in the domain of feedback and assessment but faced challenges in delivering summative or macro-level assessments. It assumed a certain level of user knowledge, leading to limitations in accurately assessing learners’ abilities and knowledge levels. However, users could address these challenges by refining the prompts to guide ChatGPT’s responses. Additionally, the learners’ metacognitive skills play pivotal roles in adjusting prompts to align with their difficulty level and understanding.

Regarding planning, ChatGPT exhibited its ability to assist learners in creating lesson plans for independent learning. It efficiently generated plans based on learner goals and objectives, showcasing its potential to support learners’ planning processes. However, it lacks the ability to incentivize learners with grades, a form of leverage often held by instructors.

Individualization is a hallmark of human tutoring and has implications for each area explored. The anticipation is that this can be a strength of AI systems. However, at this juncture, it is a challenge. While ChatGPT can follow the thread of the conversation, it is not consistent or robust. This is likely due to the probabilistic nature of the existing system’s dependence upon large language models and predictive algorithms. This approach emphasizes the probability of a plausible response over the likelihood of a helpful answer.

There is an interesting interplay between AI and the learner concerning self-regulated learning. While AI can support many of the capacities associated with SRL, such as planning and goal setting, it is less well suited to others, such as motivation and monitoring for understanding. The value of the AI system is dependent upon the SRL skills of the learner. For example, any support provided in planning depends on a motivated learner requesting help from the system.
9. Limitations
The current study is a point-in-time exploration that reflects the current state of a rapidly evolving system. Given the rapidly changing nature of these systems, any deficits noted here, with the proper guidance, can be ameliorated. It will be interesting to see if the tools develop in directions that promote learning. The companies behind these tools will guide them in directions that produce financial gains, not necessarily individual or learning gains.

10. Further Research
A comparison with similar tools, such as Anthropic’s Claude 2.0 and Google’s Bard, will be necessary. Standardizing prompts for similar studies could provide a valuable mechanism for conducting learning research. Standardization could assist in developing benchmarks to enable reasonable comparisons across tools [14].

Observational studies of student interactions with AI systems could also provide valuable insights into using these tools for learning. Observations could include chat transcripts as well as think-aloud protocols.

11. Implications
This work contributes to our emerging understanding of how AI systems can support student learning by following prior work that treats the system as a subject in a psychological experiment [15]. In its current form, ChatGPT can serve as a valuable tutor in support of independent learning for topics such as computer programming. While controlled studies will need to verify this, achievement gains produced by AI tutors can rival Bloom’s human tutor findings from 40 years ago [16]. However, the problem, as articulated by Bloom, was that the two-sigma benefit of a human tutor was not a scalable option. It is now.

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